

RESEARCH SERIES AIR QUALITY

**REDUCING  
POLLUTION  
EMISSIONS**





The FIA Foundation is an independent UK registered charity which supports an international programme of activities promoting road safety, the environment and sustainable mobility, as well as funding motor sport safety research. Our aim is to ensure 'Safe, Clean, Fair and Green' mobility for all, playing our part to ensure a sustainable future.

The FIA Foundation Research Paper series seeks to provide interesting insights into current issues, using rigorous analysis to generate conclusions which are highly relevant to current global and local policy debates.



Clean Air Asia promotes better air quality and livable cities by translating knowledge to policies and actions that reduce air pollution and greenhouse gas emissions from transport, energy and other sectors. It was established in 2001 by the Asian Development Bank, World Bank, and USAID. Since 2007, Clean Air Asia is a UN recognized partnership of more than 250 organizations in 31 countries in Asia and worldwide. This paper is based on scoping research prepared by Rob Earley, Transport Program Manager of Clean Air Asia, Maria Tanya Gaurano, Environment Researcher of Clean Air

Asia and Melissa Cardenas, Consultant for Clean Air Asia, for the FIA Foundation. It aims to identify areas of need as well as opportunity to continuously reduce air pollutant and greenhouse gas emissions from the global population of vehicles which could be addressed by global policy initiatives.

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# SUMMARY

Transportation is a key driver of economic growth and contributes to poverty reduction. It accounts for half of total global oil consumption and 20% of world energy use.<sup>1</sup> The transport sector currently accounts for 23-24% of total global CO<sub>2</sub> emissions from the combustion of fossil fuels, with road transport responsible for 17-18% of the total. Relative to other sectors, transport has exhibited the highest CO<sub>2</sub> growth, with aviation and road transport as the primary drivers.

Even as motorization rates in the United States and Europe have stabilized in recent years, the total global population of vehicles continues to expand at a rapid pace, particularly due to the high demand for personal motorized transportation across the developing world. China and India, and emerging countries such as Indonesia, Brazil, Mexico and others have seen continuous increases in the populations of vehicles in their respective cities. This rapid increase has significantly contributed to fuel consumption, greenhouse gas emission and health-damaging air pollution from the transport sector. The International Council on Clean Transportation (ICCT) estimates that in 2030, the number of motor vehicles on the world's roads will double from its 2010 levels - from 1.4 billion units to around 2.8 billion cars, trucks, motorcycles, and other vehicles. The International Energy Agency (IEA) estimates fuel demand from the sector to grow by as much as 40% by 2035.<sup>2</sup> This increase in the number of vehicles translates to higher emissions and fuel consumption.

While more advanced technologies and stricter standards have resulted in reduced PM<sub>2.5</sub> and HC emissions in some regions for the period 2000 to 2015, NO<sub>x</sub> emissions have actually increased in China and India for the same period. Emissions from short-lived climate pollutants (SLCPs), such as black carbon, are expected to increase in China, India, Africa, the Middle East, and the rest of Asia-Pacific. It is projected that by 2030, India will be the largest regional contributor to on-road emissions of SLCPs, making up about 24 percent of the total.

The aim of FIA Foundation is to ensure 'Safe, Clean, Fair and Green' mobility for all, playing our part to ensure a sustainable future. FIA Foundation is interested in supporting work on key areas with the most potential to significantly reduce emissions in the transport sector, and commissioned Clean Air Asia to identify the most relevant issues. This research identifies five such key areas:

1. Curbing ultrafine particulate and black carbon emissions from diesel vehicles.
2. Addressing emissions from two- and three-wheel motor vehicles.
3. Action on promoting and coordinating efforts and initiatives in green freight.
4. Optimizing automotive performance and reducing health impacts through inspection and maintenance (I/M) programs.
5. Prevention of migration and continued use of outdated vehicles and engines.

# BACKGROUND

## Identifying priority areas

This research uses two frameworks to assess strategies to reduce emissions. These are the Systemic-Technical-Behavioural framework by Gorham<sup>3</sup>, and the Avoid-Shift-Improve (ASI) framework<sup>4</sup>. Both frameworks classify strategies according to the factors in transport (i.e. system, consumer-users, or technical aspects) that these address.

