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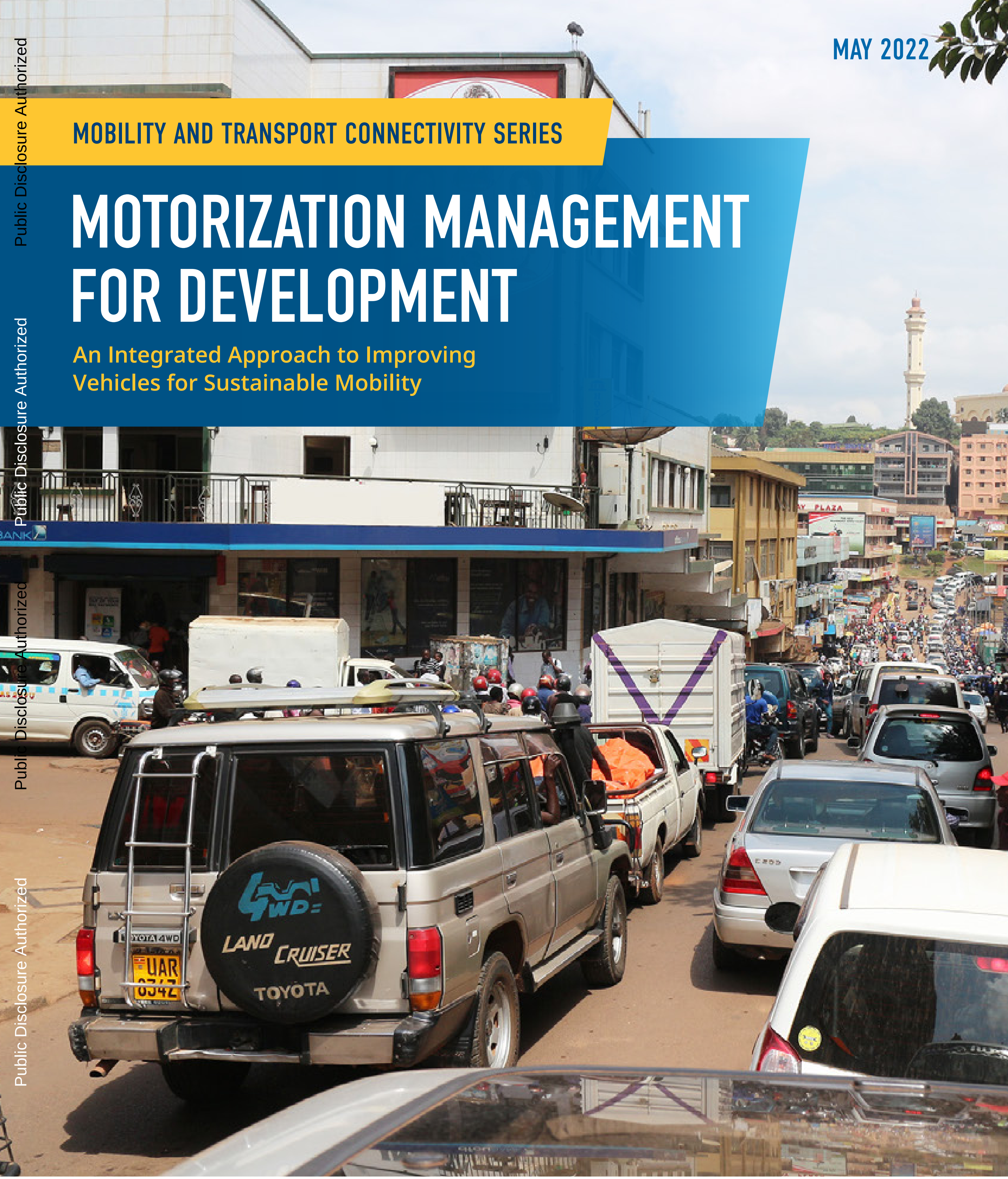
MOBILITY AND TRANSPORT CONNECTIVITY SERIES

MOTORIZATION MANAGEMENT FOR DEVELOPMENT

An Integrated Approach to Improving Vehicles for Sustainable Mobility



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MOTORIZATION MANAGEMENT FOR DEVELOPMENT

An Integrated Approach to Improving Vehicles for Sustainable Mobility

Lead author: Roger Gorham
Contributors: Dipan Bose, Maria Cordeiro, Georges Darido, John Koupal, Raman Krishnan, Kazuyuki Neki, and Yin Qiu

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Acronyms

ASI	Avoid-Shift-Improve
AVRP	Accelerated Vehicle Retirement Program
CITA	International Motor Vehicle Inspection Committee
CKD	complete knock down
CO	carbon monoxide
CO_2	carbon dioxide
DPOs	Development Policy Operations
DPOS	Dynamic Profile of Standards
ELV	End-of-Life Vehicle
GHG	greenhouse gas
GRSF	Global Road Safety Facility
IBRD	International Bank for Reconstruction and Development
ICE	internal combustion engine
IDA	International Development Association
IPF	Investment Project Financing
KGGTF	Korean Green Growth Trust Fund
MaaS	Mobility as a Service
MM	Motorization Management
MVIMS	motor vehicle information management system
NDCs	Nationally Determined Contributions
NMHCs	non-methane hydrocarbons
NOx	nitrogen oxides
ODA	official development assistance
OEM	original equipment manufacturer
PM	particulate matter
PPP	public-private partnership
PTI	periodic technical inspection
SKD	semi-knock down
SOE	state-owned enterprise
SOx	sulfur oxides
SuM4All	Sustainable Mobility for All
SUV	sport utility vehicle
UNFCCC	United Nations Framework Convention on Climate Change
VIMM	Vehicle Inspection Management Module
VKT	vehicle kilometers travelled

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Executive Summary

Introduction

Across the developing world, countries are experiencing rapid growth in urbanization and motorization. While high motorization rates potentially mean that more people will be able to claim the benefits of improved accessibility to goods and services as a consequence of enhanced mobility, there are questions about the sustainability of this future. Will countries be able to build and maintain infrastructure to accommodate increasing numbers of vehicles? Will the increasing number of vehicles and their characteristics support attainment of the Sustainable Development Goals (SDGs)? Will they put in jeopardy countries' ability to meet their climate commitments under their Nationally Determined Contributions (NDCs)?

From a development impact standpoint, the nature of a country's motor vehicle stock and how it grows affects three key and tangible outcomes. First, the quality of the motor vehicle stock affects road safety outcomes—that is, the number of people killed or seriously injured in motor vehicle crashes. The characteristics of vehicles and their fitness or roadworthiness can affect fatality and serious injury outcomes. Second, the quality of the motor vehicle fleet affects air quality, particularly in cities. Motor vehicles are a key source of harmful air pollution, including carbon monoxide (CO), fine particulates ($PM_{2.5}$), sulfur oxides (SOx), and ozone precursors (oxides of nitrogen and various hydrocarbons), and the amount of these pollutants they emit is directly related to how the vehicle was built and how well it is maintained. Finally, the profile of the vehicle fleet—what is the size and weight of vehicles in the fleet, how big are their engines, what kind of power control technology do they use, and how did their manufacturers engineer the technology of the vehicle to balance power with efficiency—affects the (fossil) fuel consumption of the vehicle stock as a whole, and, consequently, the greenhouse gas (GHG) emissions profile of the road transport sector.

This report presents the World Bank's Motorization Management (MM) framework, which is intended to support client countries in the development of policies and measures aimed at managing vehicle stocks in a proactive, phased, and systematic manner to make them safer, cleaner, and more fuel efficient. The MM framework reflects a series of policy considerations and programs that can be implemented to improve the quality of fuels and vehicles in a country's stock.

Motorization in the Developing World

Fundamentally, motorization is a technology diffusion process, and, typical of such processes, follows a logistic distribution over time (see Figure 2.1). Vehicle adoption begins relatively slowly, but then progresses rapidly at the steepest point in the slope, before tapering off as the society approaches a hypothetical "saturation" level, which, in North America, is identified as around 600 cars per 1,000 persons. Understanding the logistic nature of motorization processes is important from a policy standpoint. Where on the curve a country is at any point in time will affect whether vehicles currently in use will comprise a large or a small proportion of the vehicle stock five years from now. The implication is that the kinds of policies and measures that might be appropriate at the lower end of the steep curve reflected in Figure 2.1 might be quite different from those that would be appropriate toward the upper end of that curve.

As of 2018, actual motorization penetration levels worldwide were 266 motor vehicles per 1,000 persons, but motorization rates vary substantially by region. The North American median is around 657 vehicles per 1,000 persons, while in Sub-Saharan Africa, median motorization penetration is only 20 vehicles per 1,000 persons. Worldwide, passenger cars, vans, and pickups account for about 73 percent of all in-use vehicles, while motorcycles and other two-wheelers account for an additional 23 percent. Only about 4 percent of the worldwide vehicle stock are trucks, which is striking considering how dependent most economies are on road transport.

Motorization Management in the Sustainable Transport Agenda

MM is a deliberate, diligent, and coordinated process to shape, through public policies and programs, the profile, quality, and to some degree, quantity and intensity of use of the motor vehicle stock as it progresses through a country's motorization process. MM seeks to shape the way motor vehicles are managed throughout their effective in-use life in a given country, in order to improve safety, environmental, and fuel consumption outcomes. This life-of-vehicle approach means targeting policies and measures at different phases of vehicle life, including vehicle entry, active use, and vehicle exit, and the conditions that underlie demand for motorization. Because meeting some of these objectives also requires improvements in fuel quality and availability in certain cases, MM necessitates consideration of fuels and vehicles as a system. MM also looks at the important aspects of reuse and recycling of vehicles, parts, and materials linking to the overall vehicle life cycle from vehicle design, production, and post-production until scrappage.

As with other aspects of the sustainable transport agenda, MM is not concerned only with policies per se, but rather the entire governance ecosystem that gives rise to desirable policy outcomes affected by the evolution of a country's vehicle stock. Developing the right policies, to be sure, is an important aspect of MM, but so is the development and strengthening of institutions to carry out policy analysis, to ensure compliance, and to manage stakeholders and communications, to name a few. MM policies will also affect government revenues and expenditures, and these impacts also fall within the purview of MM.

Specifically, MM is concerned with five key policy outcomes aligned to the development agenda. These are:

- Road safety – making the stock of in-use vehicles safer, both in terms of avoiding crashes and in their safety performance when crashes do occur
- Air quality – making the stock of in-use vehicles (and the fuels they use) cleaner
- Climate mitigation – making the stock of vehicles being used more fuel efficient
- Sustainable transport and lifestyles – using motor vehicle governance to support other priorities in a broad, sustainable transport agenda

- Fiscal stability – ensuring continuity of resources by managing the fiscal impact accompanying the motorization process.

In some cases, policies can promote synergies among these objectives, while in others, trade-offs need to be negotiated. Different countries, or different governments, might prioritize these objectives differently. A key focus of MM, therefore, needs to be not only developing strong policies, but helping to develop a robust policy-making process.

To highlight the complexity of negotiating these different potential objectives in a broader context of development policy, 10 concepts are proposed to stimulate discussion. These concepts relate to how vehicles are accepted into a country, how they are monitored while they are used, how they are cycled out of the active stock, and how demand for motorization grows. Policy makers need to determine for themselves how relevant these concepts are for their situation.

Vehicle entry

1. To protect *public health* and *safety*, vehicle importation or manufacturing *thresholds* should be used; to meet national public policy *goals*, economic *incentives* targeted to vehicle purchasers, manufacturers, or importers generally work best.

2. Age is not a good proxy for air quality, safety, or fuel-efficiency performance characteristics of light-duty vehicles (LDVs), especially those in noncommercial service; to improve LDV stocks, policies should focus on specific air quality or safety performance features, or fuel intensity characteristics, rather than age alone.

Active use

3. Enforcement actions are more effective if accompanied by strong communication and education programs.

4. Lifestyle or economic transition points are the most important moments to influence households and firms' decisions about their vehicle fleets; at these moments, they are susceptible to being nudged toward more sustainable choices when information and finance options are available.

Vehicle exit

5. Changing the permitted uses of current vehicles in the stock as they age may be a more politically acceptable way to manage risks caused by usage of obsolescing vehicles rather than abruptly banning their use.

6. Assigning lifetime usage limits when vehicles are added to the national stock through either import or manufacture could be an equitable way to address the long-term challenge of an aging and obsolete vehicle stock.

7. For heavy-duty vehicles (HDVs) and LDVs used for commercial transport, incentivizing vehicle turnover (for example, replacement and scrappage) is as important as the quality of vehicles brought in. For LDVs used for own-account transport, the relative importance of vehicle turnover/replacement depends on where an individual country is on the motorization curve; incentivizing turnover becomes more important as motorization penetration increases.

8. Management of End-of-Life Vehicles (ELVs) and batteries must not be an afterthought, but rather built into the MM framework from the beginning.

Motorization demand

9. Although MM focuses on vehicles, it is the use of those vehicles that is the source both of environmental and safety risks as well as accessibility benefits to societies.

10. Managing motorization should be understood as one element of a broader, sustainable transport approach; MM policies should align with that approach and take into account both vicious and virtuous effects broader policies may have on motor vehicle demand.

Elements of the Motorization Management Framework

Effecting change to motor vehicle stocks requires a clear method for implementing the principles laid out above. The methodology recommended in this paper identifies five core elements of an MM approach: (1) facilitating a clear and transparent policy-making process by which to establish goals and priorities; (2) gathering and assessing data with continuous analytics; (3) adopting and promulgating prospectively vehicle and fuel standards consistent with the vision; (4) strengthening the "nuts and bolts" of motor vehicle stock governance and human capital development in the automotive value chain; and (5) working to ensure that vehicle stock growth and turnover is adequately addressed in vehicle market mechanisms available in the country.

1) Facilitating a clear and transparent policy-making process

In Organisation for Economic Co-operation and Development (OECD) countries with mature motor vehicle manufacturing industries, as well as in China and India, a common refrain among manufacturers and policy makers alike is that transparency is as important as the specific policies governing vehicle manufacturing requirements themselves. Manufacturers need to know what the rules of the game are and be afforded ample time to plan their strategies accordingly. Governments in these regions have responded by establishing clear rules and expectations for vehicle performance and fuel specifications years in advance of when these rules take effect. In many low- and middle-income countries without a motor vehicle manufacturing industry, such long-term clarity and transparency is lacking. The result for these countries is not only that doing business in the automotive sector is challenging, but also that countries have little clout with which to actually influence vehicle markets. Individual countries, or, better yet, economic blocs, can change this dynamic by being more deliberative and structured in policy processes.

2) Gathering and assessing data with continuous analytics

Motorization policy should be grounded in empirical analysis based on evidence of what works. This means developing mechanisms to be able to observe and track characteristics of car and truck ownership, motor vehicle use, energy consumption by different kinds of vehicles, on-road fuel intensity, new car fuel intensity, and other characteristics of road transport at the national level. These parameters also need to be gauged against other factors in the economy, such as fuel prices (and fuel price fluctuations), economic indicators, industrial structure, etc. The fundamental basis for this type of analytics is access to good quality data at a reliable and sustainable frequency. Much of the data for these types of analytics are already collected by national and subnational governments on an ongoing basis, in the form of customs registries and vehicle registration rosters. What is needed are clear policies, and effective procedures, to make this data available to the public and to researchers on a regular basis, in a manner that respects data privacy and integrity requirements.

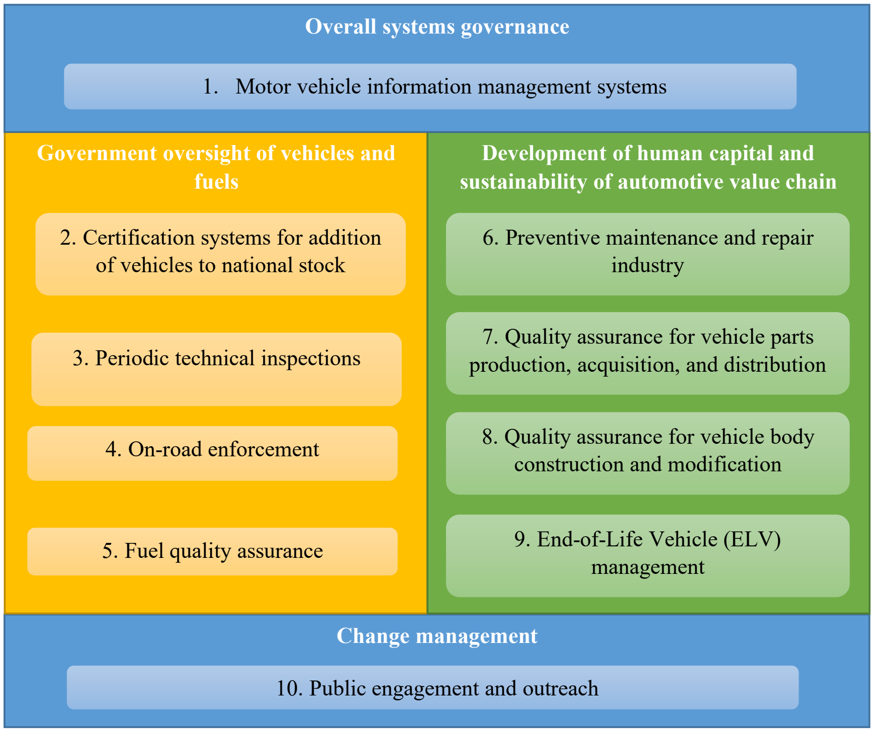
3) Adopting and promulgating vehicle and fuel standards prospectively using dynamic profile of standards for vehicle stock evolution

Goal setting and analytics should lead to the promulgation of transparent vehicle and fuel standards, both for the addition of vehicles to the national stock and for the minimal requirements of in-use vehicles to be allowed to remain circulating, with the understanding that vehicle and fuel standards are necessary, but not sufficient, elements of a successful MM program. A public process to define a policy vision within a given vehicle market is, therefore, an important part of MM. Dynamic Profile of Standards (DPOS) addresses this need as it provides a blueprint for industry and stakeholders about how regulatory standards for vehicles to be added to the national vehicle stock will be expected to change over a multiyear time frame, for example, over a decade. The objective of establishing a DPOS is to avoid repetitive ad hoc processes to tighten regulations and instead to send clear signals to the import and manufacturing/assembly industries in or targeting a country or region so that they can make adjustments.

4) Strengthening the ‘nuts and bolts’ of motor vehicle management

The “nuts and bolts” of motor vehicle management are often overlooked by the development community, but they are the core functions of governance that probably have greater impact on the success of a given policy than the policy itself. Ten “nuts and bolts” systems are identified, as shown in Figure E.1.

Figure E.1. Nuts and Bolts of Effective Governance of Motor Vehicle Stocks



Source: Original figure produced for this publication.

In essence, these 10 systems form the core of the MM agenda.

5) ***Working to strengthen market mechanisms for funding and managing vehicle stock growth and turnover***

MM cannot be conceived of solely as an initiative of government, or a question of governance of motor vehicle stocks. There also needs to be proactive attention paid to the incentives and financing environment in which motor vehicle purchases—both fleets and individual vehicles—occur. Experience in high-income countries suggests that access to credit and varied (and competing) models of vehicle ownership and availability are key. Depending on where a country is along its motorization curve (see Figure 2.1), it may need to emphasize vehicle stock turnover more than growth to meet its development objectives. In low- and middle-income countries, three factors often constrain motor vehicle markets: low purchasing power, lack of credit availability, and lack of diversity of vehicle availability models, such as formalized third-party leasing. While there are no easy answers to these challenges, and their importance varies not just by country, but also by transport subsector, some common elements are emerging that may form part of the solution for different subsectors. These elements include aggregating demand for vehicles toward fleets, where possible; eliminating capex burden for individual operators; isolating different kinds of risk (for example, payment from demand risks) so that they can be explicitly and separately treated where feasible; and creating stable, long-term, and verifiable flows that can be securitized.

Operationalizing Motorization Management in Low- and Middle-Income Countries

There are four key ways that international finance institutions (IFIs) and international development institutions, such as the World Bank, can support countries to operationalize MM approaches. First, international development institutions can help to strengthen the international framework governing the cross-border trade in secondhand vehicles. Specifically, there is a need to:

- Establish rules for acceptable practice in the export of used vehicles;
- Establish data architecture and protocols to facilitate exchange of vehicle history information among countries;
- Strengthen trade accounting frameworks to enable tracking of trade in secondhand goods, including vehicles and vehicle parts; and
- Strengthen protocols for materials recovery in a globalized circular economy.

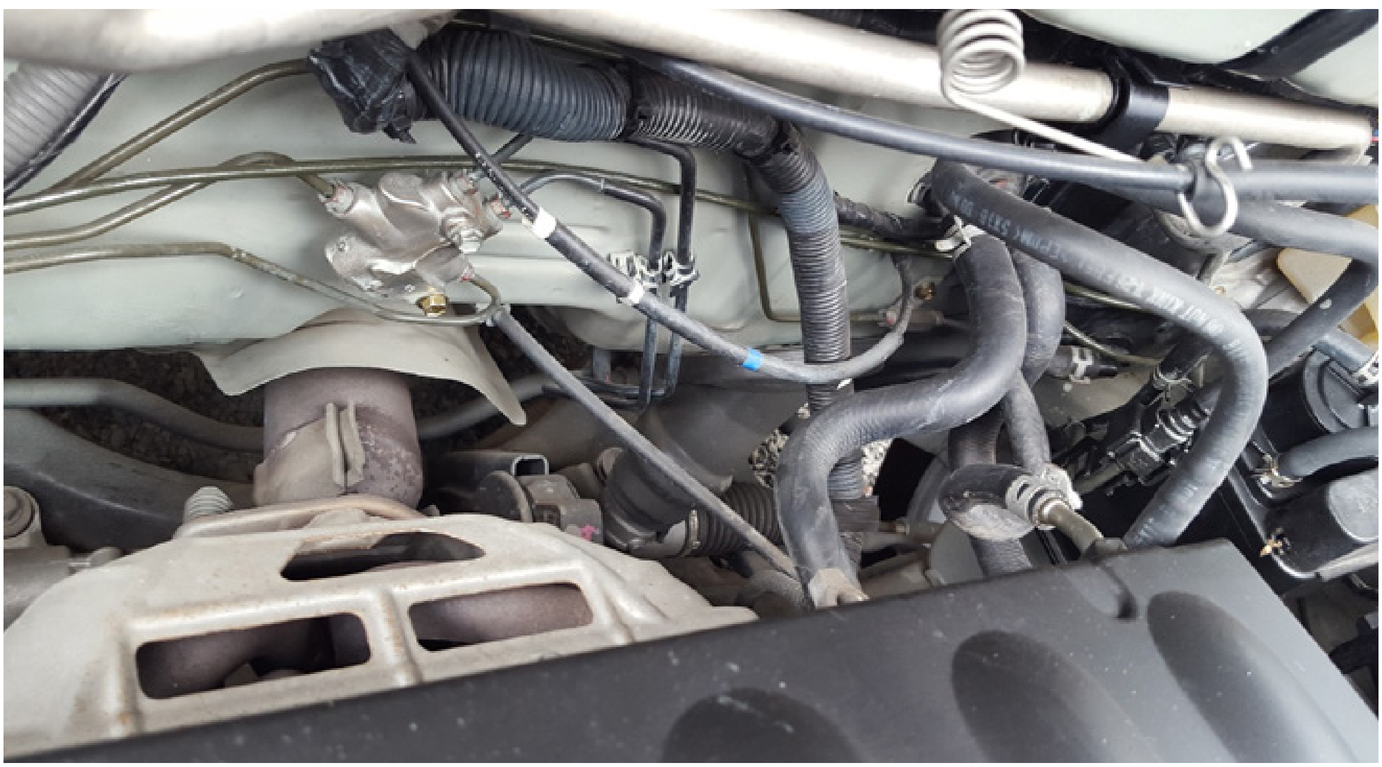
Second, IFIs can support diagnostic studies to facilitate adoption of MM approaches. Diagnostic studies would identify an appropriate sequence of actions to be undertaken in a specific context, including establishing a policy development process. Third, IFIs can support the establishment and strengthening of MM policies and institutions in low- and middle-income countries by assigning official development assistance (ODA) resources and technical assistance. Elements of an MM program can be supported through policy lending. For example, promulgation of DPOS or adopting legislation or tariff regimes to facilitate improved governance can all be supported with well-designed policy-based lending. Other elements can be supported through traditional Investment Project Finance. In addition, finance can support the private or public sectors to make (or incentivize) investments in vehicle fleet turnover. Finally, IFIs and international development institutions can help to establish or strengthen regional MM observatories, which can help fulfil the need for continuous analytics.

1. Introduction

Across the developing world, countries are experiencing rapid urbanization and motorization growth. While high motorization rates potentially mean that more people will be able to claim the benefits of improved accessibility to goods and services through enhanced mobility, it raises questions about the sustainability of this future. Will countries be able to build and maintain infrastructure to accommodate increasing numbers of vehicles? Will the increasing number of vehicles and their characteristics support attainment of the Sustainable Development Goals (SDGs)? Will they put in jeopardy countries' ability to meet their climate commitments under their Nationally Determined Contributions (NDCs)?

In many low- and middle-income countries, the demand for growth of the motor vehicle stock is met through two common practices which create substantial burdens for society: import of secondhand (used) vehicles (see Box 1.1) and growth in the propagation and use of two-wheeled vehicles. Both avenues present a double-edged policy sword for governments. On the one hand, a large proportion of used vehicles are often substandard. Anecdotal reports have long suggested that importers regularly remove key safety features like airbags and emissions control equipment in order to meet real or perceived performance requirements from buyers, and many used vehicles are traded whose physical condition cannot be vouched for. A recent study of secondhand vehicles for export in the Port of Rotterdam (Netherlands ILT 2020) found only 34 percent had roadworthiness certificates (see Box 1.2. Used Vehicles Exported to Africa: Summary of a Study of the Quality of Used Vehicles Exported from the Netherlands to African Countries for more detail).

Image 1.1. Tampered Car in an East African Country, with Catalytic Converter and Antilock Brake System Removed



Source: Henry Kamau.

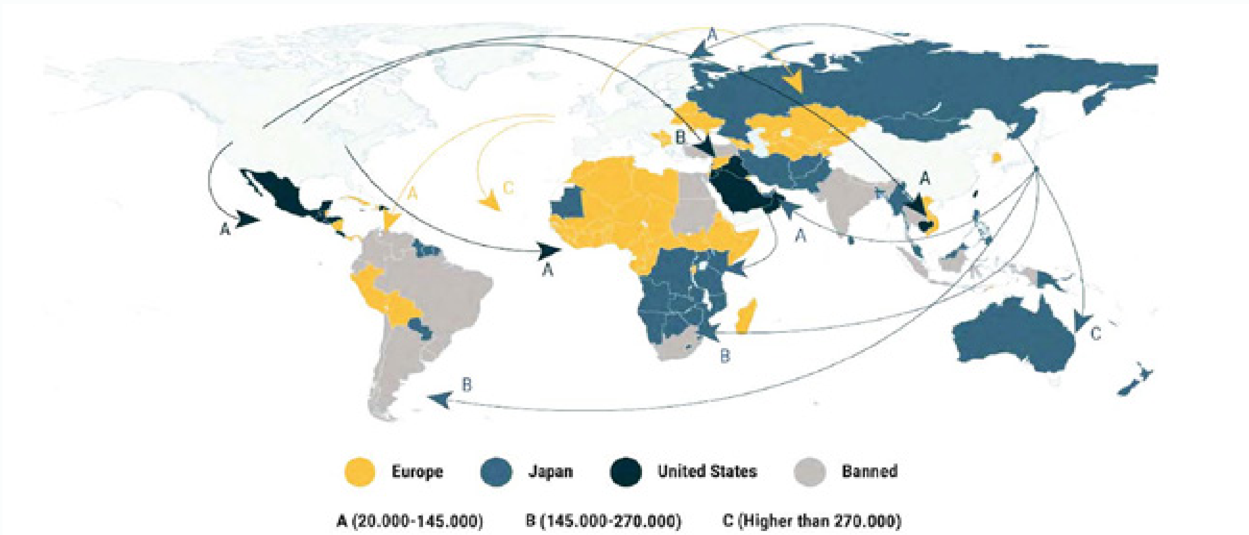
On the other hand, for the importing countries, the used vehicles imported are often already of higher quality than vehicles in the vehicle stock, so if there were mechanisms to ensure that these vehicles were being used to *replace*, rather than add to, existing vehicles, then the process of importation of used vehicles would amount to a net benefit to society. Likewise, the expansion of two-wheelers also comes with benefits but substantial costs to low- and middle-income countries. Their prevalence greatly enhances accessibility in both rural and urban environments, particularly for low-income households. However, they are associated with greater incidence of road-crash-related fatalities and serious injuries, and increased severity of the latter; their volumes and the behavior of two-wheeler drivers' efforts to skirt congestion can often hinder efforts to improve public transport performance; and their maneuverability makes them prone to be co-opted for criminal use, which means their accessibility benefits may be at least partially offset by their deleterious effects on personal security. In addition, in many countries, two-stroke engines are still allowed (or tolerated) in new two-wheelers, contributing substantially to local air pollution.

In low- and middle-income countries, addressing the double-edged sword of used vehicle and two-wheeler growth means managing the growth of the motor vehicle fleet as an important dimension of a sustainable transport policy. Not only does motorization have a multiplicity of impacts in terms of public health, use of public space, loss of productivity from congestion, and others, it also brings challenges associated with limited institutional, organizational, and managerial capacity to manage these impacts.

Box 1.1. Prevalence of Used Vehicle Imports Among Low- and Middle-Income Countries

In October 2020, the United Nations Environment Programme (UNEP) released a flagship report, *Used Vehicles and the Environment: A Global Overview of Used Light Duty Vehicles—Flow, Scale and Regulation* (UNEP 2020). The study provided the first quantitative look at the global flow of used light-duty vehicles (LDVs) available. It showed that between 2015 and 2018, 14 million LDVs were traded internationally, primarily exported from the European Union (EU), the United States, and Japan to low- and middle-income countries. The picture of the primary trade flows that emerge from this study is shown in figure B1.1.1.

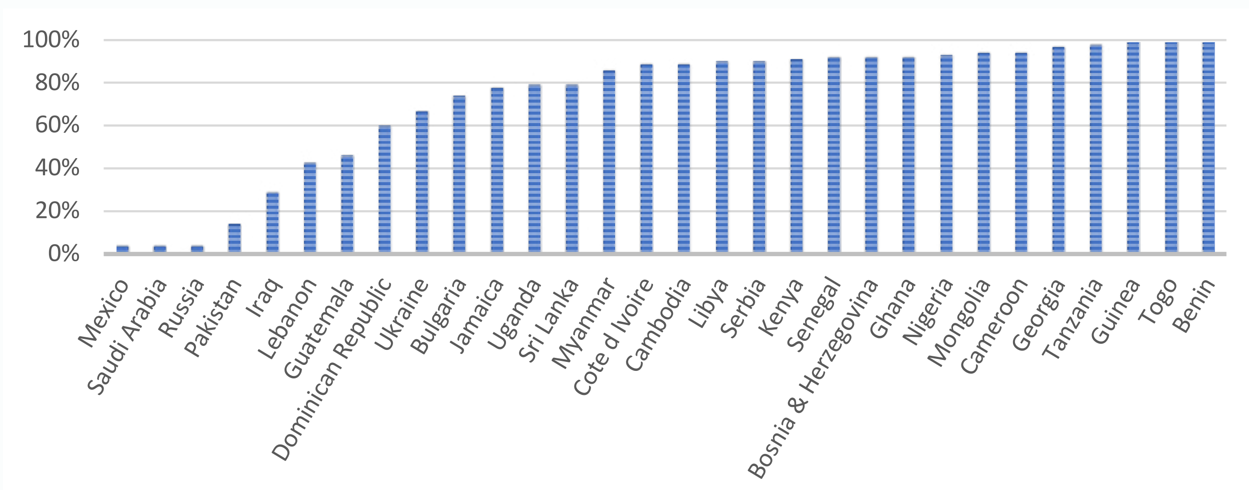
Figure B1.1.1. Primary Trade Flows of Used Vehicles



Source: UNEP 2020.

Based on the numbers generated from the UNEP study, the World Bank has estimated used vehicle import shares for a number of low- and middle-income countries. These are shown in figure B1.1.2.

Figure B1.1.2. Used Vehicle Import Share for Select Low- and Middle-Income Countries, 2018



Source: World Bank analysis based on UNEP 2020 data.

Extrapolating these numbers to all low- and middle-income countries using a regression analysis, the World Bank estimates that 70 percent of such countries imported more used vehicles than new ones in 2018, and 58 percent imported more than three times as many used vehicles as new ones.

Source: World Bank using inputs from UNEP 2020.

Box 1.2. Used Vehicles Exported to Africa: Summary of a Study of the Quality of Used Vehicles Exported from the Netherlands to African Countries

In October 2020, the Human Environment and Transport Inspectorate (ILT) of the Netherlands Ministry of Infrastructure and Water Management released the results of a study on the quality of used vehicles exported to Africa (Netherlands ILT 2020). The objective of this study was to anticipate upcoming new and harmonized policies from African countries for the import of cleaner and safer vehicles. These results are based on a desk study of data on export and fleet composition, and a physical inspection of vehicles destined for export in cooperation with the Netherlands Vehicle Authority (RDW).

In the Netherlands, every year, more than half a million used passenger vehicles are decommissioned from use domestically; about half of these are disposed of through the End-of-Life Vehicle (ELV) process while the remainder are transported abroad. The study found that approximately 80,000 of these vehicles shipped abroad have a low emission standard (Euro 0, 1, 2, or 3) and are 16 years of age or older. More than a quarter of them end up in Africa.

Libya, Nigeria, and Ghana import most of the used vehicles exported from the Netherlands. An estimated share of 40 percent of vehicles exported to African countries have foreign registries (mainly German). The United Nations Environment Programme (UNEP) has reported that the Economic Community of West African States (ECOWAS) has agreed as a bloc to adopt stricter environmental regulations that would prohibit importation of more than 80 percent of these vehicles to the 15 member states.

These vehicles are old and below the Euro 4 emission standard, and they often do not have a valid periodic roadworthiness certificate. Around 20 percent of tested petrol vehicles fail tests for emission requirements. Many of these export vehicles, therefore, are a cause for pollutant and climate emissions and less road safety in the recipient countries.

The majority of used vehicles exported to African countries are between 16 and 20 years of age. In Morocco and Ghana, however, the mean age of light-duty vehicles (LDVs) from the Netherlands is 4.7 and 13.6 years, respectively.

Shipping costs of vehicles exported to North and West Africa are the cheapest (in euro cents per kilogram) compared to other regions to which used vehicles from the Netherlands go. Libya and Nigeria receive very low-price vehicles. A quarter of the vehicles going to these countries in 2017 and 2018 had a price of below 50 euro cents per kilogram.

The majority of exported vehicles to the top destinations in Africa have a mileage of more than 200,000 kilometers. Heavy-duty vehicles (HDVs) have higher mileage than LDVs. LDVs with high mileage go to Nigeria, The Gambia, Sierra Leone, and Burkina Faso. The vehicles with relatively lower mileage (a peak of just below 200,000 kilometers) go to Morocco, Ghana, and Ethiopia.

Finally, this study shows that the quality of used cars exported to West Africa is quite similar to the quality of cars dismantled in the Netherlands. While a recycling fee has been paid for them in the Netherlands, only one out of three ends up in a recycling company to be dismantled under controlled conditions and with a high rate of reuse of material. Without a proper structure for disposal and treatment of ELVs in African countries, uncontrolled treatment of vehicles, when discarded, causes environmental harm and injuries to health and a risk of losing secondary raw materials.

Source: World Bank based on Netherlands ILT (2020).

From a development impact standpoint, the nature of a country's motor vehicle stock and how it grows affects three key and tangible outcomes, as will be discussed and highlighted throughout this report (and elaborated upon in Boxes 3.2 to 3.4). First, the quality of the motor vehicle stock affects road safety outcomes—that is, the number of people killed or seriously injured in motor vehicle crashes. The characteristics of vehicles and their fitness or roadworthiness can affect fatality and serious injury outcomes. Indeed, motor vehicles have been one of the key pillars of a safe systems approach to road safety emphasized throughout the Road Safety Decade of Action (Abel, Lindley, and Paniati 2020), but probably received the least attention in terms of official development assistance (ODA) support. Second, the quality of the motor vehicle fleet affects air quality, particularly in cities. Not only are motor vehicles a key source of harmful air pollution, including carbon monoxide (CO), fine particulates ($PM_{2.5}$), oxides of sulfur (SO_x), and ozone precursors (oxides of nitrogen and various hydrocarbons), but the amount of those pollutants they give out is directly related to how the vehicle was built and how well it is maintained. Finally, the profile of the vehicle fleet—what is the size and weight of vehicles in the fleet, how big are the engines they use, what kind of power control technology they use, and how their manufacturers engineered the technology of the vehicle to balance power with efficiency—affects the (fossil) fuel consumption of the vehicle stock as a whole, and, consequently, the greenhouse gas (GHG) emissions profile of the road transport sector.

The global fleet of light-duty vehicles (LDVs) is projected to double by 2050. More than 90 percent of this growth is projected to happen in non-OECD countries. Notwithstanding the emphasis in recent years on the potential for battery electric vehicles (BEVs) to disrupt motor vehicle markets, forecasts show that more than two billion new internal combustion engine (ICE) vehicles will be sold worldwide over the next 30 years, even under the most optimistic scenarios for the electrification of new vehicles (ICCT 2020). The speed with which developing countries motorize can be considered both a challenge and an opportunity (see Box 1.3). While developing countries are recipients of a large share of exported used vehicles (70 percent in 2018), the speed of growth of the fleet means that those vehicles will be only a small proportion of the total vehicle fleet, even if they remain in use for an excessively long period of time compared to their use in the Global North. Governments in many developing countries, particularly in Africa, therefore, have a window of opportunity now to effect motorization policies that can shape their motor vehicle fleet for decades. Indeed, evidence, such as the above-referenced Dutch study of the Port of Rotterdam, is showing that weak motorization policies have detrimental effects on vehicle stocks used in many low- and middle-income countries. With the world transitioning to alternative fuels and new vehicle technologies, like electric vehicles (EVs), additional challenges and opportunities arise for developing country markets.

Box 1.3. Rapid Urbanization and Modernization Rates in Africa

Over the past two decades, Africa has been the fastest urbanizing region in the world, growing at 3.44 percent on average, which is much higher than the rate of other rapidly developing regions, such as Asia and Latin America. Given that Africa remains the least developed region in the world, the rapid pace of urban growth will likely accelerate motorization development and challenge the limited resource base to meet the demand of the continent's growing urban populations.

Africa hosts the smallest proportion of the world's vehicle fleet (only 42.5 million in-use vehicles) with the lowest vehicle penetration rate (32 light-duty vehicles per 1,000 persons). The light-duty vehicle (LDV) fleet size in Africa is projected to grow significantly at more than 6.1 percent annually over the next few decades (EIA 2016). That means that by 2040, there will be nearly 137 million more LDVs in Africa than in 2015, a growth of nearly 400 percent, representing the compounding effects of a 67 percent growth in population, and a 183 percent growth in the number of vehicles per 1,000 persons.

Most countries on the continent are primarily import-driven in their automotive industries, and only South Africa and Nigeria currently have vehicle emissions standards. In addition, a high percentage of imported vehicles are secondhand (85 percent in Ethiopia, 80 percent in Kenya, and 90 percent in Nigeria, in 2015) from Europe, Japan, and nearby countries, mainly because of the low capacity of local vehicle assembly and manufacturing and limited disposable income to purchase new vehicles that are burdened with high tariffs and other taxes.

Source: World Bank.

How to move from challenge to opportunity, however, has been elusive. Motor vehicle manufacturing (and even assembly) across Africa and in low- and middle-income countries in many other world regions is far behind that in upper-middle-income and high-income countries. In the developing world, particularly lower-income countries, where purchasing power is low, secondhand vehicle importation is the main source of vehicle stock growth and is likely to remain so for many years or decades to come. International vehicle markets adapt to higher vehicle fuel economy standards set in advanced economies, generating benefits in developing countries with a time lag. However, dramatic changes in vehicle technologies, such as the transition to EVs, raises challenges in developing countries due to the absence of supporting industries and charging infrastructure.

The World Bank developed a Motorization Management (MM) framework with the objective of supporting client countries in the development of policies and measures aimed at managing vehicle stocks in a proactive, phased, and systematic manner. The MM framework reflects a series of policy considerations and programs that can be implemented to improve the quality of fuels and of vehicles in a country's stock.

MM is supportive of the World Bank's twin goals of ending extreme poverty and boosting shared prosperity, fostering human development and building institutional capacity in client countries. It is closely aligned with the visions of the Sustainable Mobility for All (SuM4All) initiative and of the Global Road Safety Facility (GRSF) that include universal access, improved transport safety and efficiency, and green mobility. Furthermore, MM provides a conceptual framework supportive of client countries' goals and targets for climate change mitigation and adaptation, as defined in their Nationally Determined Contributions (NDCs) to the Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC).

This report presents the conceptual framework for MM, including a description of guiding considerations, particularly those that strengthen policy effectiveness. It also proposes instruments to enhance transparency in policy development processes.

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2. Motorization in the Developing World

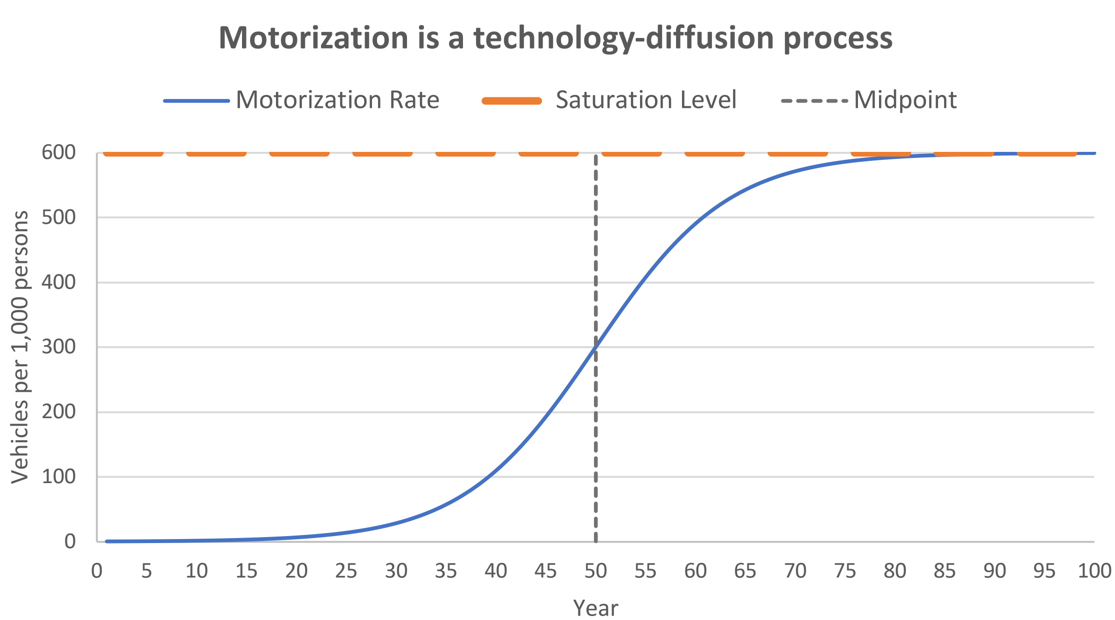
Motorization As Technology Diffusion

Fundamentally, motorization is a technology-diffusion process, and, typical of such processes, follows a logistic distribution over time, as reflected in Figure 2.1 below.

Vehicle adoption begins relatively slowly, but then progresses rapidly at the steepest point in the curve, before tapering off as the society approaches a hypothetical "saturation" level, which, in Figure 2.1, is identified around 600 cars per 1,000 persons, on the order of magnitude of North America. For example, in 2016, Kenya had about 18 cars per 1,000 persons, and Ethiopia had six vehicles per 1,000 persons, placing them on the far-left side of the motorization curve before the inflection point toward the steep slope. Academics have long debated whether there is consistency among countries about the location of the saturation line, but it is likely that the policy environment affecting land use and the costs and convenience of using modal alternatives can influence where that saturation line ultimately is, and, consequently, the steepness of the steep part of the curve. In addition, the recent emergence of digital and smart phone technology to make Mobility as a Service (MaaS) more convenient and ubiquitous than in the past appears likely to lower the saturation point, at least for developed countries.

Understanding the logistic nature of motorization processes is important from a policy standpoint. Where on the curve a country is at any point in time will affect whether vehicles currently in use will comprise a large or small proportion of the vehicle stock five years from now. The implication is that the kinds of policies and measures that might be appropriate at the lower end of the steep curve reflected in Figure 2.1 might be quite different from those that would be appropriate toward the upper end of that curve.

Figure 2.1. Motorization Process as Technology Diffusion



Source: Original figure produced for this publication.

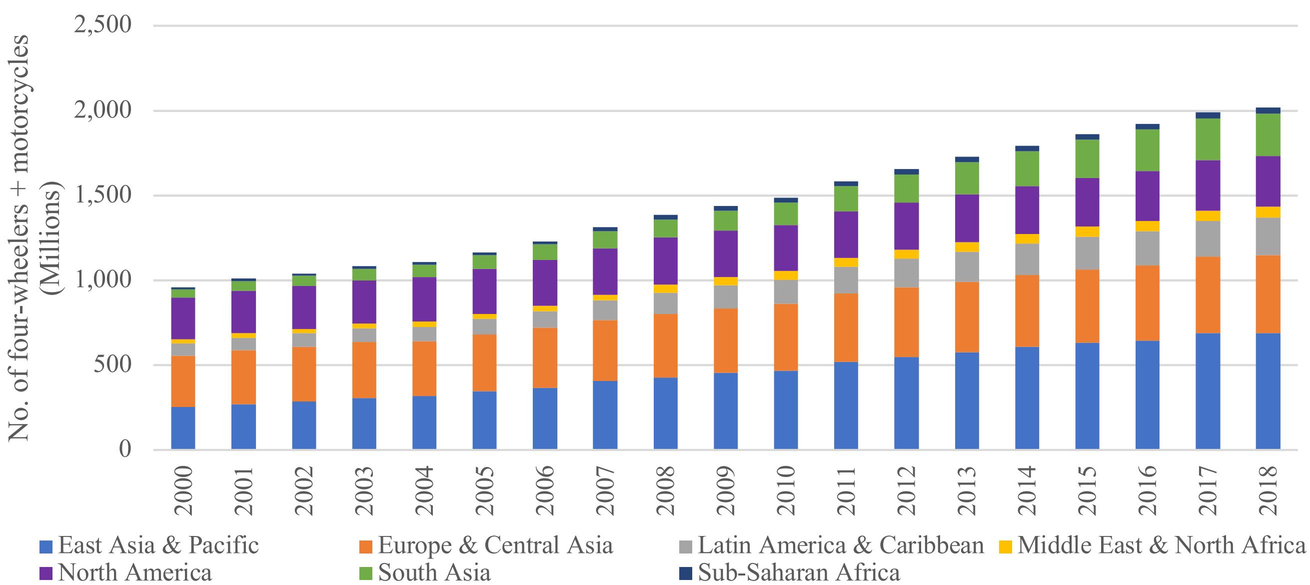
The State of Motorization Globally

This section provides an overview of the data and information available on motorization, using primarily data from the World Road Statistics (WRS), produced by the International Road Federation (IRF). WRS data are used because of the breadth of years for which the data are available; we have not done an extensive comparison among the datasets available, which include the International Organization of Motor Vehicles Manufacturers (Organisation Internationale des Constructeurs d'Automobiles, OICA), the International Energy Agency Mobility Model (IEA MoMo), and the Global Status Report on Road Safety. Some comparative calculations of the WRS data with other global compilations of worldwide motorization are presented in appendix A.

Trends in worldwide motorization

In 2000, 960 million vehicles were in use worldwide. This number has steadily increased over time, reaching 2,020 million in 2018, or an average growth rate of 4.1 percent per year.[1] The global motorization rate in 2018 was 266 motor vehicles per 1,000 persons, but actual motorization, not surprisingly, varies substantially by region. The median motorization rate in North America in 2018 was 657, while that of Sub-Saharan Africa was just over 20. (Comparative graphs of motorization rates by region are shown in appendix A.) The largest growth in vehicle numbers in the first two decades of the present century was experienced in East Asia and the Pacific region, where the number of vehicles increased by 436 million vehicles (from 254 million to 690 million) between 2000 and 2018. Median motorization rates in that region were 158 vehicles per 1,000 persons in 2018. The South Asia region experienced the second-largest increase in vehicle numbers at 201 million vehicles within that same period, with a median motorization rate of 29 vehicles per 1,000 persons in 2018 (see Figure 2.2). In terms of growth rate between 2000 and 2018, the

Figure 2.2. Number of Vehicles in Use by Region between 2000 and 2018

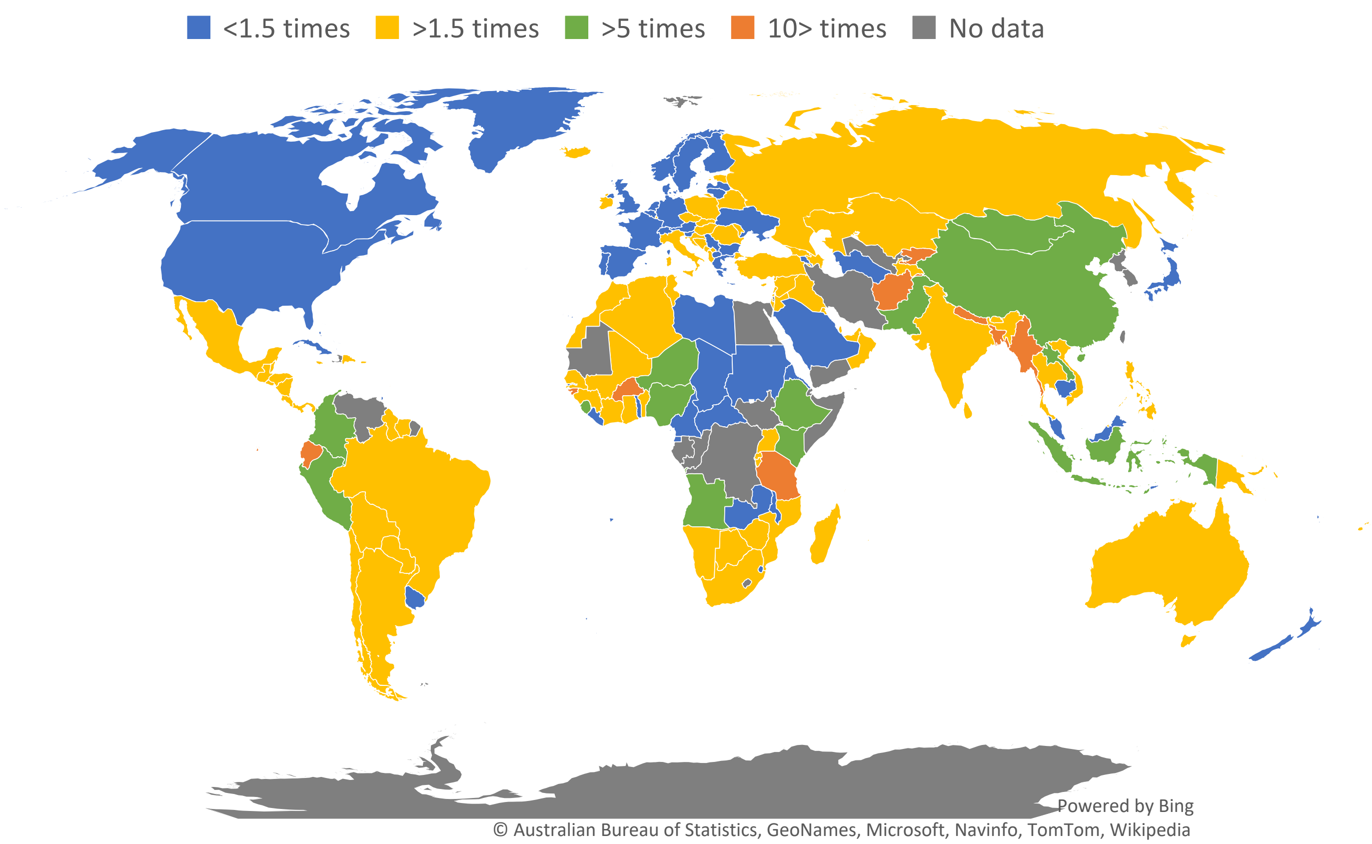


Source: World Road Statistics.

1 These numbers include passenger cars, buses and motor coaches, vans, pickups, lorries, road tractors, and motorcycles

South Asia region had the largest growth rate at 9.5 percent per year, followed by the Latin America and Caribbean region at 6.4 percent per year, the East Asia and Pacific region at 5.7 percent per year, and Sub-Saharan Africa at 5.6 percent per year (see Figure 2.3).

Figure 2.3. Change in the Number of All Types of Vehicles in Use between 2000 and 2018



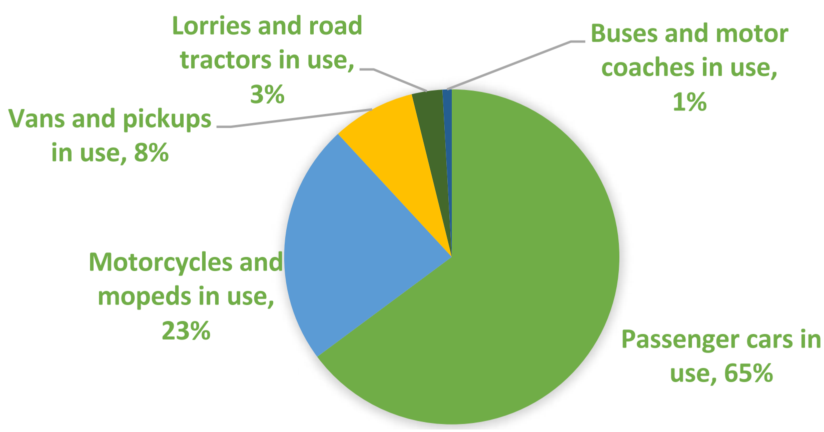
Source: World Road Statistics.

Proportion and Trends by Vehicle Types

Globally, passenger cars accounted for the largest share of vehicles in use, at 65 percent in 2018. Motorcycles and mopeds accounted for the second-largest share, at 23 percent. Together, they accounted for 88 percent of the total vehicles in use in 2018 (see Figure 2.4).

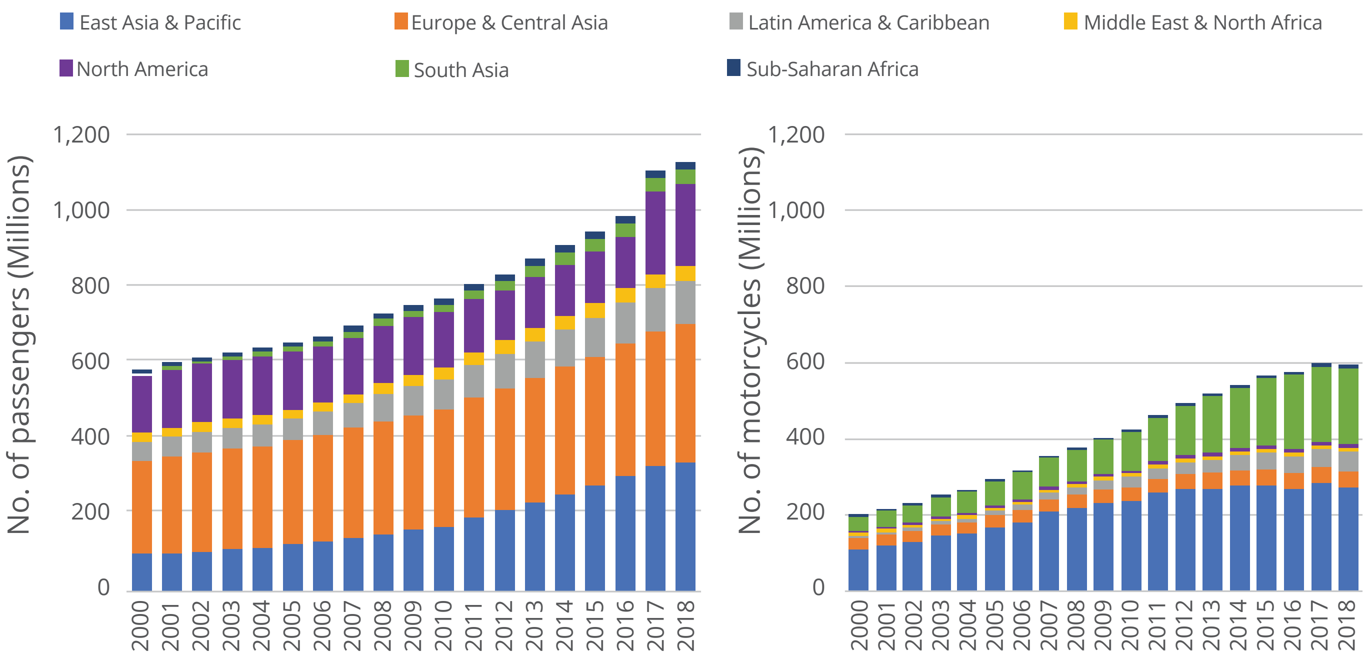
Trends in the numbers of in-use vehicles have shown a steady increase, with the number of passenger cars and motorcycles at 582 million and 202 million, respectively, in 2000, reaching 1,126 million and 595 million, respectively, in 2018. The growth rate of motorcycles in use between 2000 and 2018 was 2.9 times, which was higher than the growth rate of passenger cars, which was 1.9 times. The East Asia and Pacific region experienced the largest increase in actual numbers of passenger cars in use from 97 million in 2000 to 340 million in 2018. The South Asia region experienced the largest increase in motorcycle numbers from 38 million to 299 million within the same period. South Asia experienced the highest growth rates for both passenger and motorcycles at 4.8 and 5.3 times, respectively, between 2000 and 2018. The Latin America and Caribbean region also experienced a high growth rate for motorcycles, at 6.1 times during the same period (see Figure 2.5).

Figure 2.4. Proportion of Vehicle Types in Use in the World in 2018



Source: World Road Statistics.

Figure 2.5. Number of Passenger Cars and Motorcycles in Use by Region between 2000 and 2018



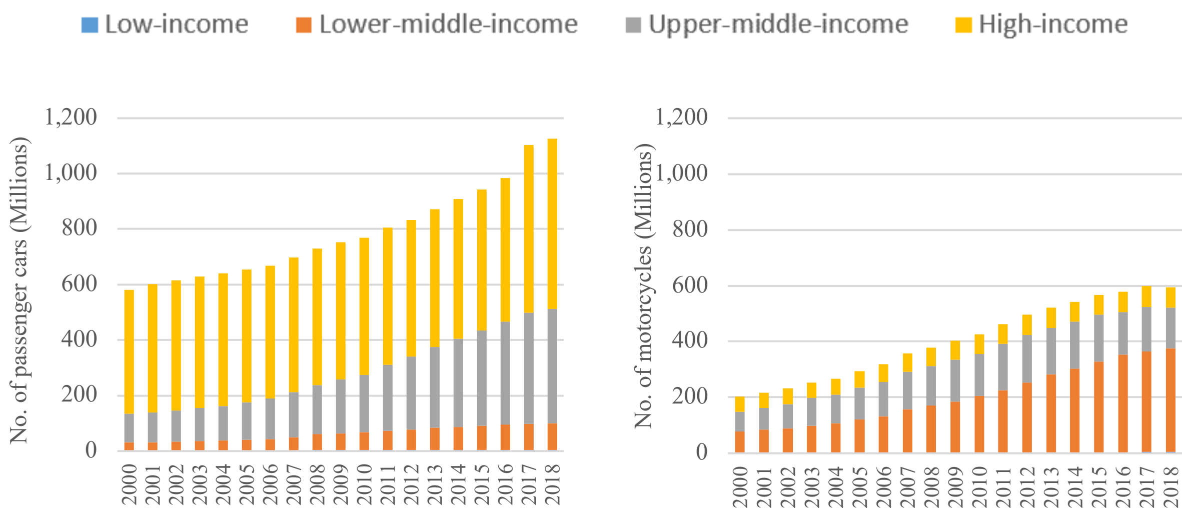
Source: World Road Statistics.

Trends of Passenger Cars by Income Level and Region

Between 2000 and 2018, upper-middle-income countries and lower-middle-income countries experienced high growth rates for passenger cars in use, at 4.0 times and 3.3 times, respectively. The number of passenger cars in use surged in upper-middle-income countries by 310 million from 103 million to 413 million within the same period.

On the other hand, the number of motorcycles in use soared in lower-middle-income countries by 295 million, from 77 million to 372 million, between 2000 and 2018. Low-income countries experienced the highest growth rate for motorcycles in use, at 6.0 times, followed by lower-middle-income countries at 4.8 times (see Figure 2.6).

Figure 2.6. Number of Passenger Cars and Motorcycles in Use by Income Level between 2000 and 2018

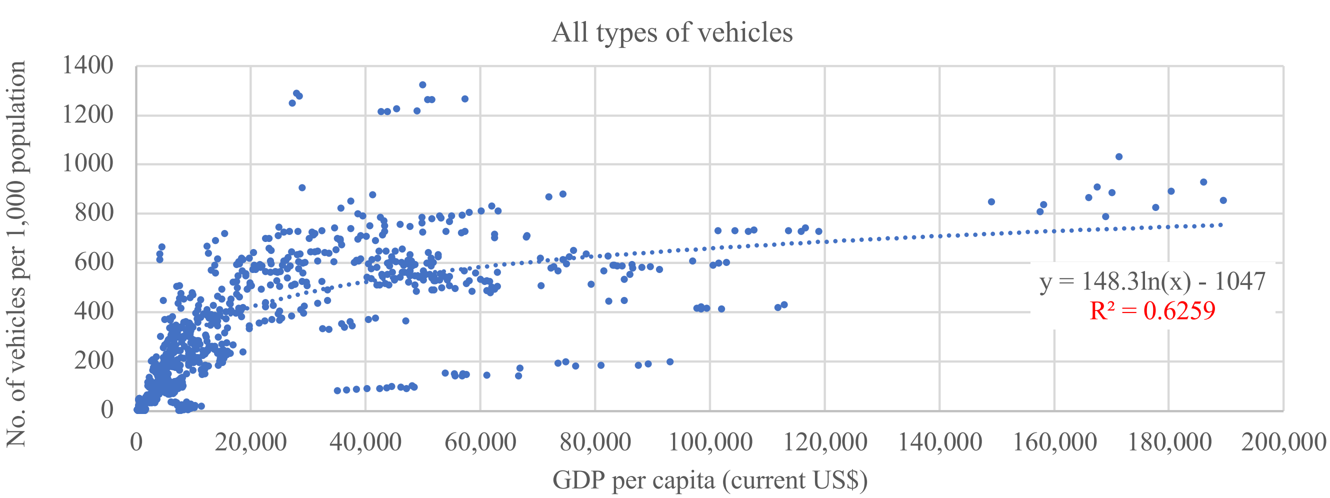


Source: World Road Statistics.

Correlation between the number of vehicles and GDP

There is a relationship between the number of vehicles in use and income (Peden et al. 2004). Data from 172 countries, including low- and middle-income countries, for the period between 2000 and 2019, confirm that there is a moderately strong relationship between the number of vehicles in use and GDP per capita (see figure 2.7).

Figure 2.7. Number of Vehicles versus GDP per Capita

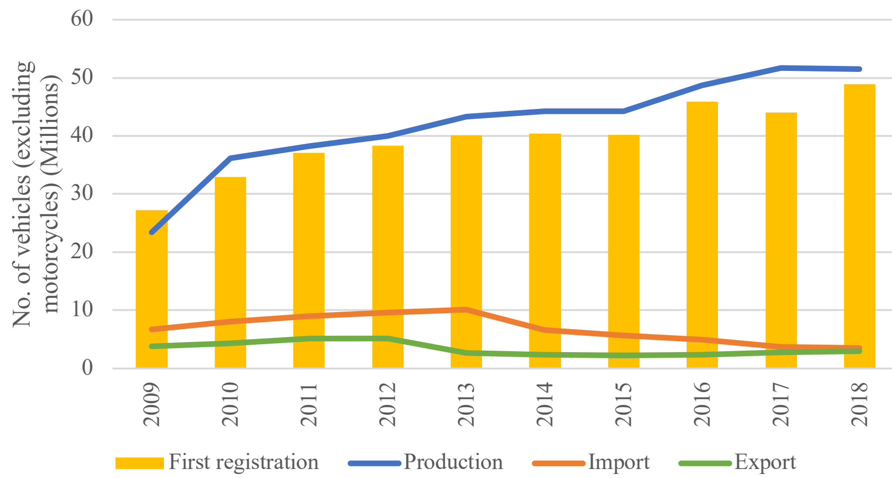


Source: World Bank based on World Road Statistics data.

Trends in vehicle imports and exports

The number of first registration and production of vehicles increased over time, and exports and imports of vehicles peaked in 2013 and then remained flat in low- and middle-income countries (see Figure 2.8).

Figure 2.8. Trends in the Number of First Registration, Production, Import, and Export of Vehicles, Excluding Motorcycles



Source: World Road Statistics.
Note: Trends shown for low- and middle-income countries only.

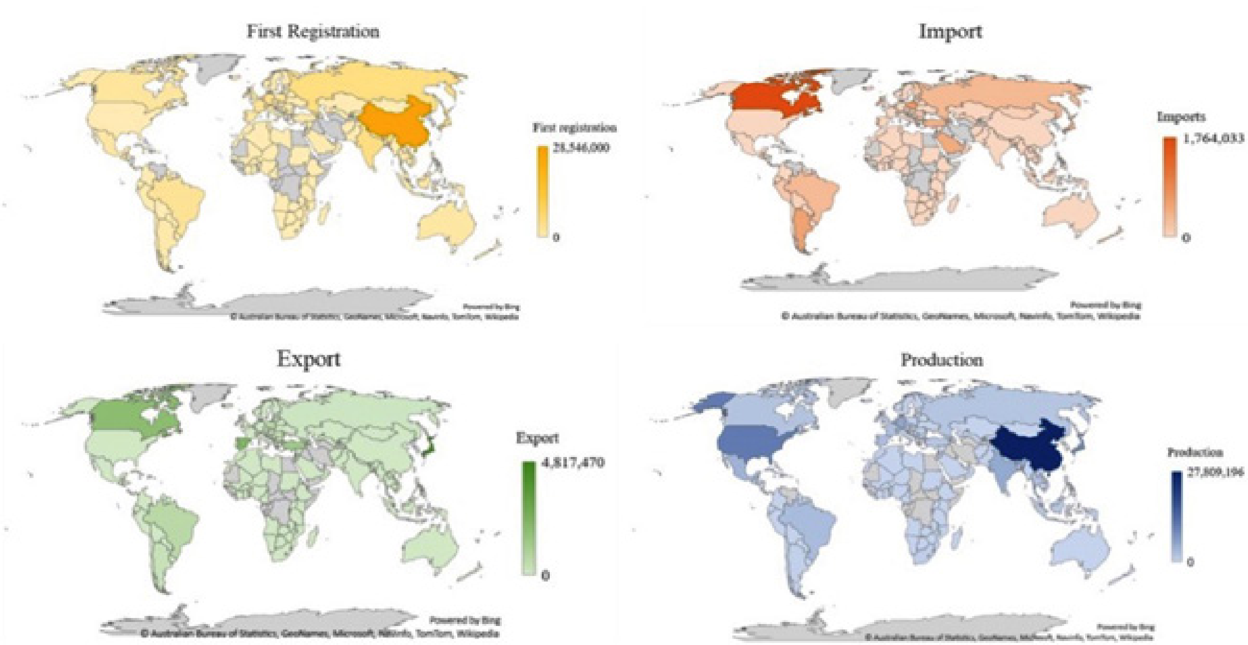
In 2018, low- and middle-income countries had a higher number of first registrations, with 48,964 vehicles, and production, with 51,503 vehicles, compared to 29,815 first registrations and 45,925 vehicles produced in high-income countries that same year. In low- and middle-income countries, imports of used vehicles accounted for about 16 percent of total imports, while exports of used vehicles accounted for about 3 percent of total exports (see Table 2.1).

Table 2.1. The Number of Production, Export, Import, and First Registration of Vehicles in 2018

	Income level				Low- and middle-income countries	Total
	Low	Lower middle	Upper middle	High		
First registration	168	7,180	41,617	29,815	48,964	78,779
Production	0	8,866	42,637	45,925	51,503	97,429
New Import	No data	67	2,611	2,463	2,678	5,141
Used Import	No data	9	559	633	568	1,201
Total Import	11	202	3,316	5,223	3,529	8,752
New Export	0	No data	2,874	9,903	2,874	12,776
Used Export	0	No data	88	66	88	154
Total Export	0	5	2,983	10,549	2,988	13,538

Source: World Road Statistics.
Note: Data are presented in thousands.

Figure 2.9. Overview of Number of First Registration, Production, Import, and Export of Vehicles, in 2018, by Country

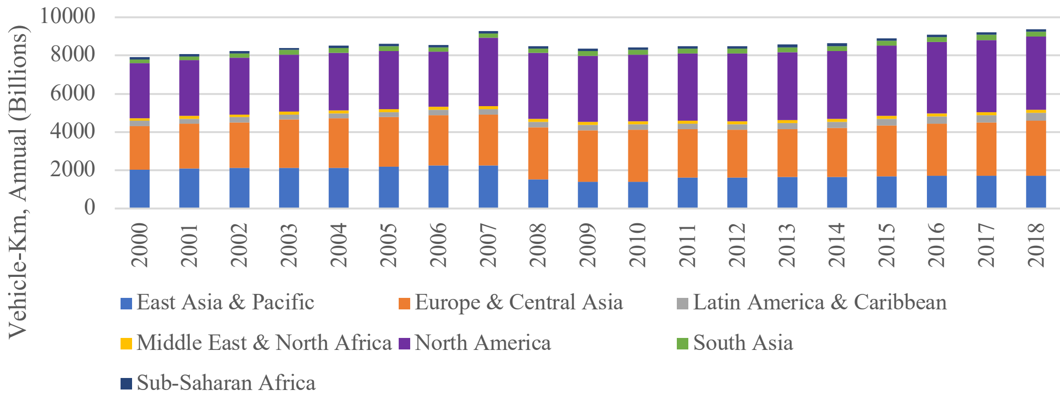


Source: World Road Statistics.
Note: Figure excludes data for motorcycles.