### 1. GORHAM'S SYSTEMIC-TECHNICAL-BEHAVIOURAL FRAMEWORK HAS THREE ELEMENTS:

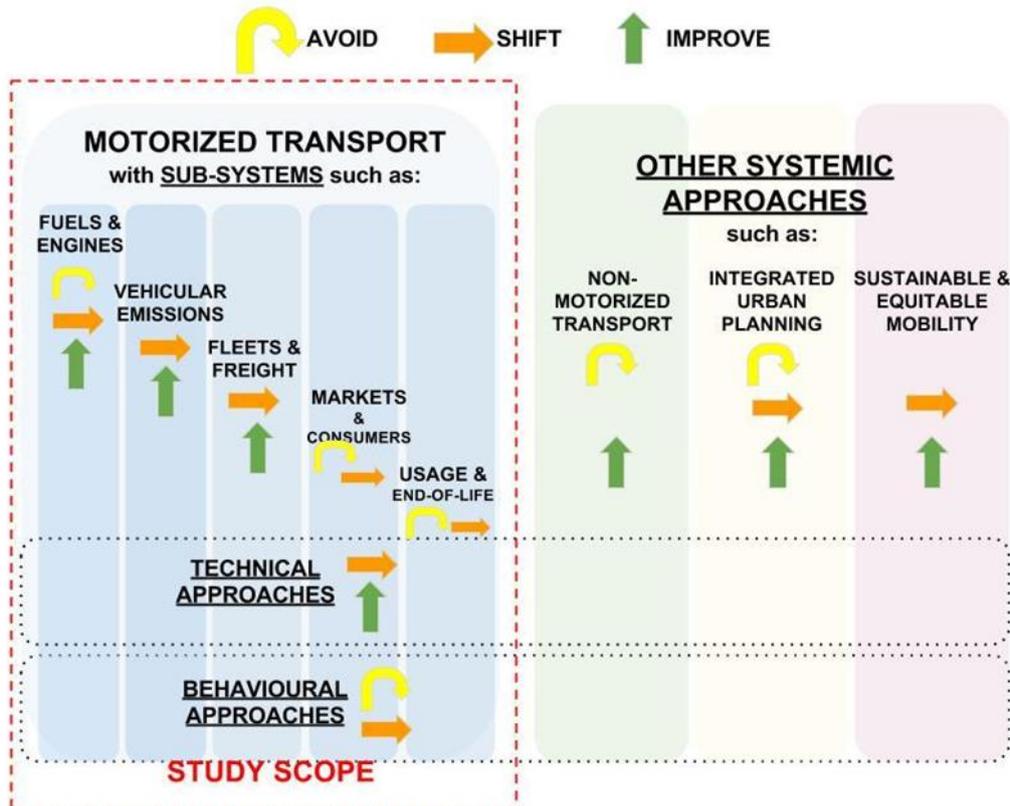
- **Systemic approaches** treat the interaction of the different components (fuels, engines, vehicles) of the transport sector;
- **Technical approaches** aim to reduce the amount of pollution per unit of transport activity, focusing on technologies, standards, and monitoring, among others; and
- **Behavioural approaches** seek to influence consumer preferences and individuals' mobility patterns.

### 2. THE AVOID-SHIFT-IMPROVE (ASI) FRAMEWORK HAS A HIERARCHY OF THREE ELEMENTS:

- measures that lessen the need to travel and the lengths of motorized travel (**avoid**)
- measures that promote the **shift** to more environment-friendly modes of transport (e.g. public transport and non-motorised transport (NMT),
- measures that **improve** vehicle and fuel efficiency through stricter standards, advanced technologies, and better transport infrastructure.

Both these frameworks show that there are a variety of factors that are important, and provide a way of categorising different approaches. Many "improve" strategies employed to address emissions coincide with what may be considered technical approaches such as improvement of fuel efficiency, development of alternative engine technologies, and formulation of standards. "Avoid" and "Shift" approaches are likewise implemented, such as policy interventions pushing for cleaner fuels and vehicles, campaigns that consider stakeholders' behaviours and attitudes (i.e. factors that influence consumer decisions on vehicle purchase, driving and maintenance habits, and general outlook towards emissions testing) are likewise also employed. Such "Avoid" and "Shift" strategies that address stakeholders' mobility choices are interpreted as parallel to the behavioural aspects considered in Gorham's framework.

This paper treats the interaction of the different components of transport: fuels, engines, vehicles, and emissions as comprising one system; specifically, the issues pertaining to this system as well as the policies and campaigns that address them. Other systemic approaches that involve non-motorized transport, integrated urban planning, and other issues in mobility, as pointed out in the previous section, are considered to be outside this paper's scope.



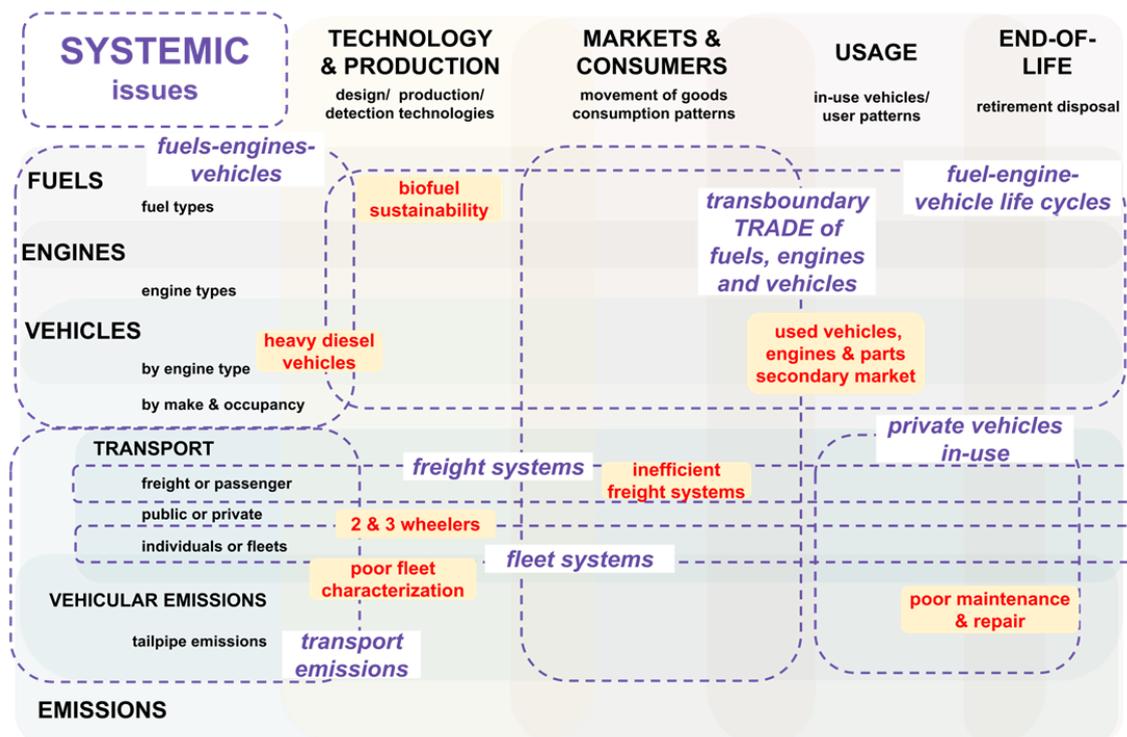
## SYSTEMIC ISSUES

Fuels, engines, and vehicles comprise the motorized transport system. These three components impinge on the level of emissions coming from the transport sector. Each one affects and interacts with the others, the result of which influence public policy, contribute to economic growth, and create demand for technological improvements, among others. These factors and their interaction need to be taken into consideration in the design and implementation of emission reduction initiatives. Trade flows, re-entry of obsolete vehicles and engines, and transboundary movement of goods and people can also be detailed.

Systemic aspects cut across different elements in motorized transport (i.e. types of fuels-engines-vehicles) and stages in the production, supply, and use of fuels, engines, and vehicles (i.e. life cycle analysis).