Traffic volumes

Traffic volumes worldwide spiked in 2007, decreased until 2009, but have been gradually increasing since then. However, it was only possible to analyze data for 96 countries, and there is a possibility of data imperfections (see Figure 2.10).

Figure 2.10. Traffic Volumes by Region between 2000 and 2018



Source: World Road Statistics.

References

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3. Motorization Management in the Sustainable Transport Agenda

Definition of Motorization Management

At its most basic level, Motorization Management (MM) is a deliberate, diligent, and coordinated process to shape, through public policies and programs, the profile, quality, and, to some degree, quantity and intensity of use of the motor vehicle stock as it progresses through a country's motorization process. MM seeks to shape the way motor vehicles are managed throughout their effective in-use life in a given country in order to improve safety, environmental, and fuel consumption outcomes. This life-of-vehicle approach means targeting policies and measures at different phases of vehicle life, including vehicle entry, active use, and vehicle exit, and the conditions that underlie demand for motorization. Because meeting some of these objectives also requires improvements in fuel quality and availability in certain cases, MM necessitates consideration of fuels and vehicles as a system. MM also looks at the important aspects of reuse and recycling of vehicles, parts, and materials linking to the overall vehicle life cycle, from the vehicle design, production, and post-production phases until scrappage.

Like other key themes affecting sustainable transport outcomes, such as road safety, asset management, or gender inclusion, MM is not concerned only with policies per se, but rather the entire governance ecosystem that gives rise to desirable policy outcomes affected by the evolution of a country's vehicle stock.[1] Developing the right policies, to be sure, is an important aspect of MM, but so is the development and strengthening of institutions to carry out policy analysis, to ensure compliance, and to manage stakeholders and communications, to name a few. MM policies will also affect government revenues and expenditures, and these impacts also fall within the purview of MM.

Motorization Management in the Policy Context

MM is one aspect of sustainable transport, focused specifically on the vehicles themselves; it is useful to understand how MM fits into broader sustainable transport policy. Over the past 20 years, a consensus has emerged among sustainable transport practitioners that the conceptual framework known as "Avoid-Shift-Improve" (ASI) broadly reflects the priorities and objectives of sustainable transport (Dalkmann et al. 2014). ASI is sometimes defined slightly differently, but as used here, it refers to: (1) the need to plan cities, neighborhoods, production and consumption processes, and transport and logistical services to **avoid** unnecessary use of motorized vehicles (where "use" in this context refers not only to whether people use motorized vehicles, but also how far they choose to or need to travel by motorized means); (2) the provision of transport mode alternatives, mode integration, and incentives such that people and goods transport **shift** to vehicles and modes that are able to move them more efficiently; and (3) the optimization of the vehicles, fuels, transport infrastructure, and operational systems to **improve** environmental and safety performance. A comprehensive sustainable transport policy will seek improvements in A, S, and I components across different scales—urban, rural, national, and international. MM addresses specifically the vehicle component of the I aspect of ASI.[2] Examples of the kinds of policies that an MM framework facilitates are shown in Box 3.1.

1 In this report, we refer to vehicle "fleet" as being the set of vehicles under the control of an identifiable agent, whether that be a natural person, a company, or a government. We refer to vehicle "stock" as the set of vehicles (separately or in fleets) that are in use in a given country.

2 It should be noted that there is also an important infrastructure management element to I under ASI that falls under the rubric of "Traffic Management" and is not generally considered under "Motorization Management."

Box 3.1. What Kinds of Policies Are Made Possible through Motorization Management?

Motorization Management (MM) asks governments to look beyond individual policies that may be recommended as "best practice" to understand what kinds of policies are really practicable in the country at a given time, and toward what goals? But, if effectively implemented, it can help countries to develop, adopt, and enforce motorization policies that can make a tangible difference toward sustainable economic development. Examples of policies whose implementation is enabled through this framework are:

- Requirements for motor vehicles to meet certain pollutant emissions standards
- Requirements for automotive fuels used in internal combustion engine (ICE) motor vehicles to meet certain quality specifications
- Requirements for motor vehicles to have certain crashworthiness configurations, such as crumple zones, airbags, seat belt and infant car seat anchorages, etc.
- Requirements for motor vehicles to meet fitness or roadworthiness standards, such as working brakes, minimum tire tread size, line-of-sight protection, etc.
- Feebates or similar programs that provide fiscal incentives for use of less fuel-intensive vehicles
- Assignment of carbon caps to specific motor vehicles, for example, in the context of regulatory or market-based climate mitigation measures

MM, then, is an enabler that allows countries to implement effective governance policies. But an effective MM framework can also help countries more effectively implement aggressive actions to influence the fuel intensity of vehicles and/or the extent of vehicle use, both of which will influence the carbon footprint of road transport. Fuel intensity can be influenced by using taxes or tariff rates to incentivize consumers to choose less fuel-intensive vehicles over more fuel-intensive ones. A revenue neutral way of creating such incentives is the use of "feebates" whereby an equilibrium point for a policy outcome (like fuel economy or CO_2 emissions per vehicle kilometer) is selected, and vehicles which underperform the equilibrium point have to pay an additional fee on the tax or tariff, while those which outperform the equilibrium point receive a tax or tariff rebate. The equilibrium point itself is continuously adjusted and made more stringent as the fleet composition changes in response to the policy. MM facilitates the use of feebates by creating the mechanisms not only for ex ante policy formulation and ex post policy evaluation and revision, but also for the assignment of performance characteristics to each and every vehicle. Mauritius, for example, had to abandon its efforts to use feebates in 2016 precisely because it lacked the information infrastructure and institutional setup to adjust equilibrium points and assign performance rating to individual vehicles vis-à-vis the equilibrium point.

Decarbonization of transport may also involve efforts to limit vehicle use, in addition to vehicle fuel intensity. As discussed earlier in this paper, reducing the overall amount of vehicle travel is a key decarbonization objective under an Avoid-Shift-Improve (ASI) framework, that is, as a function of the Avoid and Shift aspects of a sustainable transport policy writ large. But MM can also help to Improve the performance characteristics of the vehicle stock by limiting per-vehicle use, thereby encouraging fleet turnover. There are two ways MM might support stock turnover. First, MM can facilitate accelerated vehicle retirement (scrappage) programs. That is, policies might channel (or enhance) incentives for purchase of vehicles with low fuel intensity toward owners who demonstrate that this purchase *replaces* an existing vehicle and the vehicle being replaced is destroyed, not resold. (Such policies should also be designed to ensure that public funds are used to incentivize destruction of highly energy intensive vehicles sooner than they otherwise would have been in the absence of the policy, rather than simply pay for the destruction of vehicles that would have been destroyed anyway.) In other words, the policy would be intended to ensure that vehicle kilometers travelled (VKT) by less fuel-intensive vehicles replaces VKT by more fuel-intensive ones. Such a measure would have global greenhouse gas (GHG) accounting implications: used vehicles taken out of service in a country of first market and exported to low- and middle-income countries (for example, under a policy to encourage electrification of the fleet) could only be said to be reducing CO_2 emissions if they replace, rather than displace, a more fuel-intensive vehicle in the importing country.

A second way MM could help encourage fleet turnover in the long run is by establishing and enforcing per vehicle usage limits at the time of vehicle entry (certification/homologation) into the national vehicle stock. China, for example, assigns both age and odometer limits to ICE vehicles, beyond which those vehicles may not be registered for use on public roads. The premise behind such age and/or odometer limits is that at any point in time, all else equal and on average, younger vehicles should be less fuel intensive than older ones because of a combination of the technology used and less wear and tear.

Finally, incentives for vehicle fuel intensity reduction and limitations on per vehicle use to keep the fleet renewing can be mutually reinforced by using a per vehicle lifetime CO_2 emissions cap. Under such an MM approach, the policy might assign a CO_2 emissions "cap" to each vehicle of a certain class. At import, the vehicle would be assigned a fuel intensity rating based on preset criteria (as might happen say in the context of a feebate program), and then its lifetime permitted VKT in the country would be set based on the assigned fuel intensity and the cap for the vehicle class. The MM framework institutions would permit tracking of the vehicle's VKT through periodic technical inspection (PTI) odometer checks; it would automatically be classified as an End-of-Life Vehicle (ELV) once the vehicle reaches its VKT cap. Such a measure would incentivize purchasers to select the least fuel-intensive vehicle in the given class in order to have more permitted VKT. Such caps might eventually be incorporated into a market-based or other program in which the cap could be extended through the purchase of allowances.

Source: World Bank.

MM should be understood as a component of the ASI framework. It is best implemented in the context of sustainable transport policy informed broadly by an ASI approach; as such, a key tenet of MM should be that in the drive to improve motor vehicles and fuels, those efforts must not undermine policy efforts to avoid the need for motorized travel or shift the vehicles or modes by which they occur. An example of this undermining might be if efforts to improve vehicles used in public transport make the cost of delivering public transport services too costly for people to afford, and public transport mode share drops as a result.

Within the context of addressing the motor vehicle component of **Improve**, MM is generally concerned with the following five key policy outcomes aligned to the development agenda:

- Making the stock of vehicles in use safer by minimizing motor-vehicle-related fatalities and serious injuries associated with substandard vehicles and poor maintenance practices. Vehicle safety generally refers to crash avoidance characteristics of vehicles—whether they are properly maintained with functioning brakes, headlights, taillights, etc., and whether they are fitted with advanced crash avoidance technology such as Electronic Stability Control—and crashworthiness characteristics, such as whether they are fitted with proper restraint anchorages or airbags, or whether they have ample crumple zone protection for passengers in the event of a crash (see Box 3.2).

- Making the stock of vehicles in use cleaner by minimizing tailpipe emissions and other toxic and noxious effluents (including noise). This requires consideration of fuel quality and availability as part of the policy objective (see Box 3.3).

- Making the stock of vehicles being used more fuel efficient—that is, minimizing the amount of energy (especially, but not only, fossil fuel energy) needed to power the vehicle stock. Depending on the level of ambition, this may require consideration of fuel type and availability as part of the policy objective. Fuel-efficient vehicles reduce both user fuel costs and emissions of CO_2, thereby generating financial and climate benefits (see Box 3.4).

- Influencing the size and/or composition of the vehicle stock to be in line with sustainable development objectives. Some countries may articulate a vision of the level of motorization they wish to target, for example, in order to spend infrastructure resources efficiently (see Box 3.5).

- Ensuring continuity of fiscal resources—managing the fiscal impact accompanying the motorization process (see Box 3.6).

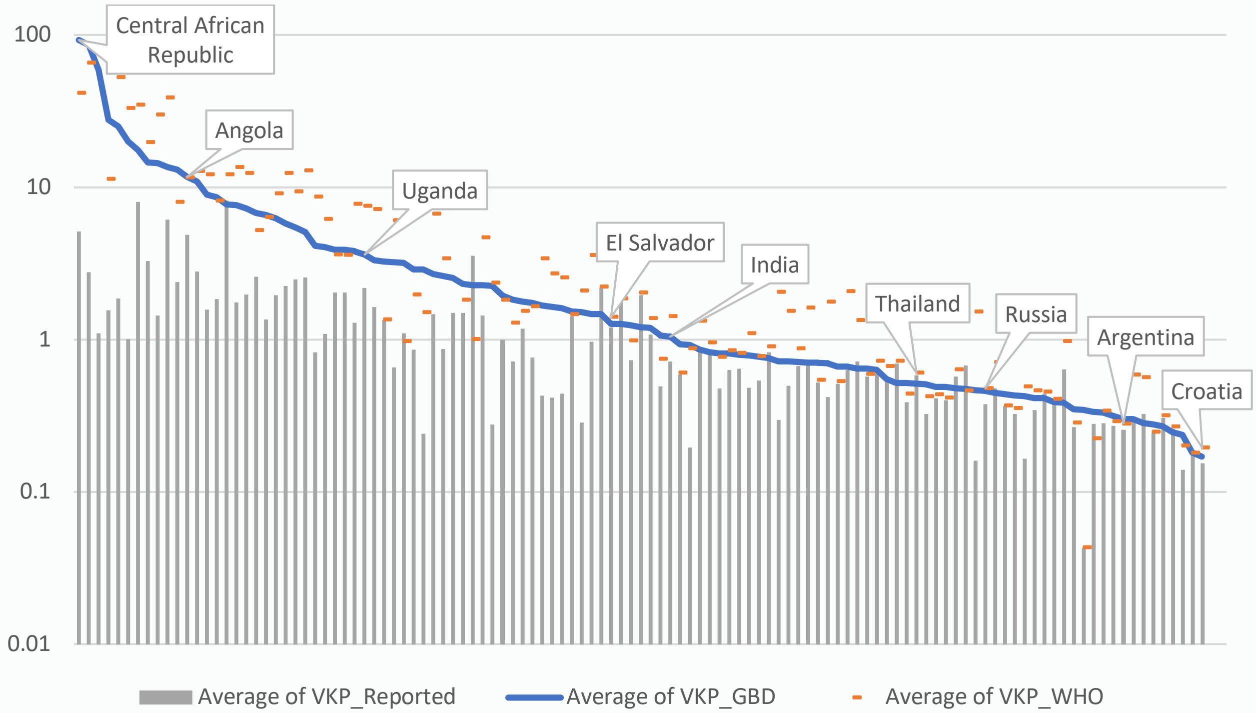
These policy outcomes may be complementary in some instances and involve trade-offs in others. Different countries might balance these trade-offs differently.

Box 3.2. Road Safety Dimensions of Motorization Management

Motorization Management (MM) measures can help improve the safety characteristics of motor vehicles. Safe vehicles are regularly identified as a key element of the safe systems approach to road safety, along with safe infrastructure, safe speeds, effective road safety institutions, and post-crash care. "Safe vehicles" refers to both configuration and fitness. Configuration relates to the way the vehicle has been designed, including whether it is fitted with seat belt anchorages, front and side airbags, adequate child-restraint systems, adequate front crumple zones, structural design to avoid rollovers, pedestrian contact height, advanced crash avoidance features like electronic stability control, and other aspects. "Fitness" refers to how the vehicle is being maintained, such as whether key features, including brakes, lights, and turn signals, are in functional order; whether tire treads are substantially worn down; whether the vehicle has been altered in a way that inhibits sight lines or passenger safety in the event of a crash; or whether there are any other hazardous conditions on the vehicle.
The World Health Organization (WHO) estimates that about 1.35 million people die each year as a result of road traffic crashes. Road traffic injuries are the leading cause of death for children and young adults aged 5 to 29 years. Ninety-three percent of fatalities occur in low- and middle-income countries, even though only about 60 percent of the world's vehicle stock is located in these countries (WHO 2018). James et al. (2020) have estimated that nine of the 10 countries with the highest probability of death from road crash injuries are low- and middle-income countries. One indicator to measure this probability is the Vehicle Killing Potential (VKP).

VKP measures the number of traffic fatalities per 1,000 vehicles. It is useful to help evaluate differences across low- and middle-income countries and fatality estimates and constitutes a more direct metric for assessing vehicle policy than the more epidemiological-focused fatalities per capita. Figure B3.2.1 shows VKP for all low- and middle-income countries, ranked from highest to lowest using the GBD fatality estimate. GBD is considered more accurate because it is based on a review of fatality records using a consistent approach across countries. VKP estimates range from 0.17 deaths per 1,000 vehicles in Croatia to 92.6 deaths per 1,000 vehicles for Central African Republic—nearly one fatality per 10 vehicles. Other countries are highlighted in figure B3.2.1. For each country, corresponding VKP values based WHO fatality estimates (based on statistical model, not actual observations in a country) and fatalities reported within each country are also shown in figure B3.2.1.)

Figure B3.2.1. Vehicle Killing Potential Metric for Low- and Middle-Income Countries Based on Three Fatality Estimates



Source: World Bank calculations based on source data.

At present, road safety data do not allow for a rapid assessment of the relative responsibility of vehicle factors in the observed fatalities from road traffic crashes. One study in China used factor analysis to calculate that vehicle condition was the third most important factor in road traffic fatalities, after driver error and driver experience. "Purpose of vehicle," which is not defined in the study, but might reflect the vehicle size and configuration, was found to be the fourth most important factor (Chen, Zhang, and Xu 2016).

Source: World Bank.

Box 3.3. Air Pollution Dimensions of Motorization Management

Motorization Management (MM) measures can help reduce the contribution of motor vehicles to ambient air pollution. Ambient air pollution is a factor in strokes (24 percent), chronic heart disease (25 percent), COPD (43 percent), lung cancer (29 percent), acute lower respiratory infection (17 percent), diabetes, and other diseases (IQAir 2020). It is the fourth-highest leading health risk factor for death, contributing to 3.75 million premature deaths in 2019, and seventh-highest risk factor for Disability Adjusted Life Years (DALYs), contributing between 10 percent and 12.5 percent of DALYs in many parts of Sub-Saharan Africa and Asia (Murray et al. 2020).

The two key index pollutants that researchers use to gauge health effects are ambient fine particle concentrations ($PM_{2.5}$) and ambient ozone (O_3) concentrations. The World Health Organization (WHO) establishes guidelines for maximum concentrations as shown in the following table.

Table 3.3.1. World Health Organization Guidelines for Ambient Air Quality Concentrations for Particulate Matter and Ozone

$PM_{2.5}$	10 mg/m^3 annual mean
	25 mg/m^3 24-hour mean
O_3	100 mg/m^3 8-hour mean

Source: Source: World Health Organization.
Note: $PM_{2.5}$ = fine particulate matter with a diameter of 2.5 micrometers or less; O3 = ambient ozone; mg/m3 = milligram per square meter.

WHO has estimated that 91 percent of the world's population lives in places that exceed these limits. A report in 2020 surveying air quality monitoring data from 2019 identified the proportion of cities by world region that met the WHO guideline for annual mean concentrations of $PM_{2.5}$ (IQAir 2020).

Table 3.3.2. Compliance with WHO Ambient Air Quality Guidelines for Annual Mean $PM_{2.5}$ Concentrations

Region	Percent of cities meeting WHO annual mean $PM_{2.5}$ guideline
East Asia	16.9
Southeast Asia	3.2
Central & South Asia	0.7
Western Asia	0
Europe	36.4
North America	80.5
Latin America & Caribbean	14.5
Africa	13.7
Oceania	79.1

Source: IQAir (2020) based on cities where air quality monitoring data are available.

Motor vehicles used in transport are a significant source of pollutants. $PM_{2.5}$ are produced in both gasoline and diesel-powered internal combustion engines (ICEs), though diesel engines produce $PM_{2.5}$ in much higher amounts, in terms of both mass and number. O_3 is formed in the troposphere through complex chemical reactions, reactions highly dependent, among other factors, on concentrations of non-methane hydrocarbons (NMHCs) and oxides of nitrogen (NOx) in the atmosphere. Gasoline vehicles are a major source of NMHCs, while diesel vehicles are a major source of NOx.

The International Council for Clean Transportation (ICCT) has estimated the relative contribution of transport-related tailpipe emissions associated with O_3 and $PM_{2.5}$ to deaths at a global level (Anenberg et al. 2019). The researchers found that, in 2015, 11.4 percent of ambient air pollution deaths were attributable to tailpipe emissions from mobile sources, amounting to a global welfare loss of US$976 billion. In terms of death and economic loss from death, $PM_{2.5}$ was substantially more impactful than O_3 by a factor of more than 10; $PM_{2.5}$ accounted for 91 percent of the total welfare loss from tailpipe emissions calculated. The researchers also calculated a transport attributable portion of air pollution deaths for the top 100 metropolitan areas. The data provided do not permit reporting a population-weighted average for these metropolitan areas, but the median value is 14.9 percent.

It should be noted that tailpipe emissions are not the only way that transport contributes to pollution. Evaporative emissions associated with refueling and hot soak of gasoline vehicles are an important source of NMHCs. Resuspension of road dust and brake and tire wear also contribute particulate matter to ambient concentrations. MM measures, however, would mostly target emissions from tailpipe exhaust.

Fuel specification plays an important role in motor vehicle pollution outcomes, so is an integral part of MM. Sulfur concentrations in fuels greater than 50 parts per million (ppm) progressively degrade the effectiveness of Euro IV/4 technology with concentrations greater than 500 ppm rendering them ineffective. For more stringent Euro emissions control technology, even more restricted levels of sulfur (generally less than 10 ppm) are required. NO_x control in Euro VI equivalent vehicles requires the availability of urea (such as Adblue). Lead has largely been removed from gasoline supply streams around the world, but other anti-knocking additives, such as methylcyclopentadienyl manganese tricarbonyl (MMT), continue to be used in many parts of the world. Manganese, like lead, can inhibit the functioning of emissions control equipment and is a neurotoxin. The ability to ensure the availability, distribution, and integrity of high-quality fuels, therefore, is an important aspect of MM.

Source: World Bank.

Box 3.4. Climate Change Dimensions of Motorization Management

Motorization Management (MM) measures can help advance the decarbonization objectives of a country. In the road transport sector, greenhouse gas (GHG) emissions are overwhelmingly dominated by carbon dioxide (CO_2) emissions from the fleet as it is being used. In-use CO_2 emissions are directly proportional to fossil fuel consumption, which in turn depends on three factors: fuel intensity of the vehicles used, how far they are driven, and the conditions under which they are operated. Comprehensive sustainable transport policies, particularly those that have an emphasis on decarbonization, can affect all of these factors, but do so differently. The table below shows how different elements of transport policy can affect CO_2 emissions.

Table 3.4.1. Motorization Management and Other Policy Approaches to Influence Decarbonization Pathways in Transport

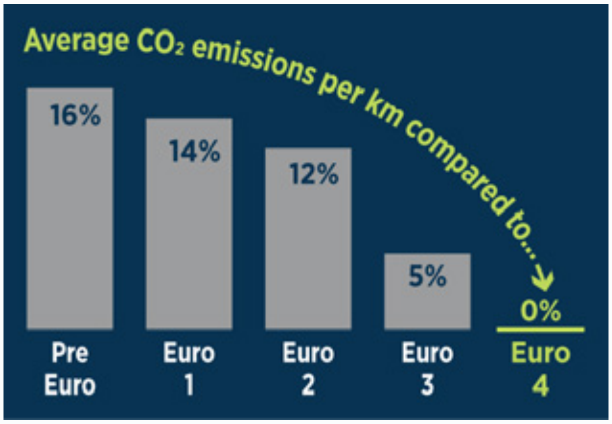
Factor affecting CO_2 emissions	CO_2/fuel tax	Motorization Management	Demand management/pricing/land-use/incentivizing alternatives	Traffic management	Infrastructure quality
Fuel intensity of the vehicles	✓	✓			
How far vehicles driven	✓	✓	✓	✓*	✓*
What conditions are they driven under				✓	✓

***** potentially via induced travel
Source: World Bank.

MM can influence the fuel intensity of the vehicles and how far they are driven. These will be addressed in turn.

Average road transport fleet fuel economy in low- and middle-income countries is challenging to determine for many of the challenges that are discussed in this report. International Energy Agency (IEA) data show that new light-duty vehicles (LDVs) in countries that are not members of the Organisation for Economic Co-operation and Development (OECD) as a whole are, on average, 10 percent more fuel intensive than in OECD countries (7.3 liters per 100 kilometers in non-OECD countries in 2020, compared to 6.6 liters per 100 kilometers for OECD countries). Furthermore, the rate of decline in new vehicle fuel intensity has been over twice as steep in OECD countries as in non-OECD countries. In 2005, average new LDV fuel intensity in non-OECD countries was 6 percent lower than in OECD countries. The likely explanation is that new cars/LDVs in non-OECD countries have been getting bigger and heavier. What internationally available data do not currently permit is a clear picture of the effect of the secondhand vehicle trade on GHG emissions globally, and within the low- and middle-income recipient countries.

Figure 3.4.1. Euro Emission Standards and CO_2 Intensity Reduction



LMICs that deploy MM reduce negative impacts from imported vehicles while remaining responsive to market demand.

For example, requiring imported vehicles to meet Euro 4 standards can lead to CO₂ reductions.

Source: World Bank calculations based on data from the European Environment Agency, https://www.eea.europa.eu/data-and-maps/figures/fuel-efficiency-and-fuel-consumption.

An MM program focused exclusively on improving vehicle safety features and pollutant emissions—that is, one that does not specifically have a climate or decarbonization orientation—might have marginal benefits for reducing CO_2 emissions by reducing the fossil fuel intensity of vehicles in important, but limited, ways. For example, in some countries with particularly old vehicles still in use, MM measures might constrain the continued use of carbureted internal combustion engine (ICE) vehicles, which remains fairly prevalent in many low- and middle-income countries, and promote adoption of fuel injection technology, which, all else equal, would reduce fuel intensity. In addition, the measures might limit the use of poorly maintained vehicles whose fuel economy has been compromised because of accident, wear and tear, and/or poor maintenance.[a] These potential impacts have not yet been evaluated quantitatively, though efforts are underway to do so. Finally, because emissions standards in OECD producer countries have been improving at the same time that average fleet fuel economy performance has also been improving, particularly for LDVs, on average, there is a fuel intensity and per kilometer CO_2 emission reduction associated with improvements in emissions standards. This relationship with respect to European Union (EU) standards, for example, is shown in Figure B3.4.1.

That said, in order to have a meaningful effect on speed of decarbonization in developing countries, MM programs should incorporate measures specifically intended to reduce the fuel intensity of newly added ICE vehicles and accelerate the transition toward alternative fuel/traction vehicles. To be sure, technology is improving over time such that, all else equal, newer vehicles should be less fuel intensive than older ones, so one would expect that fleet modernization in and of itself would lead to less fuel-intensive vehicle stock. Examples of such technology innovations include:

- Use of hybrid electric technologies to reduce fossil fuel consumption
- Use of advanced transmission technologies, such as continuously variable transmission (CVT), to reduce engine load
- Use of lightweight materials in chassis and body construction.

a For example, on typical used vehicles entering low- and middle-income countries today, performing basic maintenance such as engine tune-ups, tire pressure checks, and replacing a failing oxygen sensor (a key emissions and fuel economy component in modern cars) can affect overall fuel economy by between 5 percent and 40 percent.

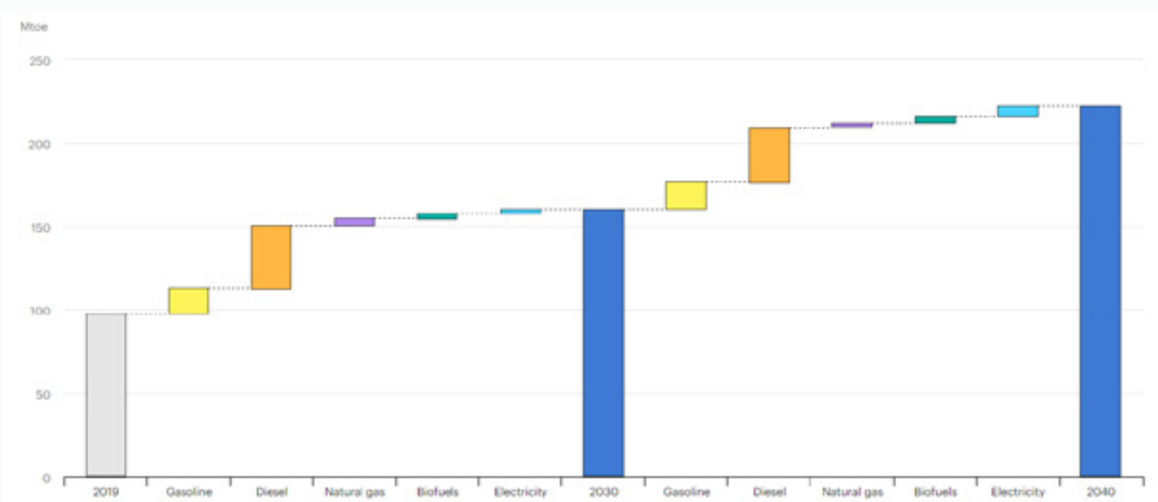
Unfortunately, fuel intensity is not always purely a factor of just technology. It depends highly on a range of other factors dependent on consumer choice, such as:

- Size/weight of the vehicles selected by consumers;
- Choice of aerodynamic design (for LDVs) or the use of fittings to improve aerodynamic operation (for HDVs), which, in turn, is often subject to consumer taste or limited by information; and
- Vehicle marketing strategies by original equipment manufacturers (OEMs), which may optimize power over efficiency in the application of particular technologies.

In the case of low- and middle-income countries that are highly dependent on secondhand vehicle imports, the extent to which consumers can actively select these characteristics versus the extent to which their choices are already limited by consumer preferences in the primary market sometime in the past is unclear. Nevertheless, providing better information about vehicles and their expected life-time fuel intensity, smart fiscal policies, and financial incentives to consumers, suppliers, and financial intermediaries can help shape characteristics of consumer preferences giving rise to the overall fuel intensity of the in-use stock.

The need for such concerted measures cannot be overstated. For example, India has a relatively aggressive policy for reducing new car fleet fuel intensity compared to other low- and middle-income countries. Even so, the IEA has calculated that India's energy demand in the road transport sector will more than double between 2019 and 2040, and that most of that increase in energy demand will come from conventional gasoline and diesel.

Figure 3.4.2. Changes in Road Transport Energy Demand by Fuel in India in the Stated Policies Scenario, 2019–40



Source: IEA 2021.

To make an impact on transport decarbonization, therefore, MM programs should include measures to incentivize sharp reductions in fuel intensity of ICE vehicles and transitions away from their use, and these measures should be as aggressive as possible. Tax, tariff, or financial incentives could be provided for the purchase of more fuel-efficient vehicles, or to incentivize purchase of electric vehicles (EVs). These incentives would need to be developed so as not to distort vehicle markets toward heavier LDVs (for example, sport utility vehicles or pickup trucks) over lighter ones (for example, sedans). These are discussed in more detail under the “Strengthen Market Mechanisms for Funding and Managing Vehicle Stock Growth and Turnover” section in chapter 4.

It is important to note that any measures which reduce vehicle fuel intensity also help to reduce hard currency losses associated with fossil fuel purchases, so there are macroeconomic benefits for the country in addition to climate benefits for the planet. These dual benefits to macroeconomic and climate objectives from decreased motor vehicle stock fuel intensity are, however, subject to take-back or rebound effects; all else equal, reduced cost of driving associated with fuel intensity reductions is correlated with increased vehicle kilometers traveled (VKT) per vehicle because of income and substitution effects. [See Gillingham (2018) for a good summary of recent (US-based) literature on rebound effect.] For this reason, we advocate throughout this paper that an MM framework should be conceived as part of (not a substitute for) a broader sustainable transport strategy.

In addition to reducing CO_2 emissions from the vehicle fleet as it is being used, MM measures can also reduce emissions of other substances that contribute to radiative forcing. These substances include black carbon, hydrofluorocarbons (HFCs), and methane (CH4). Black carbon refers to the carbonaceous core of particulate emissions (for example, $PM_{2.5}$), which has a highly variable effect on radiative forcing depending on where in the world it is present but is associated with a Global Warming Potential (GWP) of 350–400 in the GAINS model (GAINS IIASA). Any MM measures that help reduce $PM_{2.5}$ emissions, therefore, would help reduce this radiative forcing. HFCs are used extensively in refrigeration and air conditioning applications in road transport. Risk of HFC emissions from road transport is high because of mishandling by poorly trained personnel in the vehicle maintenance and repair sector (Rodríguez, Carriel, and Gavilanes 2012), and in the case of fugitive emissions following traffic crashes. Because the GWP of HFCs is extremely high (between 53 and 15,000), a small amount of emissions can result in very high CO_2eq. Finally, risk of CH4 emissions is high where compressed natural gas (CNG) is used in the transport sector. Risks of emissions are associated with fugitive gases not only in the upstream delivery and distribution system, but also in the compression process.

Source: World Bank.

Box 3.5. Motorization Management to Support Sustainable Development and Sustainable Lifestyles

Motorization Management (MM) as a set of policy tools can help countries to not only address air quality, road safety, or fossil fuel consumption reduction goals, but also to support other sustainable development objectives, such as fostering healthy lifestyles, or reducing infrastructure investment burdens. Indeed, three facets of development are highly interdependent: the amount of land-space and infrastructure investment needed to meet motor vehicle "demand," the extent to which populations perceive themselves as being "dependent" on motor vehicles to attain a certain basic or desired level of accessibility expected for a given level of development or prosperity, and the extent of motor vehicle penetration at the "saturation" point. How these factors play out in a given country will influence how "elastic" is the demand for private, motorized transport (that is, how easily travelers can be coaxed to switch to collective transport or active mobility), and how much investment in infrastructure will be required to maintain a given level of accessibility. For many countries, however, extrapolation of past rates of growth of vehicle ownership and usage implies an unsustainable and unfathomable level of investment in the future—in road and parking infrastructure—were that growth rate to be maintained.

An often unstated but very common assumption underlying motorization policy is that motorization is inevitable, and that the role of public policy is to facilitate it in the interest of enhancing economic growth. To suggest that public policy could or should be used to restrain motorization may even be considered heretical in the political culture of many countries around the world. But, as discussed in chapter 2 in the section on "Motorization As Technology Diffusion," while the process of motorization may follow the same logistic distribution across different societies, the ultimate level of saturation to which the system tends can be very different, depending on different transportation, land-use, and urban development policies of different countries and regions. Public policies can be used to influence and reduce the saturation level of motorization, and MM might play a role in contributing to such efforts.

Before enumerating the ways that MM might play such a role, it is important to emphasize that if the objective is to head off the growth of the motor vehicle stock to be within some acceptable threshold, the best way to do that is to head off the growth of motor vehicle *usage*, meaning vehicle kilometers traveled (VKT). MM is not the most effective tool in policy makers' toolbox to head off vehicle usage. Rather, travel demand management, prioritization of public and active transport in investment and traffic management decisions, and better integration of land-use and building controls with transport investments to reduce the dependence on private motor vehicle use as the principle means of enhancing accessibility should be the tools of choice to constrain the growth of private motor vehicle usage.

That said, MM can be used to complement such efforts to prioritize alternatives to car use and car-dependent accessibility enhancement in a number of key ways. First, the mechanisms of vehicle governance might be used to establish and enforce *per vehicle* usage limitations. Fiscal and regulatory policy can be used to incentivize and facilitate the use of leasing as an alternative form of vehicle availability payments; leasing could provide better legal and financial incentives for vehicle owners to limit vehicle usage. In addition, motor vehicle importation (or manufacturing) regimes can assign lifetime vehicle usage caps to vehicles which may restrain growth of VKT. Second, the same mechanisms of vehicle governance could also be used to shift the burden of the lifetime costs of vehicle ownership from fixed to variable. By "variabilizing" costs (for example, shifting fiscal policy such that the revenue-raising potential of a vehicle is more dependent on use than up-front acquisition and/or recurring registration), vehicle owners would have an economic incentive to use their vehicles less. All else equal, the less vehicles are used, the more viable are the alternatives, creating a virtuous circle reducing overall demand for vehicles.

In theory, the mechanisms of MM could also be used to place more direct constraints on motor vehicle acquisition and ownership, like increasing the costs of motor vehicle acquisition or even putting direct quotas or limitations on the number of vehicles that can be imported or registered. Such mechanisms should be viewed with healthy skepticism. Measures to make vehicle *acquisition* or *ownership* more expensive or otherwise limit opportunity for vehicle ownership on their own can produce perverse effects which may be counterproductive. Specifically, there are theoretical reasons and empirical evidence to suggest that while increasing the costs of vehicle ownership may indeed reduce the number of vehicles in a stock, it may create a perverse incentive for greater use of each vehicle. With higher vehicle ownership costs, owners are more likely to reason that they need to increase their usage of the vehicle in order to "recover" their investment.[a] Schipper and colleagues at Lawrence Berkeley National Laboratory, in their seminal work in the 1990s comparing motor vehicle use, ownership, and energy consumption among OECD countries, found evidence of this phenomenon when looking at car ownership and usage rates in Western Europe (Schipper 1995).

a Another way to understand this phenomenon is that high acquisition costs encourage an "average-cost" mindset to reducing car-related expenses by households and fleet owners, while high usage costs encourage a "marginal-cost" mindset. See, for example, UNESCAP and AITD (2001) or Walter and Suter (2003) for additional explanation.

Source: World Bank.

Box 3.6. Ensuring Continuity of Fiscal Resources

The objectives of any Motorization Management (MM) policy (for example, having a more fuel-efficient vehicle stock) or the measures to effect those policies (for example, adjusting price incentives to purchase and use more efficient vehicles) will inevitably have an impact on fiscal resources. For example, many countries fund road maintenance programs using the stream of revenues expected from fuel taxes. For many countries, import duties and value added tax (VAT) on different categories of motor vehicles imported for use also represents an important source of revenue for the general treasury. Accompanying any efforts to define different policy outcomes from an MM approach, therefore, is the need to, at a minimum, carry out fiscal impact studies to at least understand the extent to which revenues will be affected by the goals and measures contemplated. More proactively, MM policies should ideally be designed to ensure that destabilization of revenues does not produce unwanted consequences, such as deferred road maintenance. This may mean finding alternative sources of revenue that might otherwise be lost by an MM-driven policy, or else ensuring revenue neutrality in the design of specific incentives. The recognition of the need to avoid unwanted consequences from revenue perturbance, and the preferred methods to do so, could be stated as a matter of policy.

Source: World Bank.

Key Concepts for Framing Motorization Management Policy

In seeking to manage trade-offs among different policy outcomes and stakeholders, country policy makers will face an array of possible policy and implementation options. MM, therefore, cannot be prescriptive; it must take the form resulting from the political economy of national or regional circumstances. But to help frame the discussions in which such policies and objectives are developed, in this section we lay out 10 key concepts organized according to their relevance to motor vehicles at different phases in their life cycle. These concepts are not intended to be prescriptive—indeed, many may initially seem counterintuitive—but rather seek to stimulate understanding of the ways MM might influence motor vehicle stock evolution.

Vehicle Entry

To protect public health and safety, vehicle importation or manufacturing thresholds should be used; to meet national public policy goals, economic incentives targeted to vehicle purchasers, manufacturers, or importers generally work best.

Command and control policy instruments, such as regulations, can be more effective in delivering health and safety outcomes than fiscal incentives because they establish thresholds that determine minimum standards that each and every vehicle entering a country's vehicle stock must adhere to. To be effective, however, they require well-functioning monitoring and enforcement systems and institutional capacity to ensure that the standard is obtained. As will be discussed below, these systems and capacity need to minimize the absolute incidence of fraud to be effective.

Fiscal and financial incentives, on the other hand, might be more appropriate instruments to push the vehicle stock in intended directions to meet national goals over time because they can affect the economic calculus about when and what type of motor vehicle to acquire. Due to their voluntary nature, fiscal and financial incentives can take longer to induce significant change, when compared to a regulatory instrument. However, their effectiveness does not depend on a country's regulatory enforcement capacity.

Fiscal or financial incentives can refer to any policies that change the price to consumers of acquisition and/or ownership of certain kinds of vehicles compared to others. These can be in the form of incentives or disincentives, such as setting customs tariffs or registration fees[3] based on vehicle technology or emissions standard, or financial incentives, such as vouchers toward purchase of certain kinds of vehicles subject to conditions, or preferential finance or leasing terms for acquisition of vehicles consistent with the policy objective. Typical measures to affect relative acquisition or ownership prices include differential excise duty rates and/or registration fees—differentiated, that is, against a public policy parameter of interest, such as accelerating use of advanced vehicle safety features or reducing fossil fuel energy consumption of the fleet. The latter might use proxy measures to represent reduced fossil fuel energy consumption, such as vehicle size, engine size, propulsion type, fuel type, and/or standardized CO_2 emissions rates (for example, grams per kilometer).

Another popular approach is the use of "feebates," a potentially revenue neutral incentive whereby excise duties vary around an increasingly stringent target value such that purchasers of vehicles that exceed the target value pay a fee, while those that purchase vehicles rated lower than the target receive a rebate.

Age is not a good proxy for air quality, safety, or fuel efficiency performance characteristics of light-duty vehicles, especially those in noncommercial service; to improve light-duty vehicle stocks, policies should focus on specific air quality or safety performance features, or fuel intensity characteristics, rather than age alone.

Performance-based thresholds are a more precise approach than age-based limitations. Performance-based thresholds entail establishing a lower bound of acceptability for each vehicle type entering the national stock for the first time, and for the fuels that power them. Examples of parameters used to define performance-based thresholds are vehicle tailpipe emissions and vehicle crashworthiness levels.

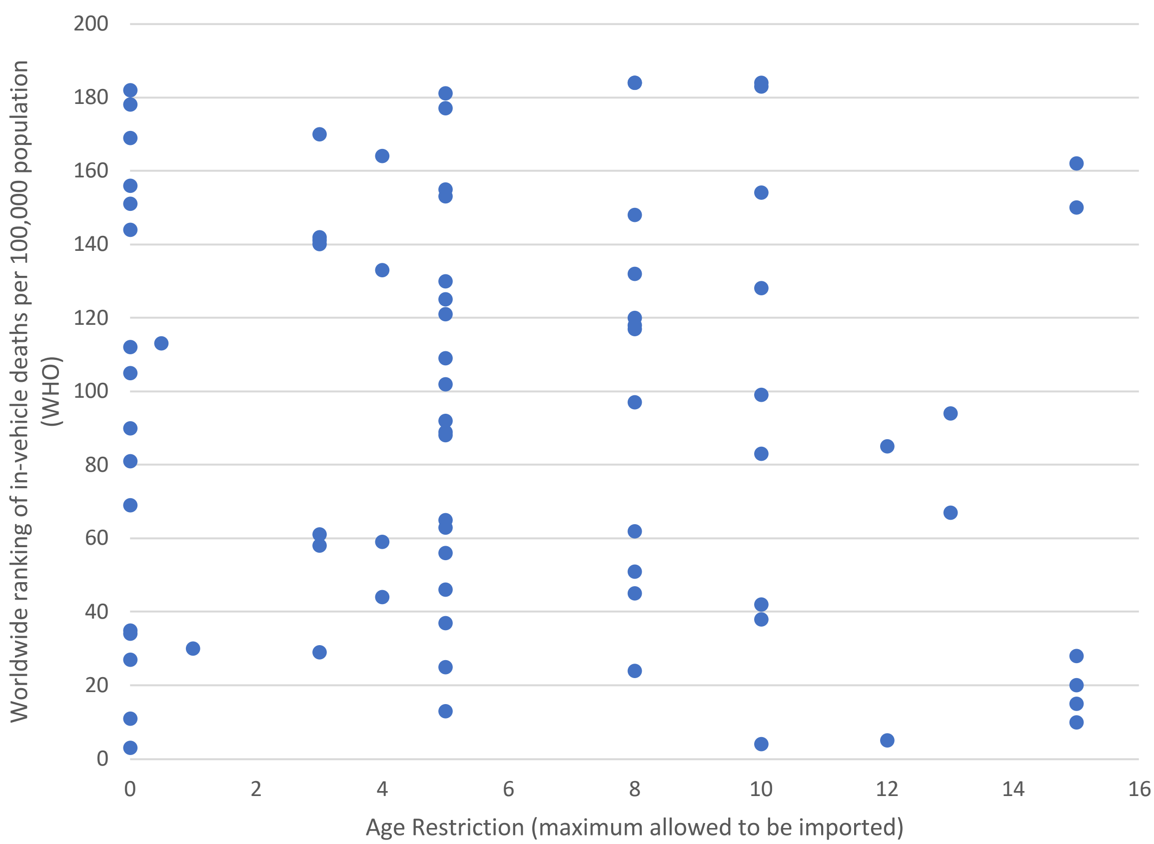
In practice, many countries that are predominantly dependent on vehicle imports rather than domestic production for annual vehicle stock addition tend to limit vehicle addition based on year of manufacture of the vehicle. In a survey of 155 countries worldwide, a report by the United Nations Environment Programme (UNEP) found that 87 countries have import limitations based on age, including 22 which do not allow importation of used vehicles. An additional 17 countries do not prohibit vehicle importation based on age but do impose taxes or excise duties based on vehicle age. In contrast, 61 countries limit imports based on emissions control technology and 11 countries limit imports based on roadworthiness performance (UNEP 2020).

3 "Registration" of vehicles can have different meanings in different countries. In this report, we refer to "registration" as the collective set of recurring administrative processes by which vehicle owners demonstrate compliance of the vehicle to norms and standards established by the relevant authority throughout the vehicle's active life under the control of a particular owner. This can include renewal of authorization for the vehicle to be operated on public streets; maintenance of license plates; certification of safety and emissions compliance following inspection; payment of time-based facility access fees, such as residential parking permits or highway usage stickers; and/or payment of recurring personal property taxes that might be applicable to the vehicle.

The reasons for the use of age-based rather than performance-based specifications to restrict vehicles entering the national vehicle stock are not always articulated in policy formulation, but their use implies that policy makers assume that vehicle age is a good proxy for vehicle safety, fuel efficiency, and environmental performance. That said, there is no clear evidence that age-based import restrictions are more effective than performance-based restrictions at advancing any policy objectives, other than reducing the average age of vehicles circulating.

An analysis of available data suggests that buyers tend to purchase up to the available limit. For example, analysis of National Transport and Safety Authority (NTSA) new vehicle registration data by the World Bank of the impacts of Kenya's restriction of imported LDVs to less than eight years showed that 80 percent of imported cars in Kenya in 2015 were seven years old at the time of import (Gorham et al. 2017). A scatter plot of in-vehicle fatality rate rankings (using data from the WHO) and countries that limit age of vehicle imports from the UNEP compendium for the 79 countries for which data are available for both (see Figure 3.1) shows no correlation between the two, suggesting that, at least as far as road fatalities are concerned, age is not a particularly effective instrument.

Figure 3.1. Plot of In-Vehicle Traffic Deaths Against Age-Related Import Restrictions



Source: World Bank calculations based on World Health Organization (WHO) traffic accident fatality data (2015) and UN Environment Programme (UNEP) compendium of import restrictions on used vehicles.
Note: Data as of 2015.

Detailed data on vehicle emissions and resulting death and disability are not available to similarly assess impact of age restrictions on these characteristics, nor are time-series data for either fuel economy or safety impacts. However, for the reasons discussed above, there is no inherent reason to expect substantial correlation. Further, analysis by the Global New Car Assessment Programme (Global NCAP) has shown that new models of similarly branded vehicles have substantially different crash-test results across different markets (Global NCAP 2015), suggesting that characteristics of vehicles actually sold are more important than age per se. We speculate about the assumptions underlying this widespread use of age-based restrictions in Box 3.7. Use of Age-Based Restrictions As a Proxy for Vehicle Performance, Speculation on Underlying Biases.

Box 3.7. Use of Age-Based Restrictions As a Proxy for Vehicle Performance, Speculation on Underlying Biases

The use of age-based restrictions as a proxy for vehicle performance in terms of safety, economy, and emissions can be misleading and may be linked to the following questionable assumptions:

Newer vehicles perform better because they utilize more advanced technology. The variability of intrinsic technology use across different markets, the widespread prevalence of vehicle tampering in secondhand markets, and the poor quality of fuels available in many countries means that the association of vehicle age with performance is, at best, crude, and, at worst, deceptive because expected benefits do not materialize.[a]

Newer vehicles perform better because they have less wear and tear. Evidence shows that emissions and crash avoidance performance of vehicles are related more to how well the vehicles are *maintained*. Well-maintained old vehicles perform as well or better than relatively new but poorly maintained vehicles in these aspects. In addition, the underlying variability in fuel economy among individual vehicles of a given class is more related to the intrinsic characteristics of the vehicles at manufacture than age-related deterioration, and the overall efficiency of the vehicle stock as a whole is more related to the classes of vehicles that are bought (for example, sport utility vehicles versus small sedans) than the age of those vehicles.[b,c] In short, if fuel economy is the key objective, restricting age on its own is an ineffective policy instrument.

Age is easier to filter for than performance. In this understanding, rather than set up an elaborate inspection mechanism for new vehicles, countries simply need to verify a single Boolean filter that can be observed from paperwork: Is the vehicle's model year of production higher or lower than the model year currently allowed entry? But this understanding overstates the simplicity of checking for vehicle age and the complexity of checking for performance characteristics. In both cases, the primary checks are made on paperwork—like age, performance characteristics are most effectively checked through an import certification process that ensures that the vehicle conforms with the requirements. In both cases, as well, controlling for fraud and corruption needs to be an important part of the process.[d] Even if it could be shown that age-based filters were "easier" for countries with limited capacity to implement than performance-based filters, the underlying logic that such filters should, therefore, be preferred is somewhat circular. The basis for policy choices should not be ease of implementation per se but effectiveness. Ease of implementation may be one among a number of characteristics that determine whether a given policy will be effective, but in and of itself, it tells nothing.

Elite bias may influence policy. A fourth factor that may influence the use of age rather than performance standards in setting standards for vehicle import may be elite bias, in which the perception is that older vehicles create a poor image for the country and may not project modernity.

a New models of similarly branded vehicles have substantially different crash-test results across different markets. For example, the Datsun Go by Nissan and the Maruti Suzuki Swift car models scored zero in crash tests conducted in India while scoring three in tests conducted in Latin America. This was due to lower structural integrity and lack of airbags in models offered in India (Global NCAP 2015). The efficiency of tailpipe emissions after-treatment systems is reduced by fuels with high sulfur content. Detrimental impacts are particularly felt in diesel particle filters, lean NOx traps, and selective catalytic reduction. In recognition of this, it is important to design and implement vehicle emission standards in conjunction with fuel quality standards. In practice, countries often implement fuel quality standards in a phased manner, and some may face difficulties in controlling fuel quality due to cross-city and cross-region spillovers. Worldwide, countries have adopted road maps for improvement of fuel quality. In 1999, India reduced diesel sulfur content from 10,000 ppm to a maximum of 350 ppm and more than 23 cities now have diesel fuel with 50 ppm sulfur content. China instituted a ceiling of 50 ppm sulfur content by 2015 and 10 ppm by 2018. South Africa limited sulfur content to 50 ppm in 2007 and 10 ppm in 2017 (Bansal and Bandivadekar 2013).

b Fuel efficiency varies significantly in most vehicle classes as can be seen in the overview of best and worst fuel economy vehicles in 2020, by EPA size classes, prepared by the U.S. Department of Energy. See https://www.fueleconomy.gov/feg/best-worst.shtml.

c The report shows that while the fuel economy improved for each vehicle type between 0.2 mpg and 1.2 mpg during the period from 1975 to 2018, the estimated real-world fuel economy for the overall fleet was lower at 0.2 mpg due to market shifts from sedan/wagon toward SUV. See https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100YVFS.pdf.

d It is as possible for paperwork to be doctored to show a newer model year than corresponds to the actual vehicle imported as it is to show the presence of emissions control equipment or safety features that do not actually exist on the vehicle imported. In both cases, corrupt officials could allow those ineligible vehicles to pass through for the right price.

Source: World Bank.

Active Use

Enforcement actions are more effective if accompanied by strong communication and education programs.

In order to advance policy objectives from the in-use vehicle stock associated with MM, vehicle owners, fleet managers (if different from the owner), and operators may need to comply with more stringent norms regarding vehicle registration, use, maintenance, and inspection than in the past in order to ensure that the use of the vehicles is within acceptable danger limits, and in order to enable public authorities to verify that this is the case. Communication and education with the public are critical to ensure acceptance of increased burdens on vehicle owners, managers, and operators, and enhance understanding of the rationale underlying enforcement actions. The costs of vehicle ownership, in terms of both resources and time for the owner/manager, will likely increase, and educating the public on the public policy rationale for imposing these cost increases will facilitate acceptance. In the absence of a clear understanding of the public policy behind enforcement actions, public perceptions will impute pecuniary motives to the specific individuals charged with carrying out enforcement, which would be open to interpretation as either double taxation or an attempt at corruption. A communication and education campaign can help reduce the extent to which this perception occurs and increase acceptance. In addition, such a campaign might also help improve compliance rates at the margin.

Lifestyle or economic transition points are the most important moments to influence households and firms' decisions about their vehicle fleets; at these moments, they are susceptible to being nudged toward more sustainable choices when information and finance options are available.

Purchase of a vehicle is a large and lumpy investment and brings along with it a commitment to meet recurring expenditures to keep the vehicle in operation. Commercial operators tend to be aware of the long-term effects and implications of this stream of expenditures and would likely take these into account in their purchasing decisions, but noncommercial buyers—those buying for personal use—may be less aware of the long-term economic implications of their purchase. Even if the buyer is aware of long-term economic costs of a vehicle purchase decision, he or she may have limited opportunity to reduce these because of limited information and/or limited vehicle financing options in the marketplace. For these reasons, providing information and more financing alternatives to vehicle consumers is an important way to make sure that vehicle turnover happens more frequently and better matches consumers' economic needs with public policy objectives.

One way to improve information flows is to make vehicle data available to the general public. In the United States, for example, the National Highway Traffic Safety Administration (NHTSA) makes certain data about individual vehicles, submitted to it by manufacturers, available for use by third parties. Prospective buyers of vehicles can query the Vehicle Information Number (VIN) on any number of these third-party sites to learn characteristics about the vehicle, including how old it is, how many kilometers it has been driven as of last inspection or registration, what kind of safety equipment it has (or should have), what emissions standard it has been certified to, what its certified fuel economy was at the time of first sale, whether it has been involved in any major or minor accidents, etc. Combined with awareness about the data and education about what these factors mean for individuals, the provision of information can be a powerful way to influence the motor vehicle market.

Similarly, financing alternatives can help reduce the impact of large and lumpy investments by spreading costs more evenly over the lifetime of the vehicle. In developing countries, the nonavailability of financing, or the limited options and financing terms for what little is available, is a well-known and common problem across different parts of the world, particularly for commercial operators. For example, it is often cited as one of the reasons for ongoing slow uptake of electric vehicles (EVs) in commercial public transport operation, even though the life cycle costs of EVs in many markets are lower than their conventional diesel counterparts (World Bank 2019).

Vehicle Exit

Changing the permitted uses for current vehicles in the stock as they age may be a more politically acceptable way to manage risks caused by usage of obsolescing vehicles rather than abruptly banning their use.

A key challenge in developing countries where large proportions of the population have very low purchasing power is that a vehicle's residual value for the owner or operator often long outlasts the point at which the vehicle becomes a menace in terms of safety or pollutant emissions. An effective MM program, therefore, should recognize this reality and seek to align the ability of owners to continue to get benefit from their vehicles while minimizing the exposure of populations to these risks. Such a policy would make explicit and controlled what is de facto common but variable practice in the industry: as vehicles age, they tend to cycle from urban, to peri-urban, then to rural use, from heavy to lighter uses, and from passenger-serving to freight-serving uses. Examples of how such a principle could be implemented in practice include adoption of mileage-based annual registration fees for very old vehicles (a common practice in the United States, Canada, and Western Europe to enable "legacy" vehicles' limited circulation rights); use of low-emissions zones, whereby only vehicles certified to exceed certain emissions thresholds are allowed to circulate in certain areas, like densely populated or historic districts; or differentiating how and where vehicles are allowed to be used on the basis of adherence to different safety and emissions thresholds.

Assigning lifetime usage limits when vehicles are added to the national stock through either import or manufacture could be an equitable way to address the long-term challenge of an aging and obsolete vehicle stock.

Because motor vehicles have a very long anticipated useful life in low- and middle-income countries, and because of low-carbon technology shifts that are expected to be dominant over the next one to two decades, finding new ways to make sure that obsolete technologies are eliminated from motor vehicle stocks in low- and middle-income countries is particularly important. A used vehicle imported into a low- or middle-income country today may still be on the road 20 years later if there are no mechanisms or incentives to get it off the road. Under many, if not most, countries' jurisprudence, once a vehicle is imported and registered for use, the prerogative of the owner to use the vehicle as long as he or she sees fit will usually preempt the public interest in retiring the obsolete technology. One way around this could be to condition the importation permit of the vehicle in the first place to a set lifetime usage limit. The absence of an MM program would preclude such lifetime usage limitation as impracticable, but if MM mechanisms are put in place, then enforcing a cap on lifetime usage of the vehicle becomes feasible. The distributional and equity implications of any such lifetime usage cap would, of course, need to be evaluated for each country considering such a policy.

The lifetime usage cap could be based on vehicle age, mileage, or CO_2 emissions. A lifetime CO_2 emissions cap is perhaps the most interesting from a public policy point of view because such a cap could not only meet the public policy goal of facilitating the retirement of obsolete vehicles, but also help incentivize short-run purchase decisions toward more efficient vehicles. If potential importers or their customers know that vehicles' usage is capped based on lifetime CO_2 emissions in the country—this would be calculated by multiplying a reference CO_2 emissions factor, such as that established at production certification in the country of manufacture, by the annual vehicle mileage—then they can get more use out of their vehicles within the allowable cap by choosing more efficient vehicles.

For heavy-duty vehicles and light-duty vehicles used for commercial transport, incentivizing vehicle turnover (for example, replacement and scrappage) is as important as the quality of vehicles brought in. For light-duty vehicles used for own-account transport, the relative importance of vehicle turnover/replacement depends on where an individual country is on the motorization curve; incentivizing turnover becomes more important as motorization penetration increases.

Motorization policy should ideally reflect where a country is on its motorization path, as portrayed in figure 2.1. For countries toward the left side of the figure, focusing heavily on incentivizing vehicle turnover may make no sense because of the expected rate of motorization growth. In these countries, emphasis should be on making sure that the vehicles allowed to enter the country during the period of steep growth are as clean, fuel efficient, and safe as possible because they will dominate the overall performance of the stock for years, if not decades.

On the other hand, for countries farther along the motorization process, greater emphasis on turnover and replacement is warranted because there is a risk that, without such emphasis, the overall performance of the vehicle stock will be dominated by existing, and possibly obsolete, vehicles.

That said, it is also important to differentiate by subsector and the intensity of use implied. For heavily used LDVs in commercial use, as for most HDVs, incentivizing turnover may be important regardless of the where on the motorization curve a particular country is because of the public health implications (in terms of both safety and air quality) of using obsolete technology where population exposure rates may be high.

Management of End-of-Life Vehicles and batteries must not be an afterthought, but rather built into the Motorization Management framework from the beginning.

If vehicle turnover is an important objective of MM, then getting into place effective End-of-Life Vehicle (ELV) systems will be crucial because, sooner or later, large numbers of vehicles will need to be retired and disposed of. There is a strong case to be made that ELV management should play a critical role in MM programs even for countries at the low end of the motorization curve shown in figure 2.1. First, as discussed above, for many classes of vehicles, such as HDVs and vehicles used commercially, limitations on the use of obsolete vehicles could be an important public policy measure to protect health and safety, so there will still be a large number of vehicles to properly dispose of even where motorization rates are low.

Second, managed ELV programs, whereby the waste stream from vehicles is actively accounted for, could create opportunities for economic or employment development that are not immediately recognized in an unmanaged system. What presently accounts for scavenging of old vehicles for parts could transition to a structured program of vehicle materials life cycle management, from the vehicle development, production, and post-production phases until scrappage.

Third, mandates in vehicle manufacturing countries to enhance the circular economy require manufacturers to be able to track vehicles through their life in order to recover and reuse materials from motor vehicles.[4] The absence of ELV management systems in recipient countries of secondhand vehicle trade consequently represents a substantial blind spot in the efforts to improve materials management and meet circular economy goals. As the precious and rare earth metal content of vehicles and batteries increases, economic pressure to recover these materials will also increase.

Fourth, managed landfill space in any country is in relatively scarce supply; not having an effective ELV program that can help reduce the volume of the unrecycled materials of ELVs might, therefore, be quite costly.

Finally, and most importantly, disposal of motor vehicles can generate hazardous waste which, if not properly handled, can pose a risk to human health and the environment. Motor oils, fuels, and battery acids can seep into area groundwater, and refrigerants used in motor vehicle refrigeration units and air conditioning can be released into the atmosphere, where they are potent greenhouse gases (GHGs), if not properly handled. For these reasons, we advocate that countries should not wait to attain a certain level of motorization before developing ELV management programs.

Motorization Demand

Although Motorization Management focuses on vehicles, it is the use of those vehicles that is the source of environmental and safety risks as well as accessibility benefits to societies.

MM addresses the governance ecosystem in which motor vehicles are managed, but the objective of improving this management is not to improve vehicles per se, but rather reduce the negative externalities associated with vehicle *use*. This distinction is subtle, but critically important, because policies that target vehicles that are not used intensively will be less impactful than those that are oriented toward vehicles that are likely to be very intensively used. Moreover, policies that focus primarily on the vehicles without accounting for how they are used may also create perverse incentives. For example, in the 1980s and 1990s, Danish policy sought to increase the cost of LDV acquisition through taxes and tariffs in an effort to restrain the rate of motorization. However, when researchers examined overall LDV use (vehicle kilometers traveled; VKT) in Denmark compared to other countries in Europe, they could not detect a difference. It turned out that, on average, each LDV was used more intensively in Denmark than elsewhere in Europe, probably as a result of the added cost of acquisition. That is, increasing the cost of vehicle acquisition seems to create a perverse incentive for vehicle owners to reduce the *average* cost of the investment by driving more (Schipper 1995).

4 The most prominent of these mandates include European Union Directive 2000/53/EC on End-of-Life Vehicles which mandated not only collection, treatment, reuse and recovery, development of coding standards, and dismantling information for ELVs and their components, but also prevention of creation of waste through use of recycled and recyclable materials; the ELV Recycling Act (enacted 2002, in force 2005) in Japan; and the Act for Resource Recycling of Electrical and Electronic Equipment and Vehicles in the Republic of Korea (2007).

Managing motorization must be understood as one element of a broader, sustainable transport approach; Motorization Management policies should align with that approach and take into account both vicious and virtuous effects broader policies may have on motor vehicle demand.

MM should be understood as one component of, not a substitute for, good transport policy. As discussed above, MM measures would seek to influence the vehicle component of **I** in an **ASI** approach. But it is important to bear in mind that how effective Avoid and Shift policies are will, in turn, affect the *shadow* price of acquiring and using motor vehicles—that is, what is the relative cost of acquiring and using motor vehicles compared to other modal and lifestyle alternatives given a set of public policies enacted and public investments being undertaken? Understood this way, it is clear that MM measures will be more effective if conceived of and implemented in a broader ASI policy context.

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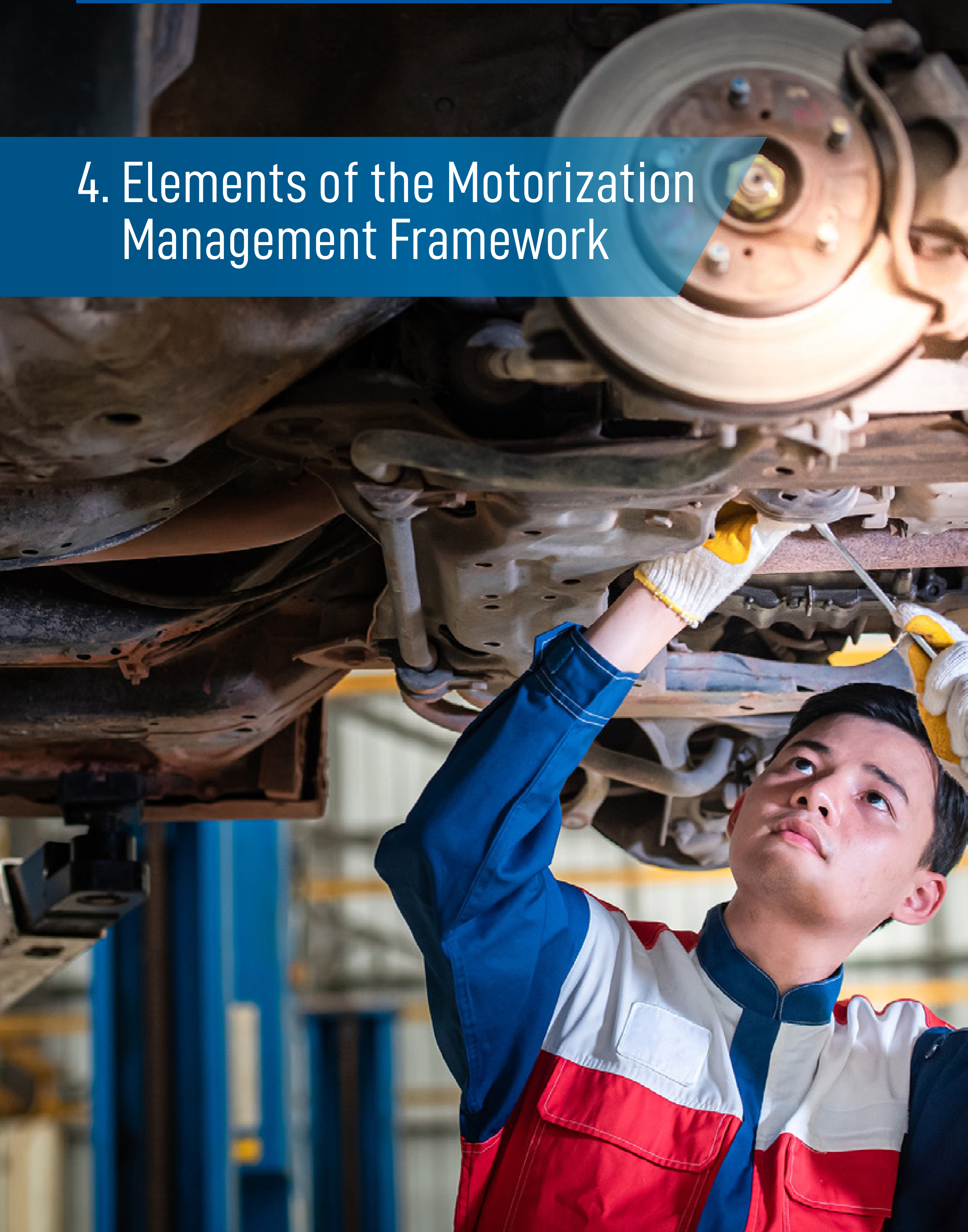
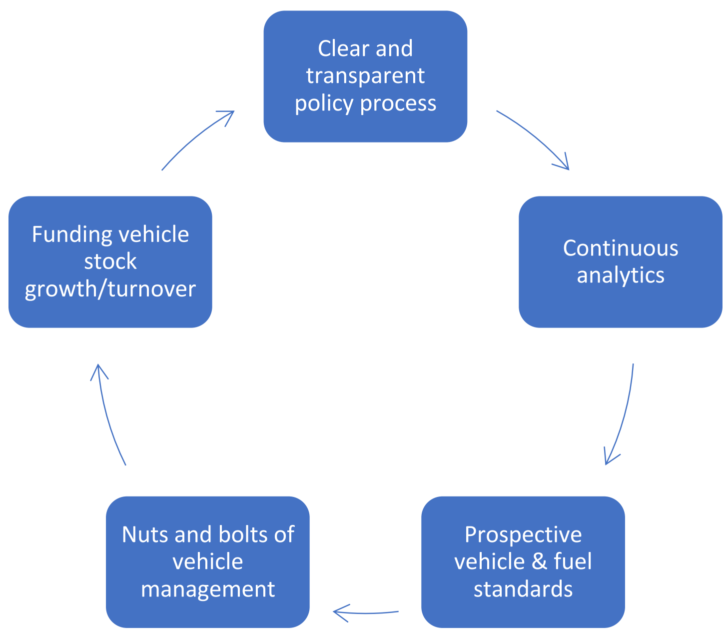
4. Elements of the Motorization Management Framework



Effecting change to motor vehicle stocks requires a clear method for implementing the principles laid out above. The components of such a methodical approach can be grouped into five core areas, what we refer to as the elements of the Motorization Management (MM) framework: establish goals through a clear and transparent policy process, gather and assess data using continuous analytics, adopt and promulgate vehicle and fuel standards prospectively, strengthen governance and industry, and create market mechanisms to fund both stock growth and stock turnover.

As suggested in Figure 4.1, these elements are not necessarily sequential, but rather should work harmoniously in a continuous cycle of improvement. They will be discussed in turn.

Figure 4.1. Core Elements of a Motorization Management Approach



Source: Original figure produced for this publication.

Establish a Clear and Transparent Policy Process for Setting Goals and Priorities

As highlighted in the discussion under the "Motorization Management in the Policy" section in chapter 3, legitimate policy objectives related to motor vehicle governance may conflict with one another. Establishing a structured process by which to put in place motor vehicle policies involving multiple stakeholders is, therefore, a critically important part of the MM process. Which stakeholders should be included depends on local context, but would likely include representatives of motor vehicle importers; operators' associations from different subsectors, like intracity passenger transport operators, intercity passenger transport operators, taxi operators, or commercial freight transport operators; representatives of automotive aftermarket industry, such as vehicle parts suppliers or the motor vehicle repair industry; representatives from subnational governments or civil society groups that may have a particular stake in air quality, road safety, or climate change outcomes; and representatives of petroleum product suppliers, to ensure that fuel standards are consistent with MM policies developed. Original equipment manufacturers (OEMs) should also be considered key stakeholders, even if there is little or no automotive manufacturing in the country, and even if vehicles are acquired into the national stock primarily through importation of secondhand vehicles. Buy-in and support from OEMs remains critically important because they may otherwise seek to undermine consensus on policy development if they fear it will inhibit their ability to provide vehicles for the market. They will also need to certify/warrant new vehicles, and in some cases, honor the certificates or warranties of secondhand vehicles.

The overall policy-making process itself could be managed by the central government if it has the capacity to do so, or, more ideally, through a regional economic bloc with support of its members, for example, through a series of structured meetings of the stakeholders facilitated through a secretariat and informed by commissioned background papers on relevant topics. Alternatively, depending on the political economy of the country and the regional context, the policy process might be anchored in academia or instigated by the private sector. However initiated, the transparent process is most likely to be successful if all stakeholders share an understanding that the status quo is both untenable and likely to be disrupted in the medium term. With rapidly changing technologies and the industry worldwide in flux, getting to this shared understanding may not be particularly challenging.

Gather and Assess Data with Continuous Analytics

Motorization policy should be grounded in empirical analysis based on evidence of what works. This means developing mechanisms to be able to observe and track characteristics of car and truck ownership, motor vehicle use, energy consumption by different kinds of vehicles, on-road fuel intensity, new car fuel intensity, and other characteristics of road transport at the national level. These parameters also need to be gauged against other factors in the economy, such as fuel prices (and fuel price fluctuations), economic indicators, industrial structure, and so on. The fundamental basis for this type of analytics is access to good quality data on a reliable and sustainable basis. The good news is that many, if not most, governments already systematically collect this type of data as part of their taxation and governance systems vis-à-vis motor vehicle stocks. The bad news is that many do not make this information available to researchers on a sustained basis, particularly in low- and middle-income countries.