Issues that show gaps in the systemic aspects of motorized transport include:

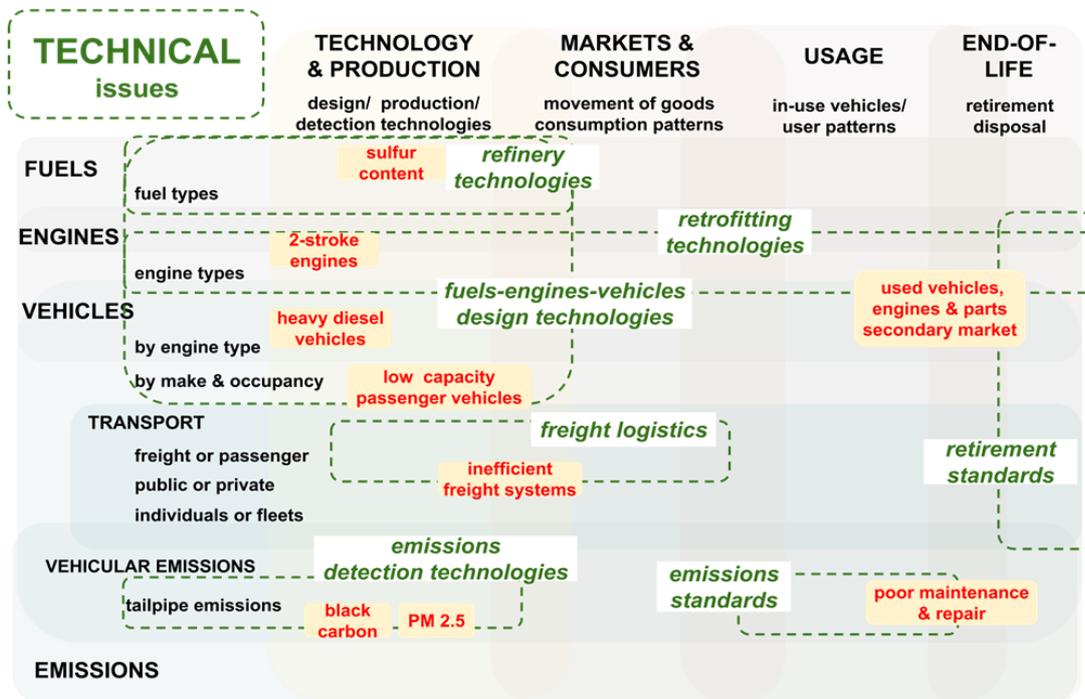
- Prevalence of heavy duty diesel vehicles, related to a specific fuel-engine-vehicle combination regarding transport of goods in emerging countries with poor road networks;
- Increased dependence on 2- and 3-wheelers for mobility, attributed in part to poor understanding and limited systemic management of public transport fleets;
- Significant emissions from transport of goods, a consequence of the lack of a well-planned and executed freight system;
- Poor abatement of emissions owing to bad maintenance and repair habits, acknowledging the role and contribution of consumer-users in I/M programs; and
- Re-entry of retired engines installed in in-use vehicles via the second-hand market; related to engine-vehicle life cycles and transboundary movement and supply of goods.



## TECHNICAL ISSUES

Technical aspects require activities such as research and design of alternative engine technologies, increasing fuel efficiency, and establishing emissions standards, and roadside inspection protocols. These usually involve research and development of design, production, or detection technologies, data analysis, or formulation or evaluation of policy standards. For example:

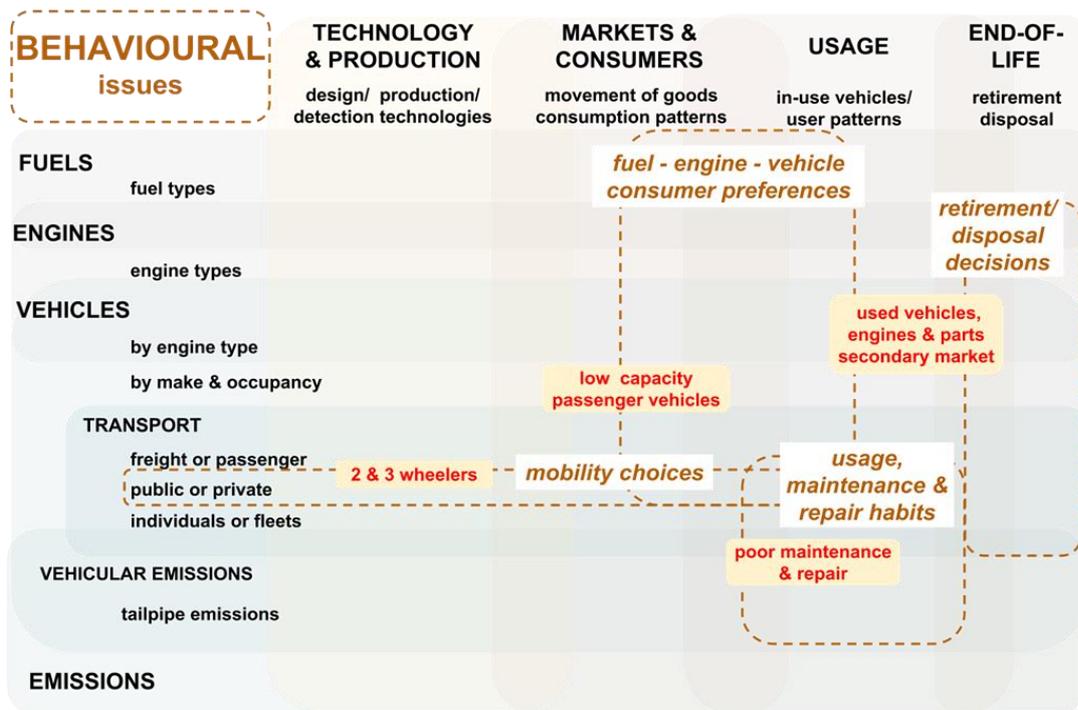
- Required refinery upgrades to further reduce sulphur content in fuels;
- Substitution of, shift to, or retrofitting of alternative fuels and technologies to replace outdated, “smoky” engines;
- Conduct of research, design, and production of new fuel-engine-vehicle combinations to improve fuel efficiency;
- Data analysis and modelling of freight logistics (and integration with passenger transport planning) to address inefficiencies in the freight sector;
- Limitations of current emission detection technologies to effectively address ultrafine particulate matter and black carbon from diesel vehicles; and
- Emissions and retirement standards determined by technical experts affecting current in-use vehicles suited for retirement.