The availability and access to high-quality data on MM has the potential to generate benefits in a variety of fields. However, benefits are often not recognized due to uncertainty about the value potential of the data, lack of strategy to capitalize on data sharing, the investments required to develop the systems, and capacity to compile, manage, exercise quality control on, and share data, among other factors. This can be accompanied by concerns related to privacy, security, competitiveness, accountability, and the desire to avoid additional or more stringent legislation. Frequently, data governance is an unfunded, low-value agenda item for government agencies. As a result, relevant data for MM are often scattered across different agencies, are incomplete and of variable quality, and have high barriers to access them. The data required for effective MM are varied. They can encompass, for example, the number of vehicles registered by vehicle type; vehicle imports and exports by vehicle type; and vehicle characteristics, including vehicle fuel efficiency, emissions levels, safety provisions, among others. The number of parameters to be collected and managed can be extensive and cover diverse business areas. Data can be required at various levels of granularity, such as national, regional, and local levels, and are required to be compiled and managed continuously over time.

Data relevant for MM can be generated by public bodies, businesses, citizens, and the vehicles themselves. Several agencies may be involved in data collection, management, and dissemination. Therefore, it is useful for data governance to be institutionalized, founded in clear provisions in policies and legal frameworks that set institutional mandates, budgets, coordination mechanisms, and standards. Data governance can be supported by business plans that are established to address stakeholder needs and to deliver on agreed goals.

Low- and middle-income countries frequently experience varying levels of capacity on data governance for MM. Vehicle registries can be updated with new vehicles entering the country's vehicle stock, but there may be no requirement to keep track of vehicle resales within a country or when vehicles are scrapped and exit the fleet. Frequently, motorization data are collected as part of individual studies under specific projects and do not observe a specific data standard. There is a lack of data management systems and infrastructure that enable interoperability and make data available for combining and repurposing for different applications and different users. There is a lack of technical and administrative capacity and of budget to implement and enforce data management processes. It is also common to have different data sets for the same parameter being owned by separate agencies.

Countries can manage the situation by centralizing the governance of official data within one institution, like the national statistical office, and by establishing the systems and requirements for regular compilation of data from other institutions and the publication of defined parameters. This is a positive step forward as it clarifies data ownership and which data sets are official. This requires that agencies have in place the technical and administrative capacity and processes to collect data and manage it within established quality standards. A challenge that is frequently encountered is that the statistics published are often too aggregated or incomplete to be useful for policy analysis. In addition, each country may aggregate data differently which results in difficulties in cross-country analysis and benchmarking.

Countries collaborate internationally within specific fora and initiatives, such as in the International Energy Agency's (IEA's) data tools and products, the International Road Federation's (IRF's) World Road Statistics (WRS) publication, and the World Health Organization's (WHO's) Global Status Report on Road Safety (GSRRS) publication. The private sector globally shares data with data aggregators and data marketplaces, generating new revenue streams, while keeping in control of data and handling data privacy concerns. The global automotive ecosystem is complex, and partnerships fluctuate.[1] These initiatives provide a useful contribution to increase data availability globally. The level of openness of data varies by country income group, with low-income countries presenting a lower openness scope (see Table 4.1).

Table 4.1. Assessment of the Openness of Data, by Country Income Group

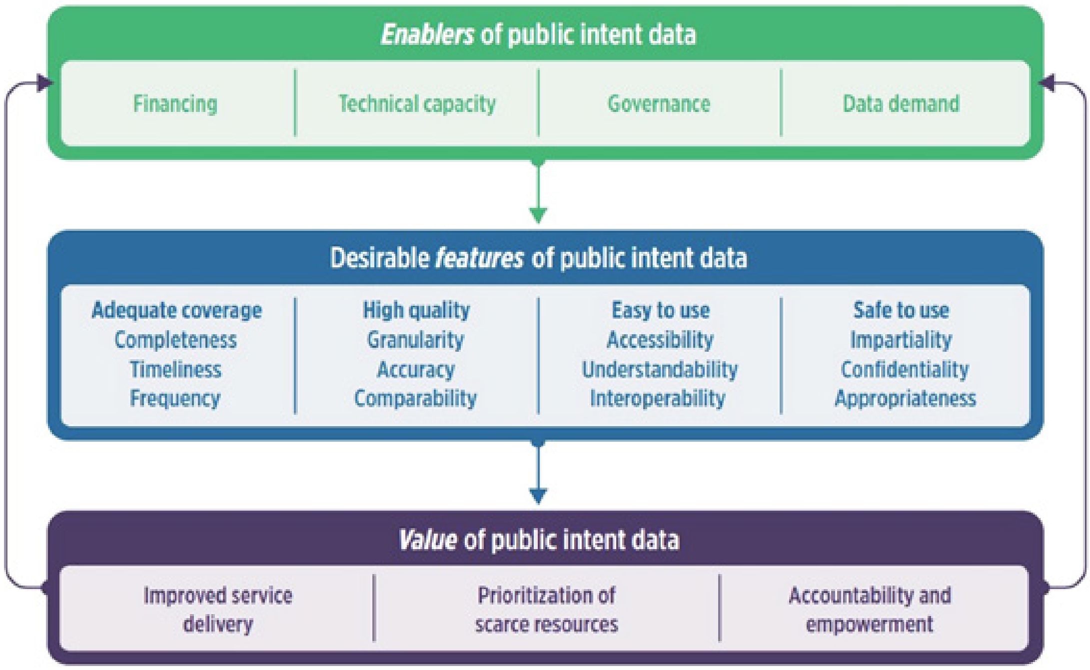
Indicator	Low-income	Lower-middle-income	Upper-middle-income	High-income
Openness score (0–100)	38	47	50	66
Available in machine readable format (%)	37	51	61	81
Available in nonproprietary format (%)	75	85	81	84
Download options available (%)	56	68	68	78
Open terms of use/license (%)	11	19	22	44

Source: World Bank 2021.
Note: The openness score is the average by country income group on a scale of 0 to 10.

The World Development Report 2021 (World Bank 2021) proposes to extend the goal of generating and making available more high-quality data to strengthening the capacity for using data more effectively toward development outcomes. It is essential to empower low- and middle-income countries to participate equitably in global data markets and their governance and to strengthen their infrastructure and skills to turn data into value (see Figure 4.2).

1 Original equipment manufacturers (OEMs) give high priority to data privacy as leaks or issues may have a negative effect on the trust, reliability, and reputation of the brand (KPMG 2020).

Figure 4.2. Positive Feedback Loop Connecting Enablers, Features of Public Intent Data, and Greater Development Value



Source: World Bank 2021.

To get started, low- and middle-income countries can define their future vision and develop a road map to deliver on it. Bridges can be built between data science and transportation, between relevant agencies, departments, and partners. Low- and middle-income countries can define the needs, issues, and problems that they would like to address and set objectives for big data analytics.

Low- and middle-income countries can be supported to strengthen their legal frameworks for enabling data sharing and establishing safeguards for managing associated risks, and to strengthen institutional technical and administrative capacities for implementation. Low- and middle-income countries can also be supported in terms of assessing financial needs and funding sources for data governance. Support can also be provided to build systems and infrastructure for data governance, establishing data standards, protocols, and processes, for example, to streamline the cleaning and anonymizing of disaggregated data. Stakeholder awareness should be raised on the benefits and the business case for data sharing as well as on the safeguards in place. And last but not the least, low- and middle-income countries can be supported to build the capacity required to produce analysis and to capture the value created by the improved data quality and availability.

Adopt and Promulgate Vehicle and Fuel Standards Prospectively Using Dynamic Profile of Standards for Vehicle Stock Evolution

Goal setting and analytics should lead to the promulgation of transparent vehicle and fuel standards, both for the addition of vehicles to the national stock and for the minimal requirements of in-use vehicles to be allowed to remain circulating. To be clear, vehicle and fuel standards alone are not effective tools of MM but effecting improvements to vehicle stocks is unlikely to be successful without them. In other words, vehicle and fuel standards are necessary but not sufficient elements of MM. Standards have two key functions. First, they establish the legal basis on which incentives and enforcement actions can be developed and targeted. Second, for countries reliant largely on imports of secondhand vehicles, they form an unequivocal statement to importers and exporting countries of what standard of vehicle and fuel will be permitted. In this sense, even if a given country lacks the implementation wherewithal to fully enforce its own standard, simply promulgating the standard might help the governments of exporting countries justify prohibition of their export.

One of the main purposes of vehicle and fuel standards, both as a legal document and as a signal to importers and exporters, is to provide clarity to public and private actors. In Organisation for Economic Co-operation and Development (OECD) countries with mature motor vehicle manufacturing industries, as well as in China and India, a common refrain among manufacturers and policy makers alike is that transparency is as important as the specific policies governing vehicle manufacturing requirements themselves. Manufacturers need to know what the rules of the game are and be afforded ample time to plan their strategies accordingly. Government policy makers, in turn, respond to this need: rules governing requirements for fuels, vehicles, and manufacturing processes are established years before they go into effect, allowing manufacturers to plan and adjust their business strategies, procedures, and marketing approaches. In the case of increasingly stringent pollutant emissions limitations (as well as different approaches to improving average fleet fuel economy or CO_2 emissions intensity), the initial motivation was to put in place technology-forcing rather than technology-following limitations, but the effect has been to level the playing field and provide clarity to allow manufacturers and fuel suppliers to carry out multiyear strategies to position themselves in the marketplace.

In many developing countries, such long-term clarity and transparency is lacking. Where private manufacturers looking to develop country or region-specific strategies would like clarity, instead, they have murkiness. Where they seek consistency in approach not only among countries, but also over time within an individual country, they have potential fickleness that inhibits their ability to develop a long-term marketing strategy that extends beyond a year or two.

A public process to define a policy vision within a given vehicle market is a very important part of MM in order to establish clarity for vehicle manufacturers to understand and plan for national or regional markets. Dynamic Profile of Standards (DPOS) addresses this need as it provides a blueprint for industry and stakeholders about how regulatory standards for vehicles to be added to the national vehicle stock will be expected to change over a multiyear time frame; for example, over a decade. The objective of establishing a DPOS is to avoid repetitive ad hoc processes to tighten regulations and instead to send clear signals to the import and manufacturing/assembly industries in or targeting a country or region so that they can make adjustments.

As a policy document developed through stakeholder engagement, the DPOS can be implementation-method neutral. That is, it might define how the profiles of entry vehicles should change over time, though it need not specify how such changes should be implemented—for example, through regulation or pricing incentives. Those details might be left to administrative decision. But the profile of standards defined in the DPOS must be attainable and dynamic. It must be attainable because otherwise stakeholders will give the DPOS document no credence. And it must be dynamic—that is, show the profile of standards over time—both because the private sector needs to understand the rules of the game and how they will change over a reasonably foreseeable time period, and because policy making/standard setting is a time-consuming and costly endeavor, so rather than go through this painful process ad hoc every few years it is better to identify the changing profile over time in one go. This also allows for more give and take in negotiations with stakeholders.

A DPOS can be an important part of an MM program but use of such a policy instrument is generally not currently practiced by countries that do not have their own motor vehicle manufacturing industries. Several characteristics would distinguish a DPOS in countries without a domestic manufacturing industry from similar instruments in countries that do have such an industry.

- DPOS is meant to apply to all vehicles being added to the national vehicle stock, not only “new” (not previously used) vehicles. The DPOS defines characteristics that are intended to apply to all vehicles added to the vehicle fleet in a given year, whether they are imported secondhand, imported for first use, manufactured locally, or assembled locally using complete knock down (CKD) kits or other techniques. If the vehicle is intended to be registered for the first time in the country in question, then the DPOS should apply.

- DPOS should emphasize technology-following rather than technology-forcing standards. In countries with substantial domestic automotive manufacturing activity (for example, the United States, Canada, the European Union (EU), Japan, the Republic of Korea, China, India, etc.), standards—particularly those linked to fuel economy or pollution emissions—have often been established with the intent to force technological innovation by automotive manufacturers. The Euro standards of the EU or Tier standards in the United States, for example, have formed the basis of a strategy to ratchet up innovation by automobile and truck manufacturers to improve commercialization of technologies in anticipation of a future requirement. By contrast, the objective of the DPOS in import-reliant countries, such as those of Sub-Saharan Africa or Latin America, in most cases would be to constrain purchasing decisions for entry vehicles toward better-performing vehicles that already exist in other markets. Because of this distinction between technology-following and technology-forcing standards, the sequence of standards that made sense in OECD markets with substantial domestic production as a source of motorization growth may not make sense for primarily import-reliant low- and middle-income countries. For example, many experts advocate that Euro 5/V standards add little value to import-reliant low- and middle-income countries, and that if standards are to be tightened beyond Euro 4/IV, low- and middle-income countries should move immediately to Euro 6/VI.

- There should still be participation and buy-in from OEMs. Notwithstanding that the objective of the DPOS is to facilitate the use of existing technology, not force innovation, buy-in and support from OEMs remains critically important because they will still need to certify/warrant new vehicles, and in some cases, honor the certificates or warranties of secondhand vehicles. For this reason, consultation with and involvement of the OEMs in establishment of the DPOS is critical.

- Ratcheting up of standards must realistically reflect the capacities of the maintenance and repair industries and availability of parts and compatible fuels and fuel distribution infrastructure. An important consideration and constraint in the development of any DPOS must be the concomitant development of the maintenance and repair industry to service the increasingly complex technologies associated with improved emissions control technology, to service new vehicle technologies like electric vehicles (EVs), and to have access to needed spare parts. Similarly, consideration of availability of fuels compatible with given standards must be an integral part of the development of any DPOS. More stringent pollutant emissions standards associated with internal combustion engines (ICEs), for example, are dependent on the use of technology whose performance in turn depends on the level of sulfur in fuels.

The characteristics of fuels and vehicles that could be defined through one or more DPOS processes include tailpipe emissions, fuel quality, vehicle safety (especially crashworthiness and use of advanced crash avoidance technology), fuel economy of ICE vehicles, and transition to alternative propulsion/energy systems. For practical reasons, countries might consider separating the DPOS process into two separate tracks—one for tailpipe emissions and fuel quality, and another for vehicle safety and fuel economy.[2] The constituencies for the two groupings may be slightly different, so separating along these lines may allow each to proceed on its own track.

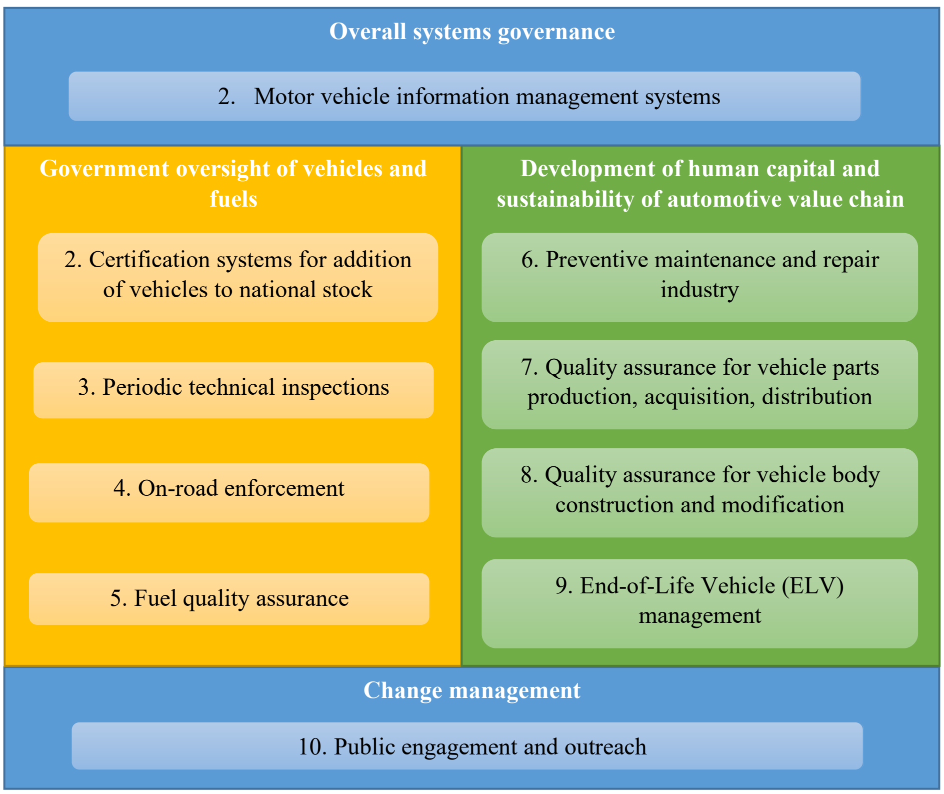
Strengthen the Nuts and Bolts of Vehicle Management

Improving the performance characteristics of the motorized vehicle stock providing transport services in a given country will depend on improving the way the stock is governed, so an important element of MM, in addition to better policy making, improved analytics, and clarity in objectives, is improved governance of motor vehicles throughout their useful life. We identify 10 governance systems which form the core of an effective MM system, as shown in Figure 4.3. Some countries may be more effective at some of these systems than others, but a comprehensive assessment of MM capabilities should aspire to assess the effectiveness of these systems and improve their functioning. These systems include the following:

2 Tailpipe emissions are closely dependent on fuel quality, so they should be considered together. Likewise, vehicle safety and fuel economy both depend on vehicle structure and weight, so should also be considered together.

- Motor vehicle information management systems;
- Certification/homologation systems (for addition of motorized vehicles to national stock);
- Periodic technical inspection (PTI) (for systematic control of in-use vehicles);
- On-road enforcement (to enhance integrity of PTI);
- Fuel quality assurance mechanisms;
- Oversight and development of preventive maintenance and repair industry;
- Oversight and quality assurance of vehicle parts production, acquisition, and distribution;
- Oversight and quality assurance of vehicle body construction and modification;
- End-of-Life Vehicle (ELV) management; and
- Public engagement and outreach.

Figure 4.3. Nuts and Bolts of Effective Governance of Motor Vehicle Stocks



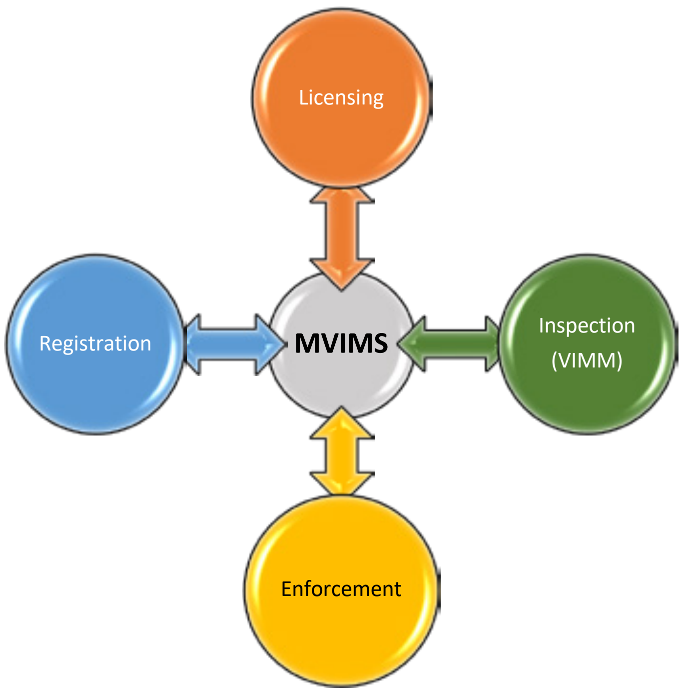
Source: Original figure produced for this publication.

The remainder of this section discusses these systems in more detail.

Motor Vehicle Information Management Systems

A motor vehicle information management system (MVIMS) is perhaps the most basic and cross-cutting of the programmatic measures to be able to use policy to improve a country's motor vehicle stock. MVIMS is a standardized, digital platform that integrates databases for vehicle registration, licensing, inspection, and enforcement. The typical structure of MVIMS is shown in Figure 4.4, all of whose modules are important and integral to MVIMS.

Figure 4.4. Typical Structure of Motor Vehicle Information Management System (MVIMS)



Source: Original figure produced for this publication.

MVIMSes need to play a central role in the MM system of a country. As such, a mature MVIMS would ideally have the following characteristics:

- Architecture that guarantees security of information and protection from cybersecurity threats;
- Accessibility for different authorized users to be able to access the system to either deposit or retrieve information in real time;
- Architecture that facilitates exchange of information seamlessly with upstream and downstream users (both public and private), including customs agencies, PTI inspectors, traffic police, and motor vehicle insurance providers;
- Ability to integrate data from other countries' MVIMSes as needed, so that, for example, vehicle records for imported secondhand vehicles from the country of origin can be made available in

the importing country,[3] or for traffic enforcement purposes for vehicles being used outside of their home country of registration;

- Centralization of characteristics of the vehicle, including make, model, model year, and trim of the vehicle; fuel used; emissions control equipment and level it was originally certified to; frequency and results of PTIs; vehicle odometer readings at each PTI; structural and major componentry modifications to the vehicle or its key systems; or potentially other key elements identified in the 1958 or 1998 agreements under the United Nations Economic Commission for Europe (UNECE) World Forum for Harmonization of Vehicle Regulations (WP.29); and

- Ability to make anonymized data about the vehicle stock available in different formats and levels of aggregation so that unaffiliated researchers (for example, academia, MM observatories) can undertake quantitative policy analysis.

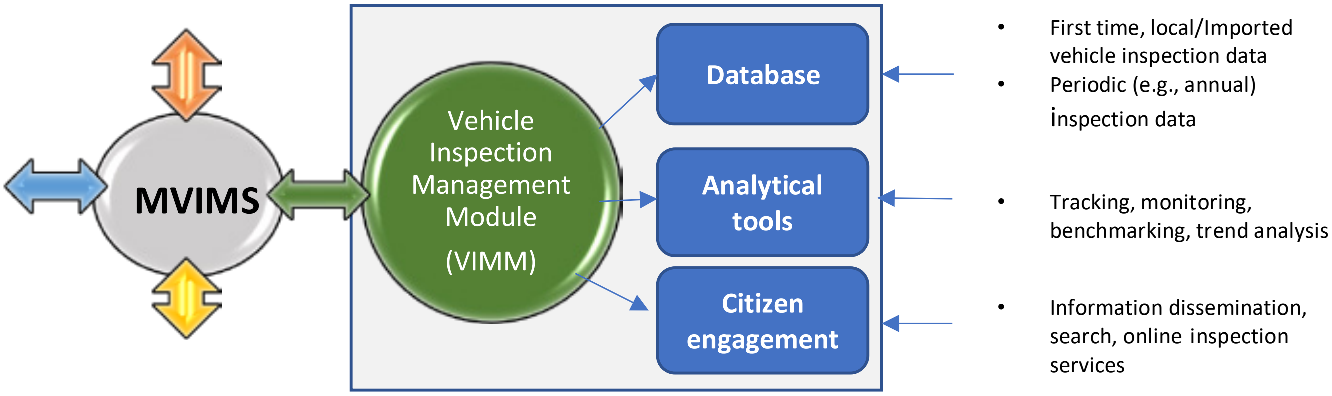
In addition to the above characteristics, MVIMSes will need to recognize the potential for increasingly modular construction of motor vehicles in the future as electrification, production mechanisms, and requirements for materials' reuse and recycling consistent with the circular economy expand. For example, use of blockchain-enabled embedded tracking systems for particular parts and subcomponents may become more widespread in the future; MVIMS data architecture may need to adapt to these needs.

To streamline the remainder of the presentation of the MVIMS, we focus on the Vehicle Inspection Management Module (VIMM) to provide a concrete example of both how MVIMS can work and how it is a key enabler for other MM implementation programs discussed later in this chapter. The primary objective of the VIMM is to help relevant stakeholders continuously manage the inspection process throughout the vehicle life cycle in compliance with vehicle performance standards. The VIMM consists of a collection of digital components to enable capturing, tracking, analysis, and dissemination of data related to vehicle inspection. It ensures timely and accurate data is captured and updated in a centralized repository. It should also integrate seamlessly with the other modules in the MVIMS and contribute to enhancing efficiency of the inspection process. While facilitating vehicle inspections that consider standard OEM system features, the design of the VIMM should ensure harmonized inspection procedures and data entry protocols administered across all inspection centers in the country. Furthermore, it offers information and data for benchmarking and research purposes.

A typical VIMM implementation consists of three components: database, analytical tools, and citizen engagement, as illustrated in Figure 4.5, and described further below.

3 There is also a simultaneous and critical need to develop an international agreement on motor vehicle data sharing that establishes obligations for exporting and importing countries with regard to exchange of data, as well as establishing/formalizing data architecture protocols for such information exchange.

Figure 4.5. Structure of Vehicle Inspection Management Module



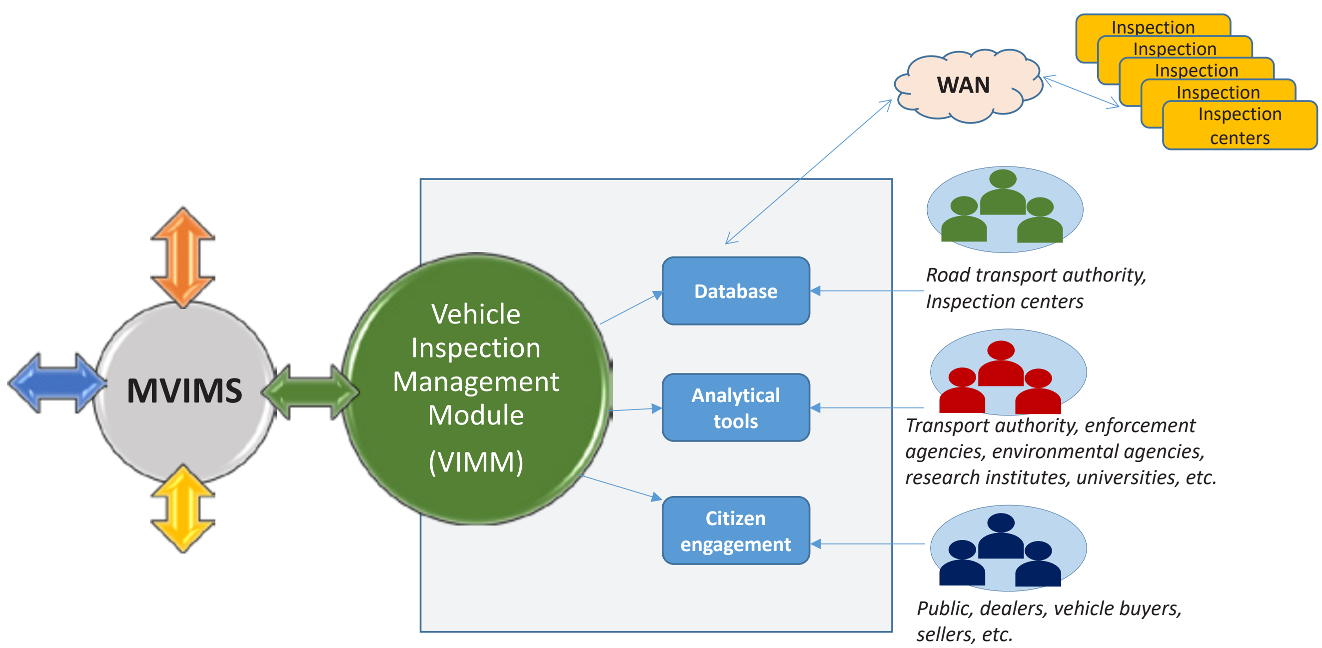
Source: Original figure produced for this publication.

- ***Database:*** The VIMM database should be a repository of complete inspection data for all vehicles actively operating on the roads. In addition to containing the inspection data corresponding to first-time locally manufactured and assembled vehicles, the database should be updated with information coming out of periodic inspections (for example, annual, biennial, etc.) as stipulated by the national inspection regime. In many countries, all road vehicles are subjected to inspection carried out by an authorized government body before importation. The VIMM database should be designed to support the codification of a country-specific regime for safety, fuel economy, and environmental standards. Although this database could be implemented as a standalone repository, in situations where the design for a larger, more comprehensive MVIMS exists already, it is recommended that the MVIMS database be utilized to incorporate features of that database. In terms of storage of data, the VIMM could either have its dedicated archival area or could leverage the centralized storage used by MVIMS.
- ***Analytical Tools:*** This module within the VIMM should consist of tools and applications that would harvest the structured data stored in the VIMM database to help users of the VIMM track, monitor, benchmark, and perform a wide range of analytics on the inspection data. Besides generating a variety of standard and customized reports for multiple stakeholders, the analytical tools should also compile a dashboard of compliance, generate alerts, and present enforcement trends taking into account the different parameters comprising the inspection regime. As an example, the analytical tools could be used by relevant stakeholders to generate reports on the number of vehicles that failed inspections and reasons for failure per year, growth in the number of imported vehicles of a particular brand that failed emissions tests in the first year, number of vehicles with inspection defects or deficiencies that have subsequently been corrected per year, etc. Analytic tools can also help to statistically identify vehicles that may have been subjected to odometer tampering.

- ***Citizen Engagement:*** This public-facing module could be implemented as a website with a supplemental mobile or smartphone app. This module should form the bridge between the supply side and demand sides of the inspection process. Through messages and explanations on inspection regime, standard procedures for inspections, benefits of compliance, penalties for non-compliance, and via frequently asked questions, this module should emphasize user awareness and changes to consumer behavior required for successful compliance. Consumers should not only be able to search for inspection records but also request inspection services online via the website or the app. Furthermore, this module should incorporate grievance management features as well to capture complaints and suggestions from the consumers.

Users of the VIMM are identified based on the modules they would be most likely to use, as illustrated in Figure 4.6 below.

Figure 4.6. Key Users of VIMM Module



Source: Original figure produced for this publication.

- ***Users of Database:*** The primary users of the database would include national and subnational road transport or road safety authorities, as well as the operators of the inspection centers themselves. While road transport authorities responsible for first-time and annual or biennial inspections would have the privileges to enter, modify, and delete data, the authorized inspection centers would be able to only deposit and read data. In case of imported vehicles, the authorities would also be responsible for uploading pre-shipment certificates and other related documents into the database. When inspection data is captured by multiple authorized inspection centers, it would be advisable to consider a tight integration between inspection centers and the central repository for the VIMM so that the data captured by the geographically dispersed centers could be exchanged digitally and in real time with the central database thereby ensuring data integrity.

- ***Users of Analytical Tools:*** This module in the VIMM would typically be used by the transport or road safety authority, inspection enforcement agencies, traffic police, environmental agencies, research institutes, universities, and other stakeholders that might be interested in the vehicular inspection data. One of the ways in which the enforcement agency could utilize this tool would be to identify vehicles delinquent on inspections and those that have failed inspections but are still operating on the roadways.

- ***Users of Citizen Engagement:*** The primary purpose of implementing this module is to inform consumers about the ecosystem of vehicle inspection with a view to changing consumer behavior toward compliance. The key users of this module will be the driving public, vehicle dealers and importers, and vehicle buyers and sellers.

Implementation agency of MVIMS and its sub-modules, like the VIMM, would vary according to the administrative structure of the country but would typically be carried out by the executive body assigned to oversee the transport services sector or road safety authority, if one exists. This may or may not be the same entity responsible for issuing drivers' licenses, but the systems should be designed to be as integrated as possible. The participation of authorized inspection centers in the VIMM through digital integration would, therefore, need to be mandated by the implementing agency. These authorized inspection centers would need to be required to deposit the inspection data accurately and in a timely manner, as required by the VIMM architecture, as part of the authorization process or when the permits/licenses are issued to the inspection centers.

Governance of the information in the various MVIMS components is of critical importance and should be established considering the various departments that may access and use the information. A robust governance protocol is required to ensure the inspection workflow is managed unambiguously and that the roles of different actors in the system are defined clearly for data inputs, analysis, information security, reporting, and decision-making (that is, a role-based access policy). The governance mechanism should include standard operating procedures and protocols to manage the privileges to access, create, modify, or delete data. The various MVIMS platforms, through their user interfaces should enable the primary custodian of the system to administer the governance effectively.

Certification/homologation systems

Certification of vehicles for addition to the national vehicle stock can refer to either import certification or production homologation/certification, depending on how the vehicle enters the stock. As noted above, we estimate that for 70 percent of low- and middle-income countries, importation of previously used vehicles outstrips that of new vehicles, and newly added vehicles are predominantly imported rather than produced or assembled locally; import certification is, therefore, a critical process to protect the integrity of the stock under an MM posture.

Import certification is the process whereby vehicles imported to the country are assessed for conformity to entry thresholds. If the country has adopted policies to incentivize vehicle purchase choices on the basis of particular characteristics, such as fuel economy, import certification is also the process whereby those characteristics are verified for the particular vehicle in question or relevant values assigned to it. Import certification applies to new and used vehicles, as well as to CKD or semi-knock down (SKD) assembly kits, though the requirements for each might differ. Processes for import certification of vehicles can vary substantially among countries. Key variants affecting the design of an import certification process include the following:

- ***Where does certification occur?*** Certification can occur at the point of export or import, or both. Kenya, for example, contracts with a private company to undertake pre-export inspections, but it has latitude to do so since more than 90 percent of vehicle imports into Kenya come from a single country, Japan. Where import sources are more diversified, quality (and fraud) control in pre-export inspections becomes more difficult to manage. However, inspections at import carries a certain risk for the importing countries that nonconforming vehicles will need to be shipped back or disposed of at public cost. Development of international agreements that put the burden on exporting countries to control or manage the quality of vehicles exported to developing countries might help this process of certification by requiring developed countries to share some of the regulatory burden.

- ***Who carries out frontline checks?*** Certification of vehicles for import (or export) is usually carried out by private companies in contract to a regulatory agency. In Kenya, for example, the company Quality Inspection Services Japan (QISJ) carries out inspections in Japan through a contract with the Kenya Bureau of Standards. How those inspection contracts are procured, how frequently, and under what conditions, and how those contracts are overseen by regulatory agencies, are critically important considerations and fraught with opportunities for corruption.

- ***How is fraud managed?*** In most certification systems, paperwork to demonstrate conformity with the country's import requirements is subject to 100 percent check. Clearly, however, some proportion of the vehicles will not conform to what is shown in the paperwork as a result of attempted fraud. The objective of any import certification system, therefore, is to minimize the proportion of vehicles with fraudulent papers that are ultimately accepted for entry, while also minimizing import-process-related costs. Many countries consider 100 percent physical inspection of all vehicles at both export and import to be too costly for consumers, so designing a system that has enough randomized physical inspections and substantial enough punitive damages when fraud is discovered to deter efforts at fraud is the critical challenge.

As a good practice example, New Zealand maintains some of the most stringent vehicle emissions and safety standards in the world, proven by its road safety statistics. It no longer has a domestic vehicle manufacturing industry. The vast majority of vehicles in New Zealand are imported from Japan. Box 4.1. discusses the key features of New Zealand's vehicle imports certification process.

Notwithstanding the perceived cost of two-stage inspections, the Brussels-based International Motor Vehicle Inspection Committee (CITA) recommends a two-stage entry certification process, similar to that carried out in New Zealand, consisting of a first stage done in the country of export (pre-shipping) and the second done at import (post-shipping). The main objective of the inspection at the export end is to determine whether characteristics of the vehicle itself would make it ineligible for import. These might include whether, at manufacture, it met the crashworthiness requirements currently required for import, whether it has necessary emissions control and crash avoidance equipment currently required for import (including whether the equipment is functional), and whether there has been irreparable structural damage or alteration to the vehicle that renders it ineligible to be deemed roadworthy. The main objective of the inspection at import is to determine whether there has been damage or tampering to the vehicle during shipping, and what repairs might be needed prior to issuance of a roadworthiness certificate. We believe that this two-stage import certification process represents best practice.

Box 4.1. New Zealand's Vehicle Import Certification Process

New Zealand provides an interesting case study of a country without a domestic automobile manufacturing industry that, nevertheless, effectively manages both vehicle safety and fuel efficiency improvements. New Zealand does not have a major domestic vehicle manufacturing industry and relies heavily on the import of vehicles, primarily from Japan, Australia, and the United Kingdom. About 50 percent share of New Zealand's imported vehicles are light-duty vehicles (LDVs) and it has one of the safest fleet ratings regarding crashworthiness. New Zealand Transport Agency (NZTA) has set up the import standards for all categories of vehicles. The two key features of New Zealand's vehicle import regime of note are extensive reference to other countries' vehicle standards in its own legal codes, and an importation process centered around entry certification, known locally as "compliance."

The set of crashworthiness standards approved by NZTA refer specifically to the frontal impact test performance. The approved standards include:

- Directive 96/79/EC of the European Parliament and of the Council of 16 December 1996 on the protection of occupants of motor vehicles in the event of a frontal impact;
- UN/ECE Regulation No. 94 Uniform provisions concerning the approval of vehicles with regard to the protection of the occupants in the event of a frontal collision;
- Federal Motor Vehicle Safety Standard No. 208, Occupant Crash Protection in Passenger Cars, Multipurpose Passenger Vehicles, Trucks and Buses;
- Australian Design Rule 69, Full Frontal Impact Occupant Protection;
- Australian Design Rule 73, Offset Frontal Impact Protection; and
- Technical Standard for Occupant Protection in Frontal Collision (Japan).

New Zealand has also put in place a mandatory vehicle efficiency labeling requirement for both new and used imported vehicles, with an exception for electric vehicles (EVs). The label design is the same for both new and used imports. However, the used import label only includes the star-based rating (up to six stars) and not a fuel economy value. New Zealand has developed an algorithm to translate efficiency ratings from the various exporting markets into its star rating. Consequently, it does not test vehicles directly for fuel economy, but it does audit the documentation provided for new vehicle imports and compares it to international databases. A number of dealers are visited every year to ensure labels are properly displayed on vehicles.

Vehicle importation in New Zealand is built around a myriad of requirements depending on the country of manufacture and the year of production of the vehicle. Entry certifiers carry out both document inspection—to ensure compliance with these requirements—and physical inspection to determine the condition of the vehicle with respect to rust, previous structural repairs, structural damage, brakes, emissions, and seat belts/seat belt anchorages, among other things. Repairs, if necessary, are carried out and certified by third and fourth parties to ensure integrity of the process. After passing document and physical inspection, the entry certifier issues a Warrant of Fitness, which is required to register the vehicle.

New Zealand also contracts with a company in Japan to undertake pre-export inspections. In this respect, New Zealand enforces a two-stage inspection process. In addition, all sales of secondhand vehicles in Japan are brokered through public auction processes, for which a detailed auction inspection sheet, made available to the public before bidding, is required. In this sense, Japanese cars exported to New Zealand are inspected at least three times before being allowed to be registered for use in New Zealand.

Image B4.1.1. Inspection Facility for Newly Arriving Used Vehicles in Wellington, New Zealand

Source: Vehicle Testing New Zealand Ltd.

Source: World Bank and New Zealand Transport Agency website.

For vehicles that are fully or substantially manufactured domestically in the country, a two-stage production certification process is commonly used, consisting of Type Approval (TA) and Conformity of Production (COP)/Homologation. TA is the procedure by which each vehicle type produced for a particular market is determined to meet all the technical and administrative requirements established in a given regulatory regime that is in place. The 1958 agreement under WP.29 of the UNECE governs the definition of a vehicle "type" internationally. COP is a related process that confirms that each vehicle is manufactured in accordance with approved specifications. Presence of a quality-management system, such as ISO 9001, often suffices to demonstrate COP. For many developing countries with nascent automotive manufacturing industries, existing TA-COP arrangements in developed countries may be sufficient in the short run to manage the volume of vehicles being produced. However, COP processes may need to be designed and introduced to ensure quality of CKD and SKD assembly in particular.

Periodic Technical Inspection

PTI is a set of requirements designed to ensure that in-use vehicles are properly maintained and kept in good working order by vehicle owners or leaseholders.[4] The main goal of a PTI program is to identify the dirtiest and most hazardous vehicles—that is, the ones that represent the greatest threat to public health—and to either get those vehicles repaired or get them out of circulation. Inspections relate to emissions and roadworthiness, and these are often done separately. In some jurisdictions, these may be carried out by separate entities, and even in different locations. An ideal system of PTI, however, will be designed so that these inspections are carried out at the same time, and made seamless for the vehicle owner. For the purpose of exposition here, however, these are discussed separately.

Inspection for emissions

ICE vehicles will emit gaseous and particulate pollutants that harm human health and have other deleterious environmental effects. Consequently, PTI programs to monitor emissions are recommended to be in effect as long as ICE vehicles are used to ensure compliance with health and environmental standards. However, a good PTI program for emissions is not intended to verify whether an in-use vehicle is meeting a particular emission standard, but rather to check whether it is exceeding a certain threshold (Posada, Yang, and Muncrief 2015; Yang, Qiu, and Muncrief 2015). This distinction is important because the way a PTI program for emissions is established and the parameters that define it are quite distinct from those of a program designed to filter vehicles coming into a country's vehicle stock for the first time. In a country with metropolitan areas with acute air pollution problems (for example, ozone or particulate smog), the objective of a PTI program targeting vehicle emissions might be to continuously get 5 percent to 10 percent of the dirtiest vehicles (with respect to the pollutant of interest) either fixed or permanently off the road. This means: (1) identifying an appropriate emissions testing protocol that is meaningful and implementable in the country in question, and (2) continuously assessing emissions performance of the fleet, and resetting thresholds to cover the worst performing 5 percent to 10 percent, rather than setting and monitoring for a given technology standard (like Euro 4) per se. In this understanding, the "failure rate" of vehicles under an inspection regime is not an indicator of the performance of the vehicle stock in a given area; it is, rather, a policy target.

4 This report adopts the nomenclature "periodic technical inspection" to refer to any required recurring technical inspection program for vehicles registered for use on public roads to ensure that the vehicle meets safety roadworthiness, and vehicle emissions verify fitness. In this report, we do not adhere to the common nomenclature referring to "inspection and maintenance" programs—that is, inspection to check pollution emissions control systems—separately from inspection for vehicle fitness for road safety purposes. From the standpoint of creating or strengthening inspection regimes that provide maximum convenience for vehicle owners and operators, integration of these two aspects of vehicle inspection as much as possible is important. The nomenclature adopted in this report, referring to both under the rubric "periodic technical inspection," is intended to support this concept.

Best practice cases from around the world point to the need to separate emissions testing from vehicle repair, with the former centralized in high-throughput facilities that can be readily monitored through both visual and electronic means. This minimizes the opportunities for corruption and facilitates investment in advanced emissions control testing equipment, if required (Walsh 2005; Fabian and Bosu 2012).

Any PTI program for vehicle emissions should be oriented toward targeting, as quickly as possible, the vehicles that cause the biggest harm. This means developing empirical data on the following:

- ***Ambient air quality.*** Key air quality problems should be documented in order to have an evidence base about which pollutants should be targeted, in which order. For example, it is important to understand whether addressing tropospheric ozone should be an important target in a vehicle inspection program, and, if so, whether focusing on non-methane hydrocarbons (NMHCs) or oxides of nitrogen (NOx) would be a more effective strategy. The answers to such questions can only be determined through empirical data collected locally in an ambient air quality monitoring program. That said, international experience suggests that particulate matter (PM_{10} and $PM_{2.5}$) is a chronic and serious public health challenge in cities, particularly but not only where there is a high predominance of diesel vehicle use. So, efforts to control PM emissions may be a worthwhile early investment even while a local empirical database is under development.

- ***Emissions database development.*** At least two years of vehicle emissions data, gathered from mandatory vehicle emissions inspections, should be compiled before emissions limitations are established. These limitations, when they are established, will need to be set in a manner that ensures that a manageable number of vehicles—for example, the dirtiest 10 percent to 15 percent—are targeted in any given year. Having detailed, local, empirical data is critical to this objective.

The two key characteristics that should define PTI program design to address emissions are the evolving nature of the vehicle fleet—what will be the predominant level of emissions control equipment in the urban fleet in the next five years, what proportion will be compliant with ISO 15765 (OBD2), and what proportion will be petrol, diesel, or other?—and the nature of the ambient air quality pollution problem being faced, which is best identified through ambient air quality and source-apportionment studies. The answer to these two key questions should determine what kinds of testing protocol and frequency are required for each vehicle. A poorly specified PTI program for emissions control that is not designed around these local characteristics (for example, borrowed from other locales without adequate analysis of local circumstances) is at high risk of either being ineffective or facilitating investment in rapidly obsolescing technologies relative to the way the vehicle fleet is evolving. In other words, poorly designed PTI programs may result in stranded assets.

Inspection centers themselves should be designated by the relevant government authority through a well-established, transparent, and predictable process. Where the capacity of this government authority is weak, efforts should be taken to limit the number of different inspection entities that require oversight. The approval of government authorized inspection centers should also extend to equipment used for inspection to be certified by an authorized body and certified training for personnel using the equipment and involved in the issuance of the certificate. It is important that the prohibition of the vehicle be clearly marked and categorized as immediate or delayed in case the vehicle shall be deemed for repair at the cost of the owner. Without a Certificate of Performance, the vehicle should be denied renewal of registration, road license, or insurance coverage, and further penalized if found to be operating during random on-road inspections.

Inspection for safety

PTI for safety should ensure that all vehicles adhere to a minimum standard of safety performance while under operation. This usually entails, among other things, subjecting vehicles to a standardized testing protocol either as a separate process from emissions inspections, or as a single process. Vehicles newly accepted for entry into the national vehicle stock (either imported or locally assembled) need not be subjected to the testing protocol at the time of registration if they will be subjected to regular inspection once under operation as part of the current fleet. This applies to all categories of motorized vehicles, including passenger cars (sedans, sport utility vehicles), heavy vehicles (trucks, larger trailers), and passenger service vehicles (taxis, shuttles, buses). Compliance with vehicle testing protocols may be ensured with the issuance of a Certificate of Performance, which must be produced by the vehicle owner or vehicle dealership during import registration or the annual inspection process. It is, therefore, the responsibility of the vehicle owner, even during the pre-import stage, to ensure the vehicle complies with the Certificate of Performance. For road safety objectives, the maximum inspection interval is one year after the first registration (or if the vehicle is not required to be registered, date of first use) and annually thereafter, as recommended by the United Nations. Further, the inspection schedule may also apply to vehicles involved in tow-away crashes and random on-roads inspections.

Technical inspection for road safety is governed internationally through the 1997 agreement of the World Forum for Harmonization of Vehicle Regulations (WP.29) of the UNECE.[5] Best practice shows that vehicle safety testing protocol should aim to cover, at a minimum, the following aspects of vehicle safety features:

- Tire condition and minimum permissible thread depth;
- Brake condition and operation;
- Structural conditions (including corrosion and rusting);
- Certificate of loading and load restraints (load anchorages, towing connections);
- Lighting (headlamps, brake lights, turning indicators, reflectors as applicable);
- Glazing (windscreen and wiper condition);
- Door operations and locking mechanisms;
- Safety belts and buckle/anchorage system;
- Airbag operations, if fitted;
- Speedometer and odometer check;
- Steering and suspension; and
- Fuel system integrity.

Development of specific vehicle testing protocols in these areas should aim to harmonize country-specific requirements with those of the WP.29, and countries

5 Agreement Concerning the Adoption of Uniform Conditions for Periodical Technical Inspections of Wheeled Vehicles and the Reciprocal Recognition of Such Inspections.

that are not contracting parties to the 1997 convention should consider membership as it allows reciprocal recognition of inspection certificates from other member countries.

Structure of vehicle inspection systems

In many countries, vehicle emissions inspection systems evolve out of an older system for vehicle safety inspections, which tends to be more dependent on labor than machinery. As a result, there is a risk that nascent PTI for emissions follow a model of decentralized inspection at small facilities that do maintenance as well as inspection. As previously noted, numerous experts (ADB 2003; Walsh 2005; Fabian and Bosu 2012) have concluded that emissions inspection systems are more effective and cost-efficient when they are carried out by centralized, test-only facilities focused on high vehicle throughput, with separation of the test from the repair function. In addition, for countries with weak institutional capacity, it is easier to oversee and manage a few large facilities or operations than many small ones. Centralized facilities also have a greater ability to invest in the latest and most technically advanced equipment, and the separation of testing from repair and servicing typically associated with centralized test facilities means there is less susceptibility to corruption. However, centralized test facilities can be seen as an inconvenience by motorists.

In practice, the structure of a PTI system will depend on country-specific circumstances, shaped by legal and regulatory authority provided in the country, and the legacy system(s) from which the PTI system evolves. But an effective PTI system should aspire to the following characteristics:

- PTI should be carried out in centralized facilities in most low- and middle-income countries, where oversight and governance capacity are likely limited. Decentralized inspection, to meet the convenience of vehicle owners, might evolve over time, but only if the oversight and governance capacity of the regulatory authority is sufficient to manage that decentralization.

- Metropolitan areas with or susceptible to bad air pollution should require PTI for emissions along with PTI for roadworthiness. The way the national system is structured, however, needs to ensure that cars not inspected in metropolitan facilities with emissions requirements are not allowed to regularly operate in metropolitan areas.

- Centralized (test-only) facilities should be operated by appropriately constituted and organized entities (for example, public or private) using Public Service Contracts (PSCs)—that is, a public or private company would operate the facility on contract to the responsible department. These facilities could either be built by the public sector and then leased out to the operator under the PSC, or else developed under a public-private partnership (PPP) model such as Build-Operate-Transfer (BOT).

The above is intended only to define general principles; the actual structure of a PTI system, both as fully mature and in terms of how it should evolve from the legacy system, should be developed through a more detailed study.

The regulatory agency overseeing the vehicle inspection system—to which the entity carrying out the actual inspections under the PSC would be contracted—would have a number of responsibilities and mandates for which capacity would need to be developed or strengthened. First, it would need to develop the regulatory capacity, decentralized into field offices as appropriate, to be able to administer a system of licenses and/or PSCs, including capacity to carry out snap inspections and facilitate enforcement actions as appropriate. Second, it would need to ensure that the necessary protocols and data protection measures are developed to enable access to the MVIMS by the vehicle inspection industry. Third, as the custodian of a great deal of operational data related to vehicles, it would need to develop the necessary capacity to exploit and utilize that data productively. This may mean development of in-house capability to analyze data, but it might also mean development of standing protocols or memoranda of understanding (MOUs) with academia to produce regular analyses of data for public policy development. Such useful data that could be collected would include profiles of the fleet; profiles of fleet usage (through collection of odometer readings); identification of anomalies that may indicate fraudulent behavior, such as odometer rolling; profiles of empirical emissions rates to identify gross emitters; and many other possible applications.

On-road enforcement

Periodic testing of vehicles under a mandatory PTI program is a necessary, but insufficient, condition to ensure compliance with requirements to maintain ICE vehicles in acceptable conditions to be allowed to circulate. As a stand-alone program, PTIs are too prone to fraud and corruption to be an effective instrument; they need to be supplemented with effective on-road enforcement. On-road enforcement programs can be useful both to ensure that motorists and inspectors are complying with the law, and to gauge the overall quality and effectiveness of a PTI program. Such enforcement needs strong, visible, and consistent parameters and protocols across jurisdictions to be effective and credible. We discuss visual and instrument-aided on-road enforcement programs in this section.

Visual enforcement

Public spotter programs encourage and enable the public to report the license plate of vehicles with visible smoke from their tailpipes. Although the breadth of intervention is limited to smoking vehicles, these programs are relatively easy to set up and have low operation costs. Successful implementation requires active program promotion to ensure high awareness, easy reporting methods, and follow-up with reported vehicles. The program requires a database that links vehicle license plate to owners and contact information (phone and address). It also relies on an existing system of inspection and maintenance centers. Once a vehicle is reported, authorities should contact the owner and ensure the vehicle is tested and repaired before it is once more allowed to ply the roads.

Hong Kong and cities in Guangdong Province, China, have ongoing public spotter programs. Hong Kong was particularly successful in ensuring public participation by recruiting and training citizen volunteers. Guangdong rewards those that have reported vehicles that are confirmed to be gross emitters. For both programs there are a variety of ways to report vehicles by phone or through a website, email, and mail. A text message option offered in Guangzhou, the capital of Guangdong Province, would have wide applicability in regions where cell phone ownership is high. Follow through is critical and these programs consistently ensure vehicle owners are tracked down and the vehicle is tested and repaired as needed.

Spot-checking programs are carried out by teams of officials, often pairing police or others with law enforcement authority with technical specialists trained to identify vehicles with potentially high emissions and conduct roadside testing. These programs are meant to complement inspection and maintenance programs by providing more targeted selection of vehicles. Spot-checking programs are often set up in locations where high-emitting vehicles are likely to be found, such as parking lots, bus stations, and motorway exit ramps. As with public spotter programs, successful implementation is contingent on not only identifying high emitters but also ensuring vehicles are repaired and retested before they are allowed to operate. Data on what vehicle makes and models have higher rates of noncompliance can be used to target roadside inspection. Spot-checking programs are also a good complement to remote sensing programs.

Instrument-aided enforcement

Both loaded and unloaded tests can be carried out on the roadside (see, for example, Box 4.2. on Morocco's use of roadside testing), but the costs and equipment requirements vary. For light-duty gasoline vehicles, one option is the lower-cost two-speed idle test, an unloaded test that was developed for carbureted engines. However, this test is less effective with today's electronically controlled engines. The Acceleration Simulation Mode (ASM), a loaded test where the vehicle is driven on a treadmill-like apparatus that replaced unloaded tests in many inspection and maintenance programs, has also been applied to roadside tests, notably in California. For diesel vehicles, the free acceleration smoke (FAS) or snap-idle smoke test measures the exhaust opacity at full open throttle. The test has simple equipment and setup requirements, which makes it easy to incorporate in instrumented spot-check programs. Although this test is useful for detecting serious malfunctions, like the two-speed idle test, the results are often variable and poorly correlated to PM emissions, limiting its usefulness to identifying vehicles with gross defects.

Box 4.2. Use of On-Road Testing in Morocco

Morocco has implemented a program of on-road testing using mobile units equipped with technical control equipment. Three mobile units are operated by the National Center for Testing and Homologation (CNEH) to monitor vehicles leaving periodic technical inspection (PTI) testing centers. These inspections make it possible to check the condition of the vehicles and to audit the technical control centers and ensure compliance with the control procedures. For the control operation, the CNEH also checks the accuracy of the measurements collected by the technical equipment of the audited center. These operations indicate the quality of maintenance and compliance with the calibration of technical equipment.

Image B.4.2.1. Mobile Testing Unit Performing Validation Check Outside a PTI Testing Center in Casablanca, Morocco

Source: Abdellilah Khalifi.

Source: World Bank.

New testing options, such as onboard diagnostics (OBD) and remote sensing, are providing promising alternatives to current roadside testing approaches. OBD systems monitor the performance of engine and emissions control systems, alert the driver about system malfunctions, and store information that can be accessed by service providers to diagnose malfunctions. OBD systems are currently installed in all new cars and most new trucks in the United States, the EU, Japan, the Republic of Korea, and China; however, system requirements in these markets vary. Several jurisdictions in the United States use OBD testing as the primary inspection and maintenance test for newer cars. The use of HDV OBD in truck inspection and maintenance is currently limited. The data stored by the OBD system can be accessed during spot-checking stops using an OBD scan tool, eliminating the need for an actual emissions test. This approach's success is contingent on OBD regulations requiring permanent storage of diagnostics trouble codes (DTC) until adequate repairs are made and other requirements to limit tampering. For markets where multiple standards exist, the lack of a standardized protocol may limit near-term feasibility. OBD systems could be hacked and provisioned with defeat devices, however, so extensive use of monitoring OBD as a way of examining emissions should also be accompanied by measures to detect the prevalence of illegal OBD modification.

Remote sensing devices (RSDs) use a light beam directed at the exhaust of a vehicle that is passing by to detect the amount of pollutants emitted and the vehicle's speed and acceleration. At the same time, a camera takes a picture of the vehicle's license plate to link the vehicle to its owners. These systems have been primarily deployed to research fleet-level emission characteristics, verify the real-world effectiveness of emission programs, and identify high emitters. It is primarily seen as a complement to PTI helping identify both vehicle types that should be targeted for detailed screening, and how effectively a PTI program is catching gross emitters over time. Much of the remote sensing deployments to date have focused on LDVs, but feasibility for HDVs has been demonstrated. Success factors for the use of remote sensing as an approach to reduce in-use vehicle emissions include optimizing the location and density of the system, establishing limits that can be enforced, and following up on detected high emissions. As with public spotting programs, an accurate and regularly updated database connecting the license plate to the owner of the vehicle is a prerequisite for remote sensing as a compliance enforcement tool.
Further, to be effective, on-road enforcement techniques, such as those discussed in this section, need to be prevalent enough that motorists perceive a reasonable chance of being caught in an enforcement action, and the consequences dire enough that they consider having their vehicle out of compliance as a high risk. For these reasons, their use should be programmed as a continual activity, particularly in metropolitan areas with air quality challenges.

Fuel quality assurance mechanisms

There are many reasons to include fuel quality assurance in a broader program of MM. In countries with porous borders, situated in regions where fuel standards are not harmonized and substantial variation of fuel quality and prices exists, there may be strong economic incentives to smuggle and distribute lower-quality fuels into countries where they may do substantial damage to vehicle emissions control systems. Even within individual countries, there can be strong economic incentives to adulterate fuels if there are big enough price differentials between them and consumers are unaware of the adulteration or the damage it can cause at the time of the fuel purchase. In many countries, adulteration takes the form of mixing kerosene with gasoline or diesel. In Ethiopia, for example, taxes on kerosene were lower than taxes on other hydrocarbons through 2017 in order to provide a price incentive for low-income households to use kerosene, rather than biomass, for household cooking and space heating. The resulting unintended incentive to adulterate gasoline and diesel with kerosene resulted in a perverse effect of making kerosene scarcer for low-income households than it otherwise would have been had taxation rates been equal with other hydrocarbons. For this reason, the tax differential was eliminated in 2017.

As with other parts of the automotive value chain, informality in the gasoline and diesel supply chain is prevalent in many countries and can be a challenge for oversight of the adequacy of fuel quality. Mbaye et al. (2020) identify automotive fuel supply as a key sector in which competition between formal and informal sectors in West Africa predominate. They report that 73 percent of petroleum products by volume in Benin are available through informal vendors. Many of these products in Benin, Cameroon, and other countries in West Africa are smuggled from Nigeria and are known to be blended and adulterated in the process (Aliyou, Houssou, and Attisso 2013).

Infiltration of impurities is another reason that fuel quality testing is critically important. Where fuel storage systems are structurally weak, water and other impurities can infiltrate fuel at storage, particularly in instances of heavy rain or flooding. Infiltration of rain and groundwater into fuels can degrade motor vehicle performance, but it can also be an indicator of other serious environmental consequences. If water can infiltrate fuel tanks, then there is a high likelihood that fuel can leach into surrounding groundwater as well.

A 2011 working paper by the International Council on Clean Transportation (ICCT) surveyed best practices in fuel compliance programs. It found several themes in common. First, a combination of upstream testing (for example, at import facilities) and downstream quality checks (for example, at retail stations) should be used. Second, presumptive liability is an effective concept to be applied, putting "the onus on fuel suppliers to deter fuel contamination and the mixing of low-quality fuel along the distribution chain." Third, prohibitive noncompliance penalties should be applied to fuel suppliers. Fourth, both financial and criminal penalties can be leveraged against suppliers. Finally, the threat of reputational damage is a powerful disincentive (Fung 2011).

Fuel marking is one strategy that has proven somewhat effective in fuel quality assurance. Fuel marking involves placing markers in fuels (such as dyes or other markers) at the point of introduction of a refined fuel product into the supply chain. In Kenya, for example, the government successfully brought down the percentage of failing fuel stations from a high of about 20 percent to 2 percent through an effective program of fuel marking and other complementary measures in 2017 (Oimeke 2020). The success of fuel marking and testing relies on long-term collaborative commitments by a number of government agencies, including the departments of energy, finance, customs, transport, and law enforcement. In the case of Kenya, the Energy Regulatory Authority (ERA) has the initial authority and responsibility in regulating fuel quality. ERA has contracted with a private company to bio mark all fuel exports and domestic kerosene at distribution and carry out random sampling to ensure that exported fuel is not dumped back into the country, and that fuel adulteration is curbed. The Kenya program also uses a "name-and-shame" approach; the names of fuel stations that are found to have either adulterated or dumped fuel are published in the local newspapers two months prior. As a result, many retail station owners have procured and regularly utilize self-testing equipment to check that all fuel deliveries to their stations are in accordance with the required standards.

Oversight and development of preventive maintenance and repair industry

In many developing countries, current maintenance practices can be observed as falling into two separate industrial "ecosystems" for vehicle maintenance; one would expect there to be a range of intermediate services between the extremes described below, but there are examples, such as Ethiopia, where such intermediate services do not exist.

On the one end of the spectrum, OEMs, such as Toyota or General Motors, maintain training facilities and dealer-based maintenance shops in order to provide after-market services to customers, as well as provide purchased services to the general public. Such services would often be too expensive for most vehicle owners and operators, commercial and noncommercial alike, but desirable as a premium service where quality is guaranteed, for those who can afford it.

Image 4.1. Toyota Vehicle Service Repair Center in Addis Ababa, Ethiopia, in 2016

Source: Henry Kamau.

On the other end of the spectrum, artisanal mechanics provide services on an informal and unlicensed basis, often in roadside shops. The size of this informal service provision is probably substantial in many countries. Murthy (2019), for example, estimated that in India, in 2017, 86.6 percent of gross value added (GVA) output of trade, repair, accommodation, and food services was informal, the highest of any industry sector group except agriculture, forestry, and fishing. In many countries, these services are often, but not always, clustered in artisanal industrial areas in large cities or at important transport junctions in the national road network. Well-known examples of such clustering include Suame Magazine in Kumasi, Ghana, or Jua Kali Thika in Nairobi metropolitan area, Kenya.[6] These services tend to be used by lower-income vehicle owners generally, and the minibus taxi industry in cities, or man-and-his-truck style operations for freight, in particular. These types of operations offer consumers inexpensive services because of the low cost of labor and lack of debt burden associated with capital investment (and, often, formal rent). They are important sources of labor growth for rapidly urbanizing areas and for semi-skilled and skilled laborers, as well as entrepreneurial microenterprises (McCormick 1999). In addition, in cities where motorization is increasing at a faster rate than the formal automobile aftermarket service sector, artisanal mechanics fill a critical niche (Elguera et al. 2020). Skills are developed not through formal training but through apprenticeship and on-the-job learning.

There is vibrant academic literature on informal sector industrial clusters in low- and middle-income country settings, too numerous to review here. Much of the literature focuses on explaining the structure of the sector and how it operates (McCormick 1999; Yaw Obeng 2002), how to professionalize it (Iddrisu, Mano, and Sonobe 2011; Elguera et al. 2020), or how to improve its productivity and manage innovation (Kawooya 2014).

Notwithstanding their advantages in meeting demand for services in income-constrained environments, small-scale, informal preventive maintenance and repair operations are associated with a number of challenging problems. They have notoriously poor hazardous waste control (Rodríguez, Carriel, and Gavilanes 2012; Oloruntoba and Ogunbunmi 2020) and occupational health practices (Monney et al. 2014; Amfo-Otu 2016). And the very informality of the sector has made it challenging to professionalize and make more productive (McCormick 1999; Yaw Obeng 2002; Iddrisu, Mano, and Sonobe 2011; Kawooya 2014).

In developed regions, too, like the United States and the EU, the automotive repair and service sector is bifurcated between large operations owned or affiliated with OEMs and small, independent businesses characterized as small and medium enterprises (SMEs), even if these latter are "formal" rather than informal. Even so, there appears to be consensus among industry analysts that in the coming few years this sector is about to undergo a period of rapid and substantial change, driven by disruptions associated with digital technology (Deloitte China 2013; Kempf et al. 2018; Quantalyse and Schönenberger Advisory Services 2019). Change resulting from this disruption would likely include consolidation among parts distributors, aggressive expansion of OEMs into aftermarket activities, digitization of channels and interfaces, access to car-generated data, increasing influence of (digital) intermediaries, greater price transparency, and greater diversity of supply for

6 Jua Kali is Swahili for "under the hot sun" and is used to describe many different types of street-based businesses.

customers in the near term. Analysts also point to the electrification of drivetrains, the emergence of Mobility as a Service (MaaS), and autonomous driving as additional disruptive factors driving industry changes in the longer run.

These trends signal particularly significant challenges for the automotive preventive maintenance and repair sectors in low- and middle-income countries. First, the technologies that are increasingly important to improve the safety and environmental performance of ICE-powered vehicles are getting more complex, requiring increasingly comprehensive and frequent knowledge transfer than a traditional system of apprenticeship can provide. That is, the sophistication of the technologies frequently outstrips the knowledge of the "master" in the master-apprentice relationship. In the conventional Jua Kali culture, this can produce two harmful responses. First, technicians may simply deactivate or disengage those technologies that they either do not understand or do not have the skills to service (Mairura and Osoro 2015), and it may cause some providers to exit the market (Akuh and Agyeman 2019). The informal nature of the sector in many countries makes the development and targeting of vocational training challenging. Second, as high-income countries increasingly move to transition their fleets away from ICE vehicles and toward battery electric (and, subsequently, hydrogen) vehicles, more and more of this technology will begin coming into low- and middle-income countries. These technologies will not only require a different skill mix from what is required in the automotive aftermarket sector currently, but also they would likely be less labor intensive. In other words, automotive maintenance will become more digitalized, requiring a different set of skills and lower levels of labor than currently required. How fast this transition happens in low- and middle-income countries is, therefore, a question of importance not only for decarbonization, but also for labor markets.

It is important to highlight that, because these technology transitions are driven by external trends, countries reliant on secondhand vehicles cannot avoid the use of increasingly complex technology, even if they have no country-specific mandate to use them. This is also the case for imports of secondhand EVs and the required charging infrastructure. As a consequence, the maintenance industry in both ecosystems needs to be capacitated to manage them. The long-term solution is to foster development of the human capital of the automotive repair industry. Particular attention should be paid to the low-end licensed mechanics' shops that can vie competitively with—and absorb labor from—the informal firms, with services that may be more expensive than the cut-rate prices offered by the informal sector, but still affordable for most vehicle owners and operators, and with reasonable quality controls. Informal firms can also be encouraged to professionalize not only through vocational training but also training for effective marketing, management, and accounting, as well as use of enhanced IT platforms (Iddrisu, Mano, and Sonobe 2011; Elguera et al. 2020).

At the same time, OEMs with maintenance training facilities or programs should be coaxed through dialogue and perhaps incentives into providing training for the industry as a whole, not just for their own branded dealers. What form this ultimately takes would be determined by the outcome of that dialogue. For example, the dialogue could result in PPP models to develop for-profit training centers. The content of such engagement could include not only curriculum development and facilitate trainings, but also the regulatory, permitting, and credentialing structure necessary for a modern repair industry.

Oversight and quality assurance of vehicle parts production, acquisition, and distribution

In many developing countries, the automotive after-sales industry has become a critical factor not only in maintaining in-use vehicle performance, but also promoting new vehicle sales; if sound after-sales services are provided, buyers are potentially more inclined to purchase new vehicles. As the automotive market matures, the potential of vehicle-part counterfeiters to tap into various business opportunities and challenges of counterfeit vehicle parts prevailing in the market have gradually emerged.

From the demand side, in many parts of the developing world, such as Africa and parts of Asia, the majority of the domestic vehicle fleet is secondhand and comparatively old even when they were imported, so they degrade faster, increasing the demand for and frequency of repairs and maintenance. From the supply side, automotive business in the world is paying more and more attention to aftermarket services which are considered to be important for enhancing customer satisfaction and brand loyalty. In some markets, such as China, the spare parts business is projected to be a core part of revenue source growth for OEMs (Deloitte China 2013).

Unfortunately, the lucrativeness of the motor vehicle parts supply business is such that it has attracted the attention of counterfeiters, who supply fraudulent parts that are often designed to look like the real thing. Because counterfeit spare parts may compromise on quality of input materials or production standards, they may play a role in traffic crashes (Peresson 2019) and they can also lead to failure of tailpipe emissions control, not to mention vehicle degradation. For these reasons, it is important for countries adopting an MM posture to design and implement the regulatory framework to address the outstanding issues in the spare parts supply chain and create a better business environment to enable legitimate parts suppliers and distributors to survive, compete, and prosper.

The counterfeit spare parts phenomenon has supply, demand, and market function dimensions to it. On the supply side, counterfeit networks are extensive, emanating out of parts of Asia, Russia, and Latin America. On the demand side, vehicle owners in developing countries tend to be extremely price sensitive when choosing spare parts. For example, a survey in Myanmar, an emerging market with a large used-vehicle stock, found that the quality of the product and service for vehicle owners seeking repairs usually ranks second and third, respectively, among consumers' concerns after price. Most Burmese car owners have little knowledge of brands and products, and usually request the product with reference to the price, not the brand. It was also observed that consumers will choose spare parts depending on their car type, used or new, when there is a high price difference between branded and counterfeit spare parts. This relationship was found to vary, however, where foreknowledge of the period of usage was known and judged to be long: the longer the spare part is expected to be used, the more likely the consumer will request and invest in a branded product. Mediating these supply and demand pressures are the mechanisms of the "gray" market. Some genuine auto parts are diverted from formal distribution channels and can be sold in circuits unauthorized by local legislation or not controlled by the brand owner.

Programs to address parts counterfeiting will involve cooperation between government and industry and should focus on both corporate and security-based measures, according to industry experts.

On the corporate side, four factors are key to effective reduction of counterfeiting: product differentiation, which limits ease in counterfeiting; stakeholder engagement to ensure that participants along the supply chain can identify genuine from counterfeit parts; consumer (end user) involvement, to educate end users on the benefits and true life cycle costs of quality parts use; and promotion of changes through brand identification. On the security side, products should adapt techniques of serialization/traceability, anti-counterfeiting authentication technologies, and tamper evidence. In many developing countries, the use of these techniques generally requires strong public efforts to make them well known.

Oversight and quality assurance of vehicle body construction and modification

A key issue for vehicle safety standards is adherence to regulatory standards pertaining to vehicle body structure and modifications. Structural changes and modifications can compromise the technical performance of the vehicle in terms of both crashworthiness and roadworthiness performance. Compliance with vehicle body standards and modifications apply to all categories of vehicles but are particularly important for high-occupancy vehicles (transit vehicles, such as minibuses) and heavy goods vehicles, where potential for modifications to adversely affect on-road stability is greater and potential damage caused in the event of crashes is greater than with LDVs.