## BEHAVIOURAL ISSUES

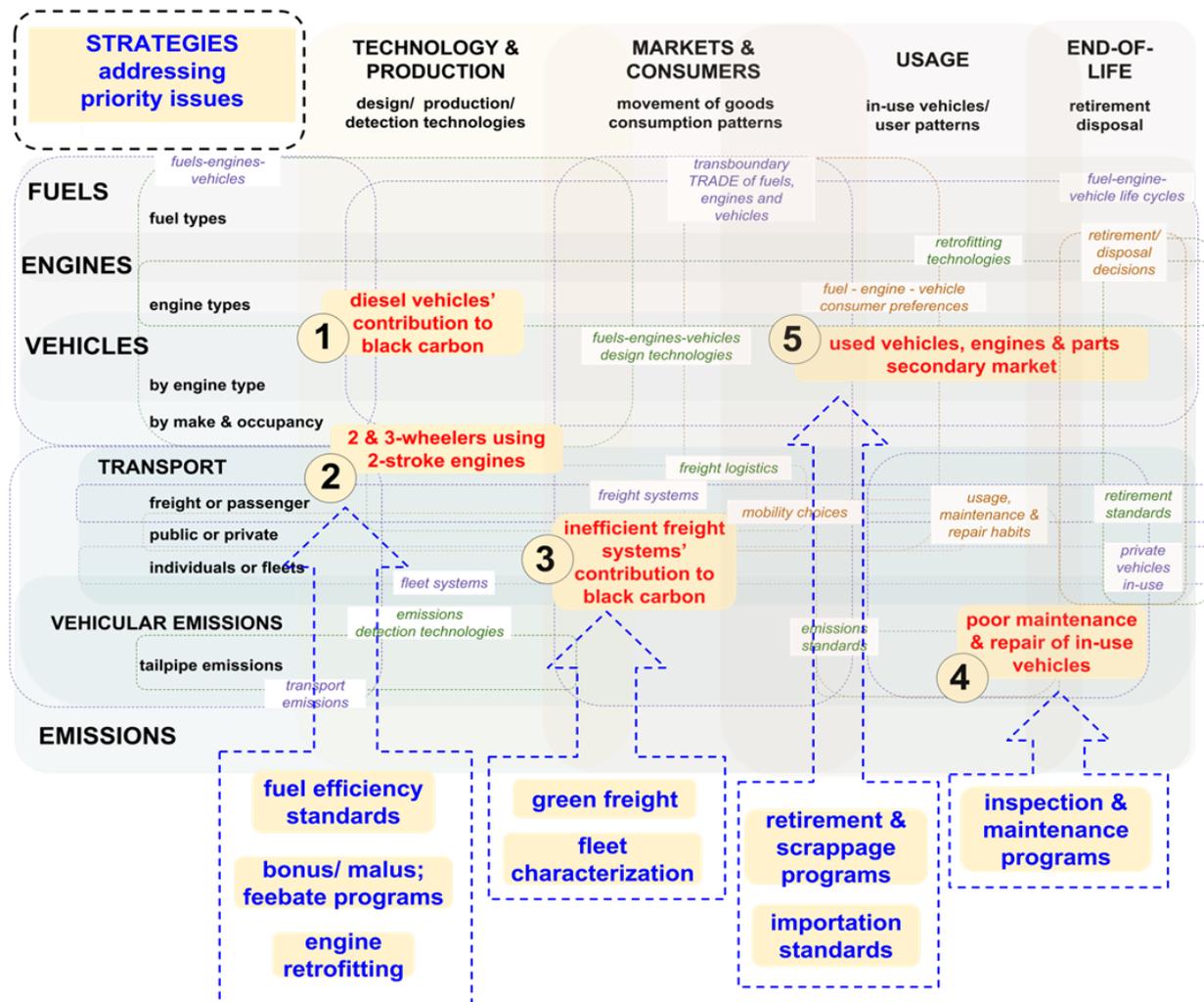
Behavioural factors involve consumer-users - in the selection and purchase of vehicles based on lifestyle and mobility preferences, usage, maintenance, and repair of vehicles, and decisions on vehicle retirement. Gorham attributes behavioural aspects of issues within motorized transport to people's choices and interactions with respect to fuels-engines-vehicles, whether as owners of private vehicles, as users of public transport, or consumers that affect the transport of goods. For instance:

- Consumer lifestyles and benefits affecting the choice of fuel-engine-vehicle combinations prior to purchase and mode-use;
- Availability or the lack of mobility options influence people's attitudes towards choosing low-cost private vehicles such as personal motorcycles, or 3-wheelers that serve as inexpensive modes of paratransit;
- Owners' usage, maintenance, and repair habits affect emissions performance of in-use vehicles; and
- Owners' capacity to pay to shift to cleaner vehicles influence the decision to retire in-use vehicles with outdated technologies.



## STRATEGIES ADDRESSING PRIORITY ISSUES

As discussed in the previous sections, there are many emissions-related issues in the transport sector in each area of the systemic-technical-behavioural framework. Several issues relate to at least two of these areas, and five issues possess a combination of all three [in red on diagram below]. Clean Air Asia verified these through a rapid survey with a pool of experts and identified strategies that have been put in place to address these priority issues [in blue on diagram below].



## 1. ULTRAFINE PARTICULATE AND BLACK CARBON EMISSIONS FROM DIESEL VEHICLES

Ultrafine particulate matter or PM<sub>2.5</sub> has grave adverse impacts on public health, specifically: aggravating asthma, respiratory diseases, and premature deaths. Recent estimates suggest that pollution from vehicles resulted in 184,000 deaths globally in 2010. This includes 91,000 deaths from ischemic heart disease, 59,000 deaths from stroke, and an additional 34,000 deaths due to lower respiratory infections, chronic obstructive pulmonary disease (COPD), and lung cancer combined.<sup>5</sup>



Installation of pollution control devices such as diesel particulate filters (DPFs) have been recommended to reduce soot emissions from motor vehicles. DPFs require very low sulphur levels in fuel and engines that are at least Euro 4 compliant. This requirement limits implementation, especially in countries where fuel and vehicle standards are still low or are poorly enforced. Moreover, many users may find maintenance cleaning and recharging of DPFs as cumbersome, with a growing trend of diesel enthusiasts opting to have DPFs removed.