Even in industrialized countries with substantial motor vehicle manufacturing and formal industries, there are numerous points in a vehicle's life at which body construction or modification oversight is important. HDVs are often manufactured by more than one company. Chassis manufacturers may build a structure that includes the engine, powertrain, suspension, brakes, steering system, and some related systems. For goods vehicles, chassis manufacturers may also build the cabin housing the operator, while bus chassis manufacture usually does not include any body element. (See examples of typical truck chassis in Image 4.2, and bus chassis in image Image 4.4.) A different manufacturer would be responsible for constructing the body, which, in the case of buses and coaches, means ensuring the safety of the passenger compartment. Chassis manufacturers then would have primary responsibility over some performance standards, like emissions, braking, and steering. The body manufacturer has responsibility over elements such as seat anchorages, safety belts, roll-over resistance in buses, lights, and noise, and also generally has final responsibility for a vehicle's overall compliance with standards. However, the distribution of responsibilities can vary, so should be understood case by case. Broadly, however, the regulatory system needs to function to ensure that chassis manufacturers provide all the necessary specifications to the downstream body manufacturer, and the downstream manufacturer conforms both to the requirements of the specification and to broader health, safety, and environmental regulations.

Image 4.2. Example of Single-Unit Truck Cab and Chassis (Fiat Ducato from AL-KO)

Source: mahertruckcenter.com

Image 4.3. Example of Single-Unit Truck Cab and Chassis (Chevrolet 3500 Crew Cab)

Source: mahertruckcenter.com

Image 4.4. Example of Bus Chassis (Mercedes-Benz OF1721)

Source: https://www.mercedes-benz-bus.com/es_AR/models/of1721.html

In addition to assuring quality at the point of body construction over imported chassis for HDVs, vehicle body construction oversight systems also need to be able to monitor other processes of vehicle modification that may impact HDVs and LDVs during their lifetimes. Examples of such lifetime modifications might include retrofit for an alternative fuel source (such as adding a CNG or LPG fuel delivery system), installation of wheelchair ramps or other facilities for disabled drivers or passengers, modification to change the way a vehicle is used, alteration of trucks for special purposes, or other changes that may be for leisure or hobby purposes.

In developing country contexts, many other vehicle modifications are often undertaken in order to adapt vehicles originally built for developed country markets to the conditions of developing countries (a process often referred to as "tropicalization"), in addition to the various reasons that vehicles may be modified as discussed above. In many low- and middle-income countries, these modifications are frequently carried out by informal sector firms, with little to no regulatory oversight. A 2013 study of vehicle alterations carried out at the Suame Magazine industrial cluster in Kumasi, Ghana, categorized the types of vehicle alterations that were observed to be regularly performed as part of the tropicalization process (Amedorme and Agbezudor 2013) and identified the following processes:

- Suspension system (leaf spring) alteration (to accommodate vehicles to irregular road surfaces)
- Chassis extension or wheelbase alteration
- Conversion of gasoline injection to carburetor system
- Propeller shaft extension
- Increase in vehicle capacity so as to carry more passengers or goods, including alteration of seating configuration
- Radiator change and thermostat removal
- Complete conversion of one vehicle type to another

- Conversion of passenger van to commercial vehicle
- Building or mounting of bodies on naked chassis
- Conversion of automatic transmission to manual transmission
- Changing of motorcycle to tricycle
- Changing of right-hand drive to left-hand drive vehicle
- Conversion of transistorized ignition system to the coil ignition system
- Conversion of one-door car to multiple-door car
- Various structural cosmetic changes, such as modifying of body styles, fixing of glasses, painting or spraying works, colored head lamp, and tinted glass
- Conversion of gasoline engine vehicle to gas (LPG) engine vehicle or vice versa.

Another study has documented the modification of trucks in West Africa by doubling or trebling their fuel tank capacity to facilitate illegal cross-border smuggling of fuels from Nigeria to nearby countries (Aliyou, Houssou, and Attisso 2013).

An earlier Ghanaian study of HDV modifications in particular catalogued the potential unintended consequences of these kinds of modifications (Adedamola 2009). These include safety hazards from reduced strength of vehicle structure,[7] overloading of engines because of additional weight (in turn increasing fuel consumption/CO_2 emissions, and premature wear of vehicle body due to vibration), disabling of rear lighting system because cables of appropriate length cannot be found, weakening of the braking system (both because of inappropriate cable lengths and use of break hoses incompatible with the pressure required), weaknesses in load support system because of incompatibility of individual leaves in the leaf spring assembly and poor welding/joining practice, increased chance of vehicle overturning because of elevated center of gravity, increased chance of accidents because turning radii are expanded beyond safe practice for local road design, and increased weight. In short, these modifications often alter the carefully engineered relationship among Gross Vehicle Weight Rating, engine size and power, braking, and load support, with little understanding of the road safety effects of these changes.[8]

Responsibility for ensuring that vehicles comply with the body structure and modification standards ultimately rests on the vehicle owner or fleet owners in the case of passenger vehicles. However, because of industry fragmentation, it is important to have a designated agency responsible for accrediting auto body builders in the countries. This agency would also be responsible for authorizing approvals for vehicle designs for specific vehicle types and ensuring that designs comply with national standards as well as manufacturer-specific technical criteria. It is critical for this authorizing agency to work closely with the lead agency on road safety to ensure that high-risk modifications are appropriately scrutinized prior to providing clearance. Typically, such standards have provisions for making exceptions if the vehicle is intended for disabled drivers and requires additional modification. Similarly, special-use vehicles, such as school buses and ambulances, may have additional criteria for consideration.

7 The materials used at Suame Magazine were frequently found to be defective, having cracks, deformations, and corrosion. Thus, they “can no longer withstand the loads on them when the vehicle is in operation.” Structural weakness from defective materials are exacerbated by weak joining practices.

8 To be sure, another set of “tropicalization” measures frequently identified does not involve vehicle body modification per se, but rather complete or partial dismantling of emissions control and vehicle safety systems when the vehicle is imported from North America, the EU, or Japan into low- and middle-income countries. This can include removal of diesel particulate filters or catalytic converters (which often have high resale value in certain markets), disabling through electronic or mechanical means exhaust gas recirculation, electronic spoofing of NOx sensors for selective catalytic reduction (or the system’s removal entirely), removal of airbags, or, as Amedorme and Agbezudor (2013) observed, replacement of fuel injection with carburetion systems. Effective first-use certification, in-use PTI, and on-road enforcement programs can help get such alterations under control.

Establishment and implementation of a standardized approach to vehicle body construction and modification quality assurance would involve four key elements:

- *Assignment of primary responsibility for overseeing vehicle body assembly, modification, and accreditation.* It is critical for an authority to be assigned responsibility to oversee the industry, either through the establishment of standards and accreditation itself, or negotiating with industry to ensure that it is developing such standards and accreditation responsibilities.

- *In-depth crash investigation of high-occupancy vehicles.* Given that the crash dynamics and applicable vehicle safety standards are quite different for passenger vehicles, it will be important for the road safety agency to undertake in-depth crash investigation for every high-casualty crash. The focus of the investigation should be identifying vehicle-related factors that not only contributed to the crash but to the overall injury outcome (for example, integrity of the overall body cage, interior components responsible for blunt impact injuries, or any other factor that may have increased the severity of the crash). Having an overall assessment of risk factors associated with passenger vehicles will help in guiding the standards and approval process for design modifications.

- *Engagement with the auto body builders.* The key for compliance with body design standards would lie in having consensus among the stakeholders that this would be uniformly enforced and economically viable. As fleet modifications come at a cost to the operators, there should be financial disincentives toward investing in the modification of existing passenger vehicles at the time of operation as well as during use. The role of visible enforcement in penalizing the offending parties must be appreciated to ensure a high level of compliance.

- *Public awareness on safety of passenger vehicles.* While the structural modifications are mostly driven by demand for increased capacity and travel needs, the regulatory framework in supplying the safety features must be advocated alongside demand concerns.

End-of-Life Vehicle management

As discussed in chapter 3, as one of the core concepts of MM, developing countries should consider developing a formal End-of-Life Vehicles (ELVs) management program for five key reasons, namely the volume of obsolete vehicles, the economic and job creation potential of ELV programs, the need to close a blind spot in worldwide efforts to create a circular economy, the need to manage scarce landfill space, and the need to improve management of hazardous wastes.

In regions of the developed world where annual registration of vehicles is required (the EU, Japan, Australia, the United States, and Canada), data show that between 3 percent and 9 percent of vehicles fall out of use on an annual basis. Though the data are imprecise, it seems that, on average, about 60 percent of these vehicles are discarded domestically as ELVs, while the remaining 40 percent are exported as secondhand vehicles to markets primarily in developing countries. Eventually, even those exported vehicles will become ELVs in the countries they are exported to.

In recipient countries in the developing world, on the other hand, virtually 100 percent of the vehicles present in the country will one day be ELVs. The MM pilot project in Ethiopia and Kenya, for example, estimated that by 2030, more than 20,000 cars and 25,000 motorcycles in Ethiopia, and more than 160,000 cars and almost 220,000 motorcycles in Kenya, will be scrapped each year; that number is expected to increase exponentially. Developing mechanisms for sustainable management of those scrapped vehicles in developing countries, therefore, is critically important for long-term green growth.

Worldwide, management of ELVs has been driven by two primary concerns, both of which are relevant for developing countries: the need to manage hazardous substances and the need to reduce landfill space, especially for countries such as Japan and the Republic of Korea, which have space constraints. In addition, for developing countries, ELV management can provide potential labor creation and/or labor formalization opportunities, particularly for newly urbanized, low-income workers.

When mandated by legislation or regulation, the ELV management chain in developed countries is typically structured around two phases: dismantling and shredding. ELVs are essentially dismantled manually through extraction of hazardous wastes—fluids, fuels, and batteries—and then high-value items with after-market value, such as engines, tires, and rims, are separated and gathered for resale. The remains of the vehicles are then shredded in industrial shredders. A series of post-shredder treatments (PSTs) are then applied to Automobile Shredding Residue (ASR): heavy and light materials are sorted through an air classifier, with the light ASR portion set aside usually for landfill. The remaining ASR material is passed through a magnetic drum to separate out ferrous metals, then a non-ferrous metal separator, and the remaining, heavy ASR is then also usually put to landfill. Over time, the objective of these mandated ELV management systems is to ultimately increase the proportion of the vehicle, by weight, that avoids going to landfill, either by being recycled or being used in thermal conversion processes.

In many developing country contexts, ELV populations may be currently too low, and the cost of industrial shredders too high, to make a compelling case for establishment of mechanized ELV management processes at the current time. However, with motorization rates increasing and potential successful application of other aspects of an MM program, a plan to evolve a mature ELV management program should be considered, as early as possible, even when vehicle penetration rates are quite low, as the lesson from the Republic of Korea shows (see Box 4.3.).

Box 4.3. The Republic of Korea's End-of-Life Vehicles Management

The Republic of Korea has had particularly progressive policies with respect to End-of-Life Vehicles (ELVs) for several decades. The Korean Automobile Dismantlement and Recycling Association (KADRA) was created in 1989 through legislation, as a partnership among car-scrapping businesses and a nonprofit corporation for recycling car parts, the Korean Automobile Recycling Cooperative (KARCO). This was a particularly forward-looking policy, since the Republic of Korea's rate of motorization at the time was only about 81 cars per 1,000 persons (World Bank calculations based on Senbil, Zhang, and Fujiwara 2007).

KADRA's role was to function as a think tank and advocacy organization in the following areas:

- Suggest improvements to automobile regulations and policies:
    - Improve legislation, including vehicle administration law, resource recycling law, waste management law, air environment preservation law
    - Propose policies of automobile disassembling and recycling
- Carry forward the environment-friendly and automobile resource recycling projects:
    - Strengthen the functions of recycling project for automobile resource cycle
    - Convert to green business environment
- Enhance the car scrap and cancellation system:
    - Provide information interface with the Ministry of Land, Transport and Maritime Affairs and Ministry of Environment
    - Carry out information data processing projects and system development
    - Vitalize automobile used parts market
    - Operate the nationally integrated management system for automobile used parts efficiency
    - Establish Integrated Distribution Network and liaison with related organizations
- Function as an association for the car scrappage industry:
    - Foster good practices and prevent illegal activities
    - Work to eradicate unregistered disassembling-recycling contractors

In 2008, the Republic of Korea enacted the Resource Recycling of Electrical and Electronic Equipment and Vehicles Act. This act established an Eco-Assurance System, which, among other things, oversees environmentally sound management of waste, including achievement of a mandated recycling rate, compliance with methods for recycling, obligation for collection by distributor, registration of ELV recycling businesses, and professionalized management of processes. The recycling rate was mandated at 95 percent by 2015. Responsibility for compliance with both guidance and ensuring the attainment of recycling rates was placed with all involved in the chain, including dismantlers, shredders, ASR recyclers, and refrigerant gas processors. In keeping with prior Korean and increased international focus on Extended Producer Responsibility (EPR), to ensure adequate measures for waste prevention at design, automobile manufacturers and importers also have responsibility for compliance; if ELV recycling costs exceed the prices that can be recouped through market mechanisms, the manufacturer/importer bears the additional cost. Over time, these costs would be capitalized into the price of the vehicles. In addition, manufacturers and importers then have a stake in trying to develop and support downstream markets.

In general, developing an ELV management program might involve the following steps:

- Establish an association of car scrappers and work to professionalize the industry. In many developing country contexts, vehicle scrappage is almost exclusively the province of the informal sector.
- Develop standard policies for management of hazardous materials from ELVs, especially for batteries, chlorofluorocarbons (CFCs)/hydrochlorofluorocarbons (HCFCs), and automotive fluids.
- Standardize approaches to vehicle dismantlement and look for ways to extend dismantlement beyond current practice, particularly looking to develop markets that do not currently exist.
- Begin to invest in mechanized vehicle shredding and post-shredding equipment initially in major metropolitan areas with populations greater than 1 million people. Such investment should seek to safeguard and enhance labor-intensive vehicle dismantlement as the primary focus of ELV treatment. (that is, shredding should not supplant other parts of the ELV process).

Change management and public engagement

MM policies and programs impact numerous segments of the population, including public agencies at national and subnational levels; the private sector, which includes vehicle manufacturers and service providers; transport users; and citizens that are exposed to transport externalities, such as air pollution, car crashes, or the more indirect effects on the cost of products and services. It is, therefore, important to identify the relevant stakeholders, understand their role in the design and implementation of MM policies and programs, and define a strategy for stakeholder engagement. Initiatives to improve MM should consider having a designated function specialized and focused on stakeholder and public engagement, outreach, and communication.

Change management and public engagement is particularly crucial in today's social media environment of atomized sources of information for the general public. The rule of thumb is that, in the absence of consistent information about the why and how of changes taking place (changes that affect a large portion of the population), that void will be filled with home-grown explanations, with people imagining nefarious motives that can quickly become accepted as fact. The best defense against rumor and conspiracy theory as the source of people's information about an MM program is having a robust program of public engagement in the context of change management.

Public engagement in policy development can be done through several methods. Some that are commonly used in transport policy include the establishment of advisory boards, comprised of representatives of the public at large or of special interest groups, which are typically selected by project managers and government authorities; focus groups and workshops, which are a means of public consultation with the objective of gathering information on issues of concern and receiving feedback to ensure the policy or program addresses needs or is politically feasible; and planning charrettes, which involve stakeholders in the definition of elements of the policy and program (Quick and Zhao 2011) and, perhaps most critical of all, social media engagement strategies.

Public engagement can serve multiple purposes, including the provision of information, improving understanding of the problem to address or barriers to implementation, generating new ideas for solutions, and building consensus around solutions. The public engagement strategy and the select engagement methods should be appropriate to achieve the objectives of engagement and reflect the practices of the local culture. This will help build trust in the process and legitimize the resulting policy and programs.

Strengthen Market Mechanisms for Funding and Managing Vehicle Stock Growth and Turnover

MM cannot be conceived of solely as an initiative of government, or a question of governance of motor vehicle stocks. There also needs to be proactive attention paid to the incentives and financing environment in which motor vehicle purchases—both fleets and individual vehicles—occur. Experience in high-income countries suggests that access to credit and varied (and competing) models of vehicle ownership and availability are key. In a sense, these are the "lubricants" of the motor vehicle markets that can facilitate—or gum up—changes toward cleaner, more fuel-efficient, and safer vehicle stocks. Depending on where a country is along its motorization curve (see Figure 2.1), it may need to emphasize vehicle stock turnover more than growth to meet its development objectives.

In the case of low- and middle-income countries, three fundamental and tightly interwoven conditions create challenges for vehicle stock greening and turnover: low purchasing power of many potential buyers, constrained availability of formal credit, and lack of diversity of vehicle availability models.

Low purchasing power. Low purchasing power (that is, lack of creditworthiness) is a fact of life for many vehicle owners and operators in low- and middle-income countries. On the commercial side, it tends to be driven by the pervasiveness of a man-and-his-bus/man-and-his-truck structure that tends to dominate freight and passenger transport operations. Commercial vehicle operations are often carried out by small-scale operators who lack the capacity to accumulate capital to facilitate investments in new vehicle stock (Behrens, McCormick, and Mfinanga 2016). On the own-account/household transport side, low purchasing power is driven not only by low household incomes generally, but also by the low quality of service and personal security concerns associated with public transport services, which drive households' desire to own a vehicle at income levels where their household resources would arguably be better spent on other uses.

Lack of availability of credit. Low purchasing power tends to lead to constrained availability of credit for vehicle purchases generally. For vehicles intended for private use, in most low- and middle-income countries, comparatively few households usually have the ability to access credit on the formal market for the purpose of acquisition of a vehicle. For vehicles intended for commercial use, as already noted, much of the commerce occurs on a cash basis, often with no long-term buildup of capital reserves. This has historically meant that it is difficult to facilitate credit because credit markets assign substantial risk to this hyper-cash ecosystem. In many low- and middle-income countries, household use of LDVs often blurs the line between purely private and purely commercial operation. Household vehicles are often acquired with the intent of supplementing household income with informal commercial service provision.

Lack of diversity of vehicle availability models. "Vehicle availability" refers to the mechanism by which households and firms get access to the vehicles they operate for either commercial or own-account purposes. In many low- and middle-income countries, the only option for getting access to a vehicle is to purchase one outright (often requiring purchasers to scrape together money to buy one outright with cash, utilizing informal finance networks, such as loans from family, friends, and acquaintances, because of the aforementioned unavailability of formal credit opportunities). This creates a lumpy cash-flow environment in which capex concerns dominate opex/Total Cost of Ownership (TCO) and establishes a perverse incentive toward preferring the vehicle with the cheapest initial purchase price. If credit were more widely available, then leasing options would be as well, which could elevate the role of TCO in vehicle acquisition decisions.

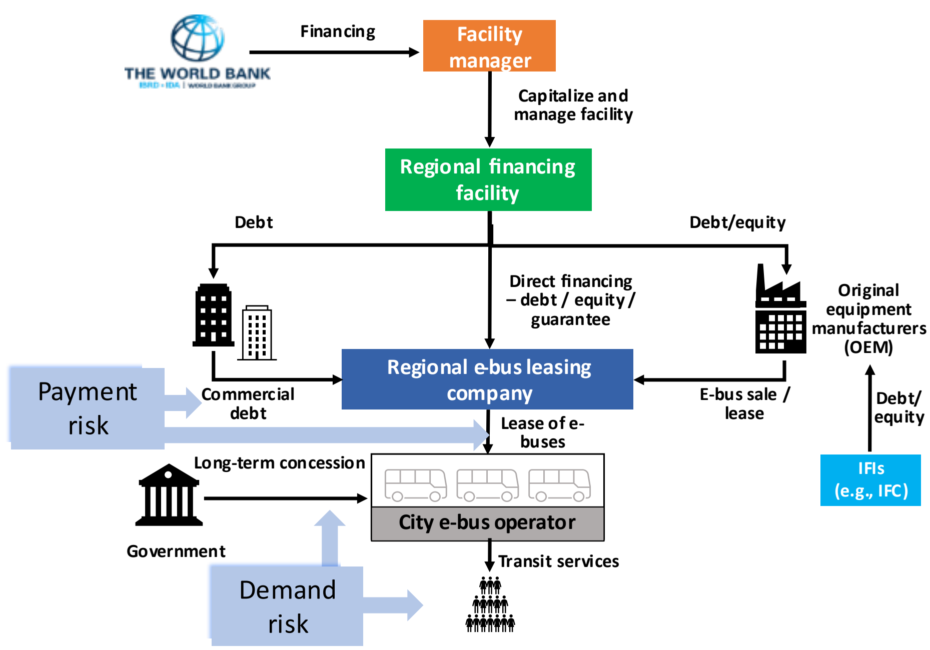
These challenges are daunting and long-standing, and do not have simple solutions. Recent work in both the World Bank and elsewhere, focused on specific subsectors (like bus electrification or taxi fleet renewal), share some overarching principles that warrant highlighting here. Whether these principles are universalizable for all transport subsectors, and how to operationalize them in complex low- and middle-income country environments, remain critical questions. These principles can be summarized as follows:

Where possible, aggregate demand for vehicles from individuals to fleets. Such aggregation of demand does not necessarily mean consolidating traditional operators per se (though this could also be part of the solution), but rather fostering the creation of third-party ownership models, whereby capital investment does not need to be made by the operator. Examples of such aggregation vary by subsector and might involve development of vehicle leasing companies for taxicab operation, bus vehicle holding and maintenance companies integrated into public transport operations, or even conventional car-sharing operations. The viability of the specific scheme will depend on the subsector and country context. That said, in low- and middle-income country markets where cartelization is already a big challenge (for example, Teravaninthorn and Raballand 2009), encouraging third-party ownership models in a way that does not create new or exacerbate existing monopolistic practices encouraging rent-seeking behavior is an inherent challenge.

Eliminate capex burden of individual operators. Encouraging the establishment of third-party vehicle ownership models can be accompanied by efforts to encourage operator participation to reduce their capex burden. De facto, many informal commercial operations already do this, where vehicles are owned by well-connected investors who rent vehicles on a daily or weekly basis to entrepreneur operators to eke out a living. But maintenance and capital accrual is often left out of this informal arrangement. Formalizing these arrangements can increase opportunities for credit, allow for more systematic accrual of capital to compensate for depreciation, improved maintenance practices (including, arguably, better compliance with PTI requirements), and better regulation of the vehicle availability arrangement.

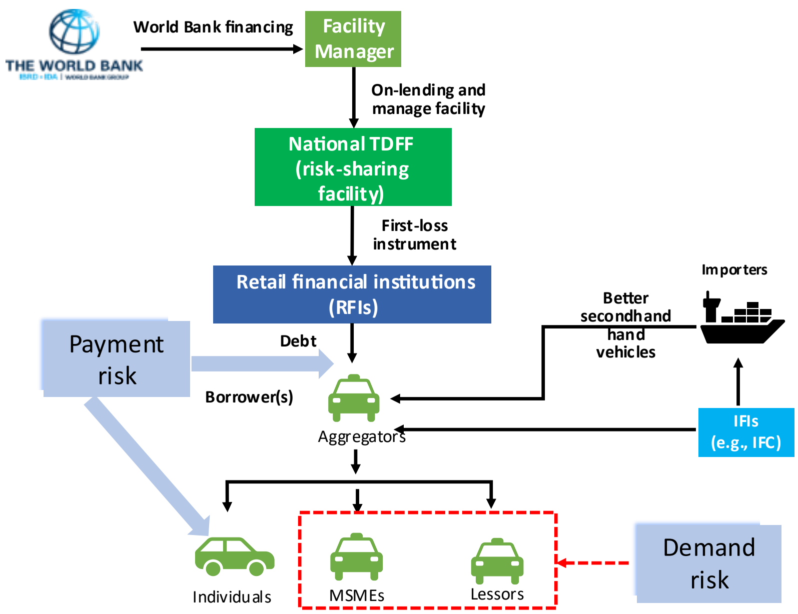
Isolate payment risks from demand risks. Aggregating demand for vehicles and using that process to try to eliminate capex burden from individual operators will not in and of itself alter fundamental challenges to funding of improvement in vehicle stocks resulting from low purchasing power. But these measures can help isolate specific risks that could then be better assigned and targeted for risk mitigation among private and public actors. For example, the recently proposed structure for development of regional financing facilities to address decarbonization in the transport sector de facto function on this principle—that of separating payment from demand risks. We show two such examples in Figure 4.7 and Figure 4.8. Again, the examples shown are not meant to minimize the challenges posed by low purchasing power of ultimate end users or suggest that this kind of solution is workable in every context, but rather they are meant to demonstrate conceptual applications of risk allocation that might play a role in helping to facilitate finance for fleet expansion or turnover.

Figure 4.7. Stylized Structure of Funds Flows for Scale-Up Investments to Facilitate Transition to E-Buses



Source: Benitez and Bisbey 2021.

Figure 4.8. Stylized Structure of Funds Flows to Facilitate Replacement of Poor-Quality with Better-Quality Vehicles in Light-Duty Commercial Fleets



Source: Benitez and Bisbey 2021.

Explicit separation and allocation of payment and demand risks creates opportunities for provision of explicit and enumerated subsidies at specific points in the overall process (delineated by blue arrows).

Create stable, long-term, verifiable flows that can be securitized. An outcome of the above strategies can be that the resulting structure of flow of funds can help facilitate interest from long-term investors through the creation of stable, long-term, verifiable flows that can be assigned risk and securitized. While the cases considered typically consider "new" or untested technologies, such as e-mobility or hydrogen infrastructure, the model could be adapted to any kind of incentive focus which a DPOS might envision, including, for example, used ICE vehicles of a certain size limitation or certified fuel economy standard.

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5. Toward a Strategy to Operationalize Motorization Management in Low- and Middle-Income Countries

This report has laid out a framework for addressing comprehensively the management of national motor vehicle stocks in low- and middle-income countries, to improve prospects to decarbonize the road transport sector, improve the performance of the vehicle pillar within a safe systems approach to road safety, and reduce mobile source contributions to air pollution. As has also been highlighted throughout this report, the kinds of measures discussed here are potentially disruptive—to formal and informal labor markets, to national fiscal systems, and to entrenched interests in the automotive sector. Successful implementation, therefore, will depend on international collaboration and support. This chapter discusses key actions that the international community can undertake in concert with low- and middle-income countries to increase the chances that such a program will be successful.

We identify four key ways that the international community, broadly, can assist low- and middle-income countries in establishing Motorization Management (MM) programs: strengthening the international framework for the trade of secondhand vehicles; taking early action to support diagnostics of vehicle stock dynamics in low- and middle-income countries and policy adoption vis-à-vis improving vehicle outcomes; supporting investments in MM systems in low- and middle-income countries; and supporting the development of permanent, regional observatories to undertake continuous fleet analysis. These are discussed in turn.

International Framework for Trade of Secondhand Vehicles

There is a critical need to strengthen the international framework for trade of used/secondhand vehicles. Five key areas in particular need to be strengthened.

Establishing rules for acceptable practice in the export of used vehicles. The key principle around which consensus seems to be emerging is that vehicles that cannot be demonstrated to be roadworthy in the country of export should not be allowed to be exported to any other country, particularly low- and middle-income countries. At present, some unknown proportion of vehicles exported from North America, the European Union (EU), and Japan should really be classified as End-of-Life Vehicles (ELVs). A study by the Dutch government of vehicles queuing for export to Africa at the Port of Rotterdam found that, in a random inspection of vehicles, 54 percent of the inspected vehicles would fail a roadworthiness test if subjected to a standard periodic technical inspection (PTI) (Netherlands ILT 2020). As ELVs, their export should be governed under the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposals.[1] Ensuring that all vehicles being exported do have a valid roadworthiness certificate or inspection certificate from PTI or something equivalent at the time of export would thus help to distinguish roadworthy motor vehicles from hazardous waste subject to Basel Convention controls. It would also help to balance the cost burden of oversight of internationally traded used vehicles between the recipient and the exporting country.

1 Substances prevalent in ELVs subject to control of the Basel Convention include lead-acid batteries (drained or undrained), battery fluid, lithium batteries, tires, mercury switches, oils, fuels, antifreeze, brake pads containing asbestos, non-deployed airbags, electrical/electronic assemblies, among others. In the absence of roadworthiness certificates, these would be considered waste products.

Establishing data architecture and protocols to facilitate exchange of vehicle history information among countries. The motor vehicle information management systems (MVIMSes) of governments that are the main source of vehicle imports in low- and middle-income countries—the United States, EU, Japan, etc.—contain substantial amounts of information about individual vehicle histories, but this historical data usually does not accompany the vehicle when it is exported to developing countries. This data blindness harms both buyers and regulators in the recipient countries—for example, if there is accident or recall history about which they should be made aware—but it also harms interests in the exporting country. For example, notwithstanding the EU requirement for certified destruction of ELVs (2000/53/EC), Directorate-General for Environment estimates that about 35 percent of ELVs across the EU go missing each year. Establishing appropriate data protocols as part of the process of used vehicle export and import would help to minimize what appears to be missing ELVs.

Strengthening trade accounting frameworks to enable tracking of trade in secondhand goods, including vehicles and vehicle parts. In its October 2020 publication, the United Nations Environment Programme (UNEP) published the results of its efforts to develop a picture of used vehicle data flows, reconstructed from painstaking and detailed examination of export and import data of individual countries (UNEP 2020). This effort only produced overall flow numbers for light-duty vehicles (LDVs); heavy duty vehicles (HDVs) were not included in this first round, nor was detailed information about the kinds of vehicles traded. Prior to this, the most complete picture of international flows of secondhand vehicles was data from 2009 (Fuse, Kosaka, and Kashima 2009), which was estimated by triangulating different trade data sources with an estimate of missing ELVs. One of the reasons for the dearth of information about trade flows of secondhand vehicles is related to coverage and detail of the available databases. Fuse, Kosaka, and Kashima (2009), for example, noted that the United Nations' (UN's) harmonized six-digit classification system in the trade database does not distinguish between new and used vehicles. There were private databases available at the time the article was written that provided sufficient trade detail to distinguish between new and used vehicles, but these covered only subsets of countries, so substantial interpolation was necessary. Strengthening UN trade data to make trade in secondhand vehicles observable in non-proprietary trade data, therefore, is an important objective for any international framework for trade in secondhand vehicles.

Strengthening regional frameworks for harmonizing standards and actions. Many, if not most, low- and middle-income countries do not have vehicle markets of sufficient size to substantially influence international flows of vehicles. For this reason, taking actions such as adoption of harmonized vehicle and fuel standards as regional trading blocs makes sense. (See Box 5.1. for a recent example.) The international community in general, and the UN system in particular, should support actions taken at the regional level.

Box 5.1. ECOWAS Regional Trade Bloc Introduces Harmonized Import Vehicle and Fuel Standards

In February 2020, 15 West African countries cooperating in the Economic Commission of West African States (ECOWAS) adopted harmonized fuels and vehicle standards. This decision will have major impacts on the import of used vehicles in West Africa, as currently most used vehicles being imported do not meet these standards. This is the first harmonized used vehicles policy at a regional level in Africa and includes:

- As of January 1, 2021, all used light-duty vehicles must meet Euro 4 vehicle emission standards.
- Each country will set an age standard with a maximum of five years old for light-duty vehicles and

10 years old for heavy-duty vehicles, to be implemented within 10 years.
Similar initiatives are being considered in East and Southern Africa.

Sources: UNEP 2020; Netherlands ILT 2020.
For more information: https://www.unep.org/news-and-stories/story/west-african-ministers-adopt-cleaner-fuels-and-vehicles-standards.

Strengthening protocols for materials recovery in a globalized circular economy. As noted in chapter 4, many governments of automobile producing countries have developed laws or mandates requiring that vehicle producers recover materials from the vehicles they produce when they become ELVs, in order to minimize the mass of material going into landfills. These governments include the EU (2000/53/EC), Japan (ELV recycling law of 2002), and the Republic of Korea (Resource Recycling Act of 2006). Some US states have enacted similar laws, though the US federal government currently has no requirement for materials recovery from vehicles. Assessments of the success of these programs have shown substantial gaps in compliance, including the abovementioned finding that many vehicles that should be identified as ELV are simply missing (Fergusson 2007). A key need in the establishment of an international framework for trade in secondhand vehicles, therefore, is to clarify the protocols and responsibilities that govern materials recovery to enhance the circular economy.

Diagnostic Studies to Facilitate Adoption of Motorization Management Approaches

A critically important early action for MM is a diagnostic study, for individual countries, or, preferably, for groups of countries which might create harmonized standards for vehicles and fuels as a bloc. The diagnostic should use the best available data to understand the nature of the existing motor vehicle stock (both in terms of composition and vehicle use), recent trends in how the vehicle stock has been growing, inventory policies and other factors that influence that growth, and forecast—as best as existing data will allow—how the stock is expected to grow under a business-as-usual scenario. The diagnostic should also systematically assess the existing institutional framework and capacity for managing the various aspects of motorization discussed in this report, as well as the structure of different parts of the automotive industry, from vehicle acquisition to aftermarket and end-of-life practices in the country. The diagnostic study would then tailor recommendations to the specifics of the country or groups of countries in question. Multilateral development banks (MDBs) and other assistance agencies should seek to support such studies as part of sectoral diagnostics or project pipeline work and use the results to inform country engagement in the sector.

Diagnostic studies would identify an appropriate sequence of actions to be undertaken in a specific context, including establishing a policy development process. This policy development process can be supported by the international development community and might lead to specific measures, such as those outlined in Box 3.1.

Support Low- and Middle-Income Countries' Establishment and Strengthening of Motorization Management Policies and Institutions through Official Development Assistance Resources and Technical Assistance

Diagnostic studies would identify an appropriate sequence of actions to be undertaken in a specific context, and they would also likely identify specific investment needs. Indeed, official development assistance (ODA) to support low- and middle-income countries in establishing MM programs could take the form of both policy-based and investment lending. Investment lending, in turn, could support two different kinds of investments: investments to strengthen government oversight and investments to influence market outcomes. These will be discussed in turn.

Investments to strengthen government oversight

Programmatic investments are capital expenditures needed to effectively create or strengthen the various programs introduced in chapter 4. These might include the following:

MVIMS. This investment would include not only hardware for servers and software for database management and interface, but also all the hardware and software to ensure real-time connectivity from all the geographically dispersed locations in a country that may need to access the system, both wired and wireless. Depending on the ambition and starting point, the investment required for this most basic of enabling measures might be no more than US$100 million.

First-use certification system. This investment would include facilities and equipment to carry out both back-office functions and frontline inspections of vehicles entering a country. Some or most of this investment might come from the private sector under a public-private partnership (PPP) arrangement, but the land to accommodate the facilities would most likely need to be provided by the government, as part of physical planning for customs warehousing associated with the port or dry port. The size of the facilities required would depend on the anticipated number of vehicles imported monthly, the extent to which two-stage certification is used (see discussion under the "Certification/homologation systems" section in chapter 4), and whether exporting countries adopt export standards (see discussion under the "International Framework for Trade of Secondhand Vehicles" section in chapter 5). New Zealand is considered the gold standard for first-use certification systems for new and used vehicle imports. Based on estimated equipment costs mandated under New Zealand's regulations for first-use certification, and assuming importation of 100,000 two-wheelers per year, 100,000 LDVs per year, and 10,000 HDVs per year, we calculate an initial investment need of about US$18 million for equipment, not including costs associated with land acquisition and construction of building the facilities on the roughly 20,000 square meters of space needed. This volume of imports would generate roughly 450 person-years of employment.

PTI. Capital investment required for PTI systems consists of physical infrastructure for carrying out inspections, including land, structures for inspection arena, office buildings, infrastructure for staging areas, inspection equipment, etc. We estimate that to establish a basic program of PTI from scratch to inspect roughly 35,000 LDVs, 20,000 two-wheelers, and 12,000 HDVs per year would require an initial investment of about US$3 million to US$5 million for equipment, not including costs associated with land acquisition and the construction of the facilities on the roughly 12,000 square meters of space needed. This investment could be provided by the public sectors in a conventional public service contract arrangement, or by the private sector, in a PPP arrangement. In the case of the former, the public sector would assume demand risk, while in the latter, the private sector would assume some or all of the risk. This demand risk could be mitigated through various risk mitigation instruments, including the use of guarantees.

On-road enforcement programs. Substantial capital investment is not needed for on-road enforcement programs, but use of instrumentation in on-road enforcement would require acquisition of equipment, potentially including service or operations contracts with the manufacturer or a third party, where local expertise is not available. Existing programs suggest a cost of about US$1 to US$2 per year per vehicle to administer a program of roadside enforcement, remote sensing data collection, compliance and analysis, reporting, and administration.

Development of human capital and sustainability in automotive value chain. Depending on the scope of ambition for a human capital development program for the preventive maintenance and repair industry, vehicle body construction and modification industry, vehicle parts distribution system, and ELV dismantling, training centers with access to the latest equipment and facilities to undertake training may need to be developed. These centers may need to provide ancillary services, such as housing and board for students participating in programs. This type of investment could be mobilized from the private sector in an appropriate PPP and/or licensing arrangement. Capital investment in facilities and vehicle shredders for an ELV program may also be envisioned. Our own estimates suggest capital investment on the order of US$10 million to US$20 million for shredding capacity of 100,000 vehicles per year, plus land and construction costs. Both land and capital could be sourced from the private sector in an appropriate PPP and/or licensing arrangement, but most likely the land required would be linked to a regulated landfill site (or contain a dedicated regulated landfill within it). For this reason, governments would need to be closely involved in the development of ELV management facilities.

In addition to capital investment for all of the above facilities, the programs with which they are associated would also have substantial need for technical support and assistance.

Investments to influence market outcomes

In addition to programmatic investments to establish and maintain the core motorization management government programs, policies developed and implemented under an MM framework might themselves be supported with public resources to try to influence motor vehicle markets. Such resources could take the form of fiscal incentives, direct subsidies, or credit enhancements to influence market decisions vis-à-vis when and what type of vehicles consumers choose to purchase or lease. These market-influencing public investments might also be supported through ODA.

A common approach to using public resources to influence vehicle markets is through the use of Accelerated Vehicle Retirement Programs (AVRPs) to highlight how difficult it is to design these kinds of programs in an economically efficient manner (see Box 3.1). Notwithstanding that challenge, however, the sheer volume of potentially obsolete or stranded rolling stock assets against the magnitude and urgency of the climate challenge may mean that more aggressive use of publicly supported vehicle buyback programs may be inevitable.

The notion of "accelerated" vehicle retirement—essentially paying people to stop using highly polluting or fuel-inefficient motor vehicles—has been around for a long time and has been tried with greater and lesser success in various countries, both high-income countries and low- and middle-income countries. In many of the latter, however, lack of access to credit is a major reason that highly polluting or fuel-inefficient vehicles are used in the first place. Consequently, a policy of accelerated vehicle retirement in these environments needs not only to inject capital to incentivize fleet turnover, but also to help mitigate credit market failures and imperfections. In addition, whereas AVRPs in low- and middle-income countries in the past have targeted specific subsets or fleets of vehicles (for example, bus fleet replacement during public transport reform or restructuring), to have an impact on carbon dioxide (CO_2) emissions from road transport at the magnitude required to achieve carbon neutrality as quickly as possible, use of AVRPs may need to be substantially scaled up. Worldwide experience with AVRPs is highly varied, with subsidy costs ranging from US$240 to US$4,500 per vehicle for LDVs, and from US$830 to US$28,000 per vehicle for HDVs. An independent assessment of the Beijing "Yellow Sticker" vehicle scrappage effort found a benefit to cost ratio of nearly 2.5. More information about experience with AVRPs is summarized in appendix B of this report.

Establishment of Motorization Management Observatories

Supporting the development of permanent, regional observatories to undertake continuous fleet analysis is a fourth key way that international assistance can help low- and middle-income countries develop and maintain consistent MM approaches to policy. Observatories have been used to help promote policy analysis and development in other aspects of road transport for the past two decades, including observatories dedicated to road safety, urban transport, and transport corridors. MM observatories would, ideally, be established for groups of countries. They could be affiliated with one or more university and be funded in creative ways that utilize both public and private sector resources. Regardless of the funding source, though, their success will be predicated on the availability of good quality and timely data provided by the countries participating in the observatory. International support can help advocate for the establishment of such observatories, define the kinds of activities and benchmarks that such observatories would undertake and produce, and help define and harmonize protocols for anonymizing and making available to the observatories data from customs and vehicle registration country databases.

The need for AVRP scale-up, combined with the traditional challenges of finding efficient and effective formulae to make them work, highlights the compelling need for MM observatories, as well as the way the MM needs to function as a system. AVRPs are prone to unintended policy consequences, but the overarching need to cycle inefficient internal combustion engine (ICE) vehicles from the motor vehicle stock, especially in low- and middle-income countries, is undeniable. MM observatories are the institutional backbone that can enable countries and regions to course correct when AVRPs do not function initially as intended, but they can play this role most effectively when the various components of the MM system are functioning and feeding a data ecosystem that paints a clear picture of how the country and region are motorizing. Indeed, MM observatories should play this role for the range of policies and measures designed under an MM framework.

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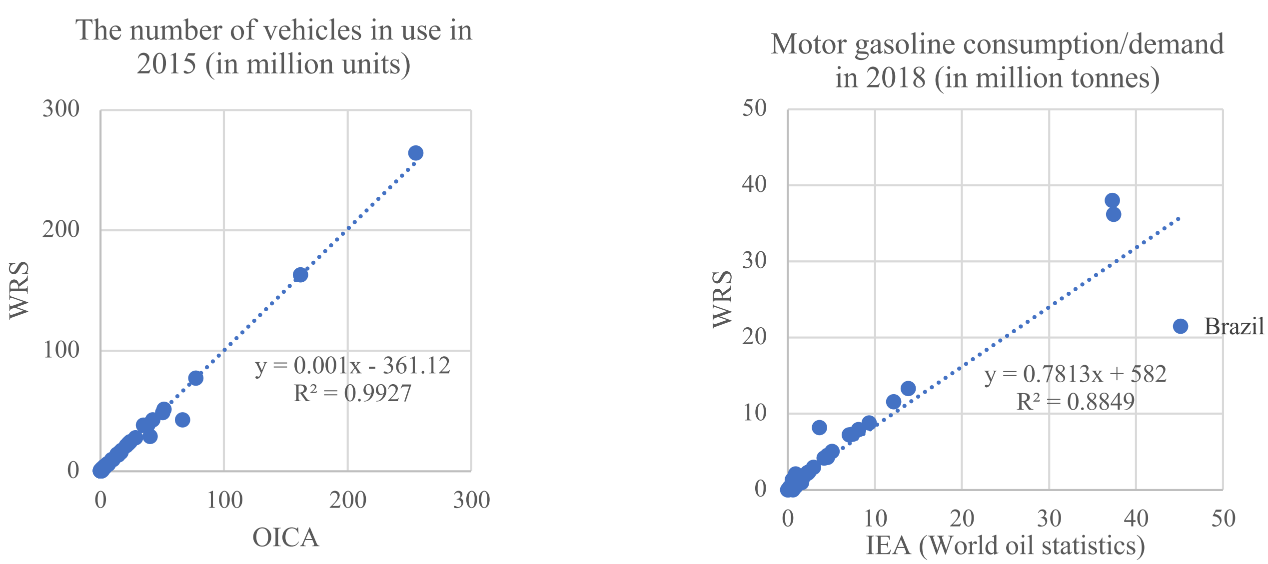
6. Appendices

Appendix A. Comparison of World Road Statistics Motorization Data with Other Sources of Data

To ensure that the World Road Statistics (WRS) data is compatible with other major data sources, the following comparisons were made in the latest years for which data were available:

- Comparison with the International Organization of Motor Vehicles Manufacturers (Organisation Internationale des Constructeurs d'Automobiles; OICA) – vehicles in use
- Comparison with the International Energy Agency (IEA) (World Petroleum Statistics) motor gasoline consumption/demand (as a proxy of kilometer vehicle traveled)

Figure A.1. Comparison of OICA and IEA Data with WRS Data for Two Key Parameters

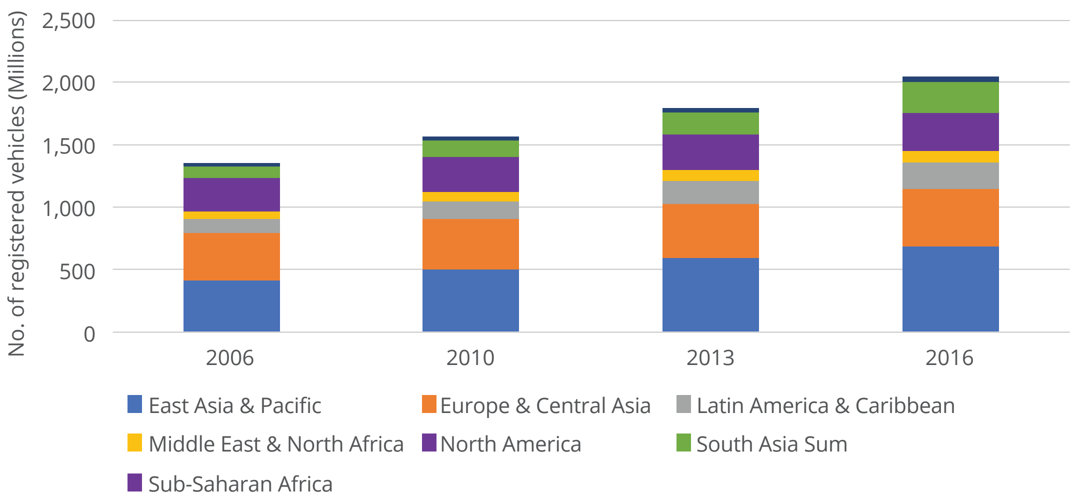


Source: International Organization of Motor Vehicle Manufacturers (OICA) (left) and International Energy Agency (IEA) (right).

Both comparisons show that they are almost identical, except for the difference in motor gasoline consumption/demand in Brazil.

This report uses WRS data because they provide data time series for longer periods and for more countries than the Global Status Report on Road Safety (GSRRS). In the GSRRS, a slightly higher number of vehicles were reported than in the WRS. For example, in 2016, the WRS reported that there were 1.92 million vehicles in 194 countries, while the GSRRS reported that there were 2.05 million vehicles in 187 countries. The number of registered vehicles provided by GSRRS is provided in figure A.2 (for mission values, the nearest historic data, or the nearest year was applied, if available).

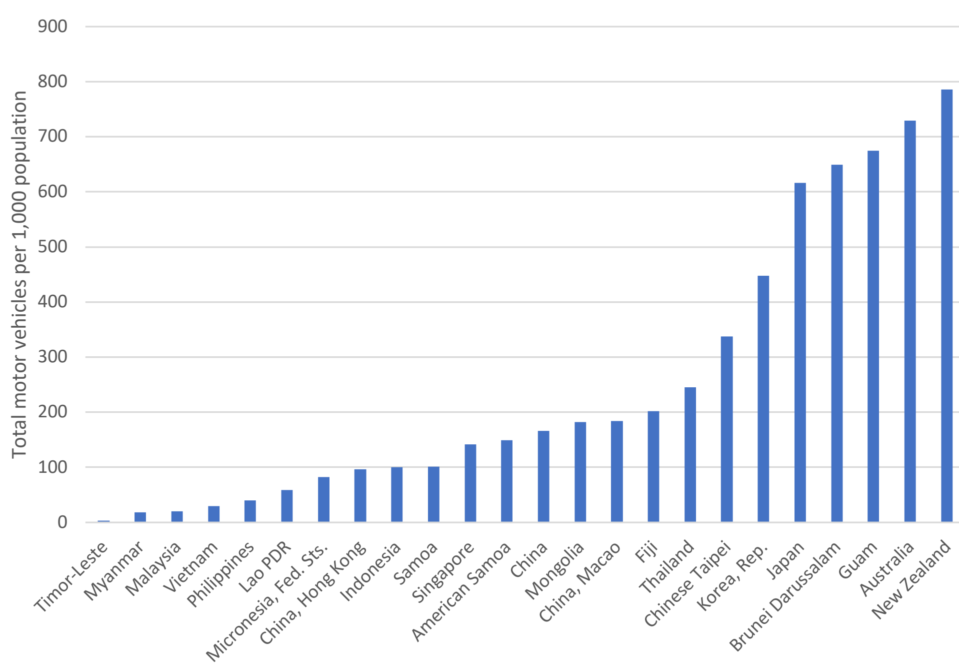
Figure A.2. Number of Registered Vehicles



Source: WHO 2009, 2013, 2015, and 2018.

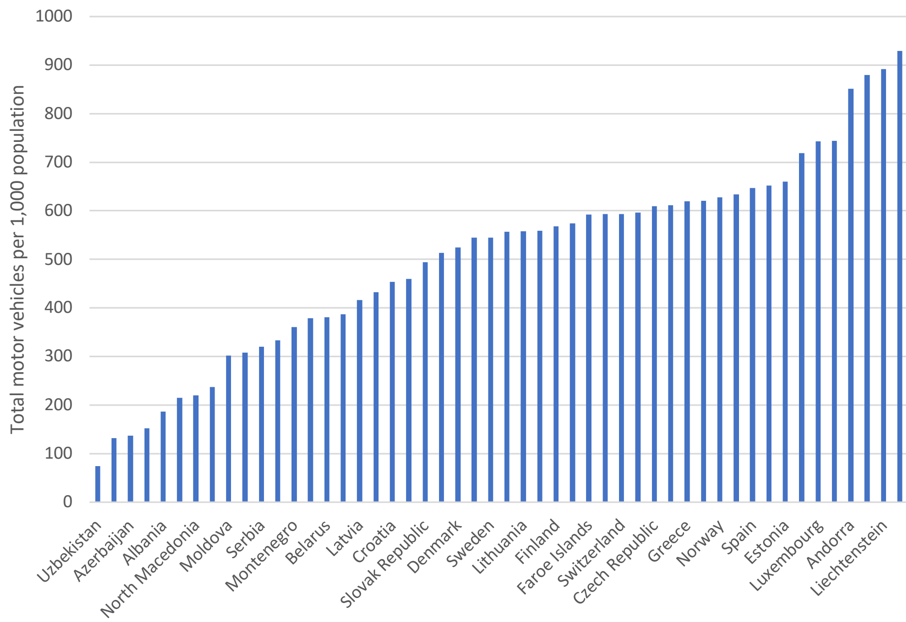
Motorization rates by region

Figure A.3. Motorization Rates in East Asia and the Pacific Region



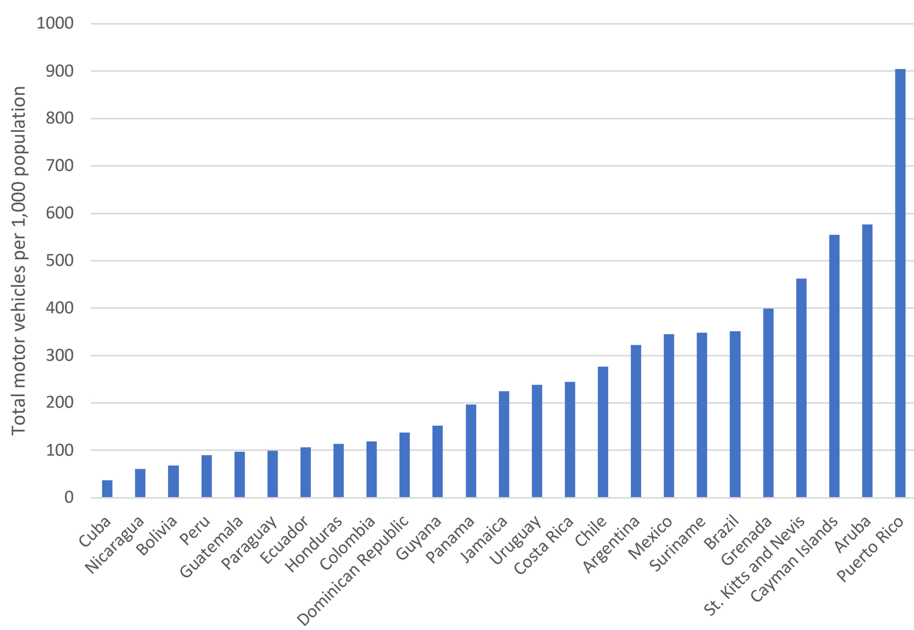
Source: IRF WRS.*

Figure A.4. Motorization Rates in Europe and Central Asia



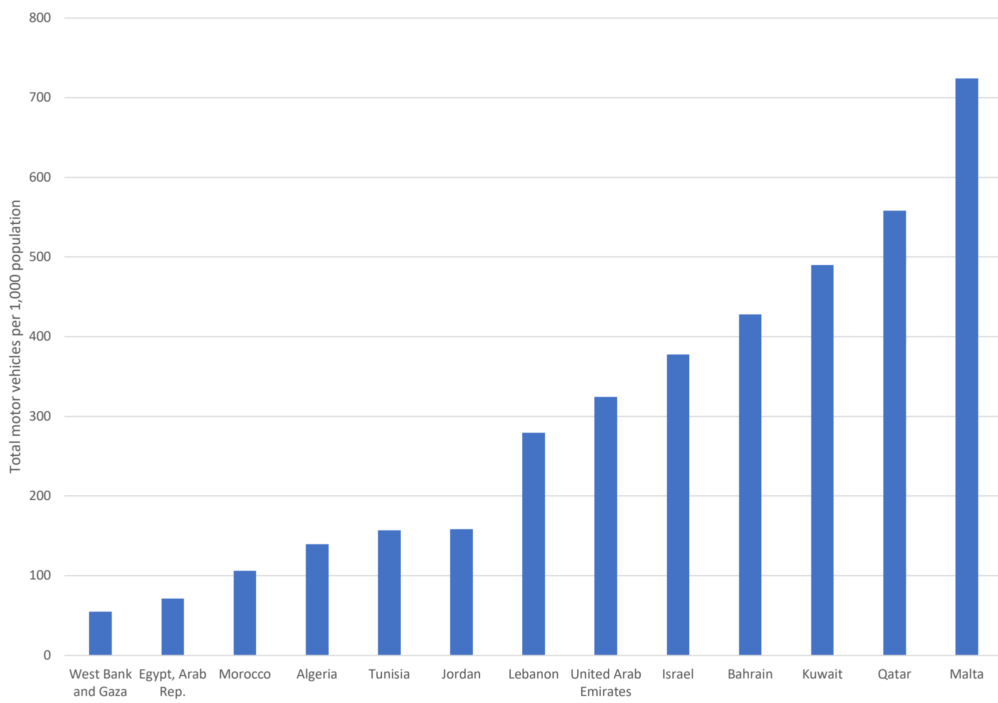
Source: IRF WRS.*

Figure A.5. Motorization Rates in Latin America and the Caribbean Region



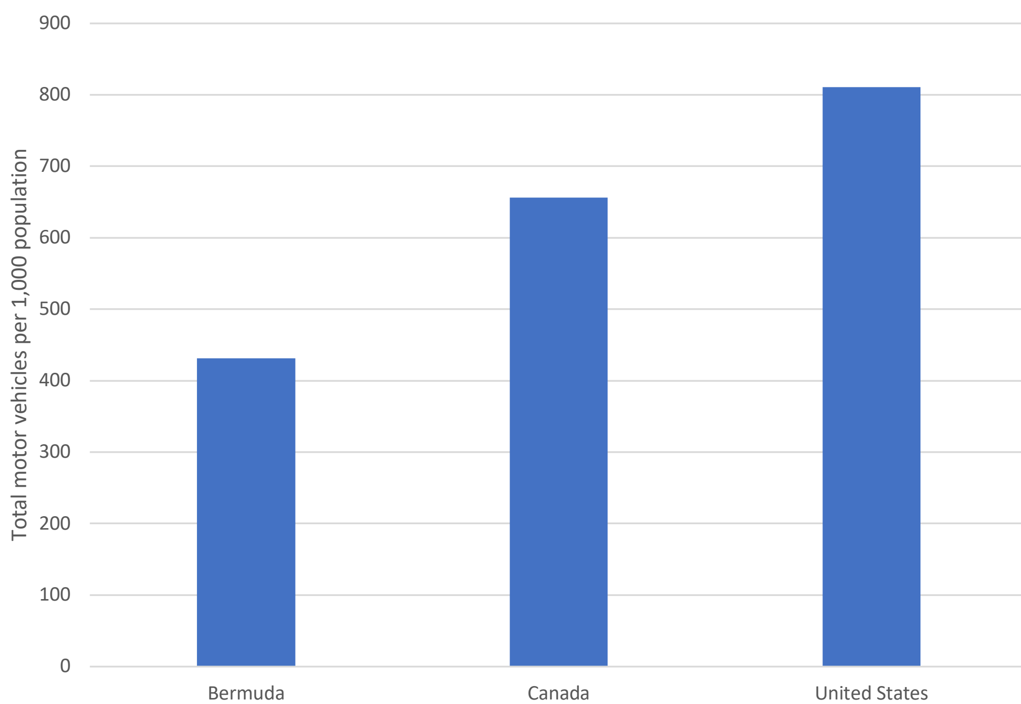
Source: IRF WRS.*

Figure A.6. Motorization Rates in the Middle East and North Africa



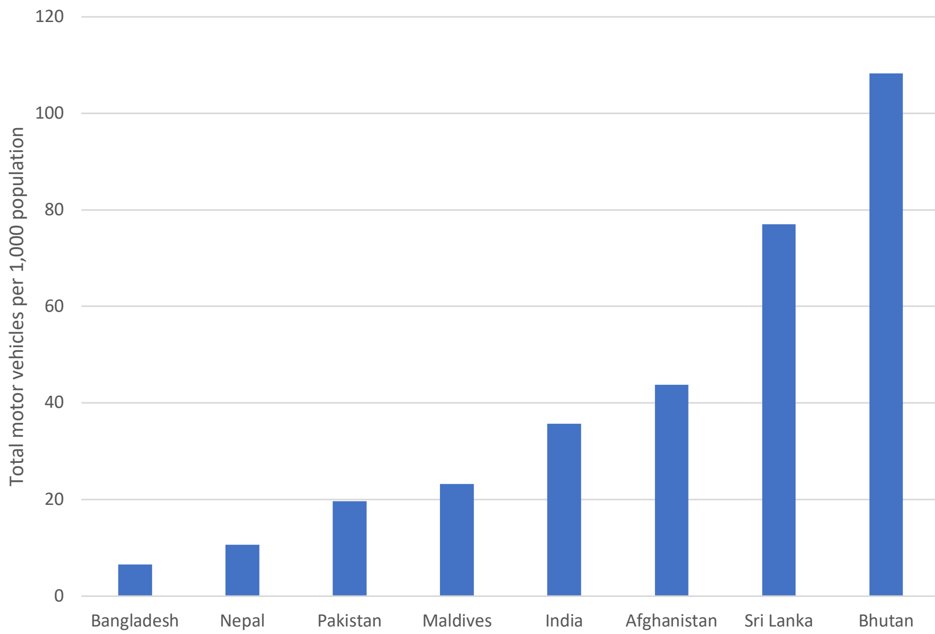
Source: IRF WRS.*

Figure A.7. Motorization Rates in North America



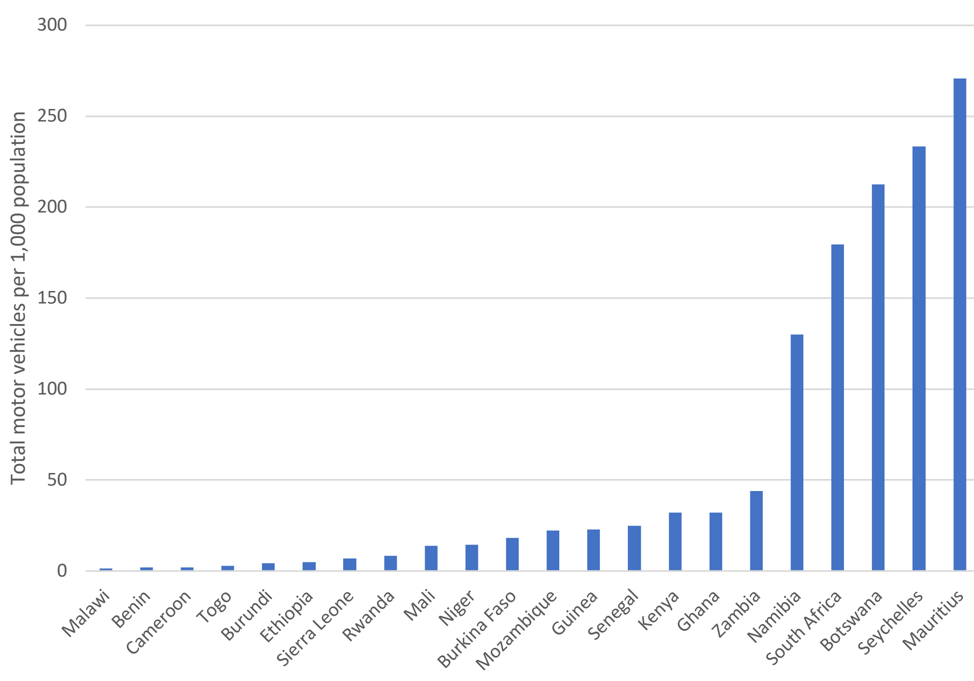
Source: IRF WRS.*

Figure A.8. Motorization Rates in South Asia



Source: IRF WRS.*

Figure A.9. Motorization Rates in Sub-Saharan Africa



Source: IRF WRS.*

*Note: All data points for all countries are for 2018, except as listed below.
2017: Algeria, Burkina Faso, Cameroon, Greenland, India, Mozambique, Nicaragua, Panama, Philippines, Qatar, Sri Lanka, Timor-Leste, Tunisia, and Vietnam
2016: American Samoa, Andorra, Argentina, and Guinea
2015: Aruba; Faroe Islands; Guam; Guyana; Lao People’s Democratic Republic; Micronesia, Fed. Sts.; Nepal; St. Helena; St. Kitts and Nevis; South Africa; and Togo
2014: Fiji, Malawi, Namibia, Puerto Rico, Samoa, United Arab Emirates, and Zambia
2013: Ghana, Mali, Senegal, and Sierra Leone

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Appendix B: Experience with Vehicle Scrappage Programs

Experience with vehicle retirement or scrappage programs stretches back at least 20 years, beginning with the Voluntary Accelerated Vehicle Retirement (VAVR) program in California in 1999. Since then, a wide range of programs have been tried around the world, with varying levels of investment and success. Subsidies for replacement of vehicles have ranged from US$240 per vehicle for light-duty vehicles (LDVs) to US$28,000 per vehicle for some heavy-duty vehicles (HDVs). Likewise, objectives have varied from targeting ozone precursors and particulate matter (PM) to specifically reducing greenhouse gas (GHG) emissions. A program in Beijing specifically targeted gross emitters identified with a yellow label, dedicating more than US$367 million to subsidizing the removal of very old, highly polluting vehicles. These resources followed a similar national initiative, which dedicated more than US$1 billion to subsidizing the removal of such vehicles. While the resources committed were high, an independent academic study estimated that the benefit-cost ratio of the Beijing investment was nearly 2.5. Table B.1 summarizes key aspects of some different scrappage programs. It is not intended to be an exhaustive survey of all scrappage programs, but rather suggests an order of magnitude of the resources involved.

Table B.1. Characteristics of Some Key Accelerated Vehicle Retirement Programs from Around the World

Scheme	Country	Years covered by program	Vehicles targeted	Approximate per-vehicle subsidy offered	How funded	Mechanism	Results
California: Carl Meyer	United States	1999–Present	HDVs, LDVs	~US$28,000 per vehicle	PTI/tire/vehicle registration fees (US$141 million per year)	Managed through grants to Air Quality Management Districts	24,000 vehicles replaced in first 12 years, reduced ozone precursors by 100,000 tons and PM emissions by 6,000 tons
Consumer Assistance to Recycle and Save (CARS)	United States	2009	LDVs	US$3,500 or US$4,500, depending on official fuel economy gap between old and new vehicle	US federal budget allocation (US$2.85 billion)		680,000 LDVs scrapped in one year, avoiding 9 million MT CO_2 eq over 25 years
National Clean Diesel Campaign	United States	2007–16	HDVs and non-road diesel vehicles	~US$9400 per vehicle	US federal budget allocation (US$300 million authorized, of which US$12 million went to vehicle replacement in 2009 and 2010)	Administered through competitive grants under four programs	2009–10 grants resulted in reduction of 706 kilotons of CO_2, as well as reduction of other pollutants
Umweltprämie	Germany	2009	LDVs	€2,500 per vehicle	German federal budget allocation (€5 billion)	Replaced vehicles registered at least 9 years and replaced by Euro 4 vehicle less than 1 year	2 million vehicles replaced, reduce PM and NOx, but CO_2 benefit unclear

Scheme	Country	Years covered by program	Vehicles targeted	Approximate per-vehicle subsidy offered	How funded	Mechanism	Results
Prime à la casse	France	2009	LDVs	€1,000 per vehicle	French national budget allocation (€550 million)	Cars replaced must be older than 10 years. New vehicles must meet 160 g/km CO_2 emission requirement	470,000 vehicles scrapped in 1 year
Cash for clunkers	Greece	2011	LDVs	Up to €2,800 per vehicle	Greek national budget allocation (€225 million)	Cars replaced must be older than 12 years. New vehicles must have engine capacity less than 2,000 cc	82,000 cars removed, but only 34,000 cars replaced
Vehicle scrappage scheme	UK	2009	LDVs	£1,000 per vehicle	UK national budget allocation (£400 million)	Cars replaced must be older than 10 years and registered by last owner for at least 12 months	400,000 vehicles replaced, 25% reduction in CO_2 intensity on average
Vehicle scrappage scheme	Cyprus	2008	LDVs	€730 per vehicle (avg.)	Cyprus national budget allocation (€11.3 million)	Cars replaced must be older than 10 years. New vehicles must have max fuel intensity of 5 l/100 kms	15,500 vehicles scrapped
National Yellow Label scrappage	China	2009–10	LDVs, HDVs	US$980–US$2,940 per vehicle (average US$2,270)	Chinese national budget allocation (US$1 billion)	Program targeted "Yellow Label" vehicles (designated gross emitters). Was abandoned in 2010 because of cost and prevalence/attraction of vehicle black market	459,000 vehicles scrapped through the program
Beijing Yellow Label scrappage	China	2008–10	LDVs, HDVs	Small cars: US$160–US$150 Med. cars: US$330–US$1,660 Large cars: US$1,500–US$4,160 Small trucks: US$130–US$1,000 Heavy trucks: US$250– US$830	Beijing municipal government budget allocation (US$367 million)	Program design reduced subsidy on average by 21% halfway through program to encourage owners to act early	More than 50,000 Yellow Label vehicles eliminated from city in 2009–10. 7,000 of these were not destroyed but rather registered outside of Beijing. An academic study found a benefit to cost ratio of 2.49 for the program.

Scheme	Country	Years covered by program	Vehicles targeted	Approximate per-vehicle subsidy offered	How funded	Mechanism	Results
Beijing Green-Label scrappage	China	2011–15	LDVs, HDVs	LDVs: US$410– US$1,000 HDVs: US$830–US$2,410	Beijing municipal government budget allocation (US$172 million in 2011–12)	Program targeted older Green Label vehicles instead of Yellow Label vehicles	266,000 vehicles replaced
Programa de Modernización del Autotransporte de Carga y Pasaje	Mexico	2004–15	HDVs	US$5,300–US$12,400, depending on vehicle	Mexico national budget allocation	Program targeted vehicles more than 10 years old. Covered up to 15% of replacement cost of vehicle	Average of 2,600 vehicles per year
Mexico City medium-size bus replacement scheme	Mexico	2001–11	Urban buses	US$7,700 per vehicle	Mexico City government budget allocation (US$34.56 million)	Program targeted pre-1995 buses to be replaced by EPA 2004-certified vehicle	Replaced a total of 4,576 buses
Cambia tu Camión (Swap your Truck)	Chile	2009	HDVs	US$8,000–US$24,000 depending on vehicle	Chilean Ministry of Energy (50%) and private sector (50%) (amount spent unknown)	Program targeted micro and small business owners with annual revenue less than US$25,000	Estimated CO_2 emissions reduction of 100 kilotons attributed to program
ELV scrapping scheme	The Netherlands	2009	LDVs	€750–€1,750 per vehicle	Dutch national budget allocation (€85 million), with €30 million from automotive sector, and €10 million from Amsterdam and the Hague.	Program targeted vehicles older than 13 years (gasoline) and 9 years (diesel)	A total of just under 52,000 units scrapped. Estimated CO_2 emissions reduction of 21 kilotons attributed to program
ELV scrapping scheme	Slovakia	2009	LDVs	€1,500 per vehicle	Slovak national budget allocation (est. €55.3 million)	Program targeted vehicles older than 10 years subject to limit of €25,000 for new car replacement	About 44,000 units scrapped. Estimated CO_2 emissions reduction of 25 kilotons attributed to program.
Cairo taxi fleet renewal	Egypt	2009–18	LDVs	US$900 per vehicle, plus subsidized credit terms for purchase of new vehicle	Egyptian national budget allocation (est. US$84 million). From 2013 on, carbon finance (CDM) generated revenues on certified emissions reductions associated with the project	Program targeted replacing vehicles 20 years and older	The program has replaced about 93,000 vehicles, of which about 43,000 vehicles were included under the CDM activity. On the basis of CERs issued, it is estimated that the entire program resulted in net CO_2 reduction of at least 735 kilotons

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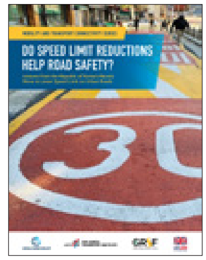

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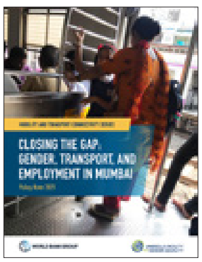

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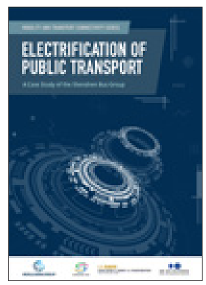

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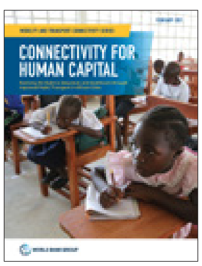

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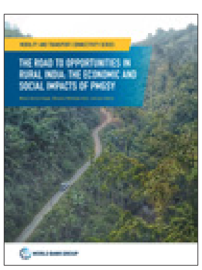

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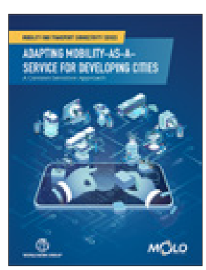

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