## 2. PREVALENCE OF TWO- AND THREE-WHEELERS

Motorcycles used as personal transportation as well as three-wheeler low-capacity public utility vehicles are increasing in number. This is particularly true in the emerging economies of Indonesia, India, and the Philippines, where these vehicles still run on two-stroke engines. These small vehicles are greater sources of emissions than their four-wheeled counterparts. Moreover, even with their relatively low fuel consumption, their fuel economy potentials are often not maximized.



- Some of the current strategies in place include: retrofitting old engines, introducing alternative fuels and vehicles (e.g. electric vehicles), and mandating fuel-neutral and globally-harmonized standards, among others.
- Feebate-rebate programs have also been suggested in cities in China, Vietnam, and Taiwan. However, in the absence and/or lack of effective enforcement of a comprehensive scrappage policy to regulate emissions from and retire motorcycles that run on two-stroke engines and other older vehicles that are only Euro 1- or 2-compliant, these types of vehicles continue to run and comprise significant percentages of total fleets.

### 3. EMISSIONS FROM INEFFICIENT ROAD FREIGHT SYSTEMS

Improving the energy and environmental efficiency of the freight transport sector is key to reducing global black carbon and CO<sub>2</sub> emissions, as heavy-duty trucks are seen to be the largest emitter of these emissions.



Managing freight necessitates not only a program to reduce tailpipe emissions from heavy duty diesel vehicles, but a comprehensive analysis of freight logistics, road networks, and multi-modal transport. A requisite to such an analysis would be the availability of data on local and international fleets, and subsequent fleet characterization.

There remains a need for a number of approaches to be piloted globally, with the aim of reducing GHG emissions as well as harmful pollutants from the freight and logistics sector, while meaningfully improving the sustainability and development status of countries around the world.

### 4. INEFFECTIVE INSPECTION AND MAINTENANCE (I/M) PROGRAMS

Vehicle fuel economy and emissions performance decreases with time and use. However, the decline in performance can be minimized by maintaining vehicles according to a regular schedule and need. Vehicle inspection programs help to identify units that require maintenance in order to improve their performance and maintenance programs ensure that the vehicles actually receive the repairs needed.

I/M programs, when effective, are considered to be the most cost-effective ways of improving both air quality through emission reduction. However, some national governments/countries lack the capacity and the resources to conduct, facilitate, and oversee I/M operations, forcing them to decentralize these processes. This exposes I/M protocols to corruption and bribery, rent-seeking behaviour, and results in ways to circumvent the system. Moreover, lack of proper enforcement results in the development of poor and inconsistent maintenance behaviour among drivers, such as “clean for a day” (i.e. cleaning engines and tailpipes only during the inspection period) to circumvent policies.

Benefits derived from I/M programs are maximized when strategies are implemented simultaneously with the introduction of clean fuels and vehicles technologies and more stringent emission standards. In practice, however, most I/M programs focus on inspection processes, with no or little support in terms of policies on maintenance solutions, incentives, and efforts.

## **5. MIGRATION AND CONTINUED USE OF OUTDATED VEHICLES AND ENGINES**

On one hand, used vehicles from developed countries that are still compliant with relatively good emissions standards in the receiving country may provide a low-cost alternative for owners with more outdated vehicles. These may actually provide a financially viable transitory option for some developing nations (e.g. newer second hand cars from Japan, for example) until economic conditions enable full transition. However, this may also unintentionally postpone the adoption of better fuel economy and emissions standards in the receiving country.

The transboundary movement of second-hand vehicles does not just involve sedans or gasoline passenger vehicles, but also include heavy duty construction equipment, delivery trucks and buses from retired fleets, among others. This puts further strain on local enforcement of tailpipe emission regulations and inspection and maintenance programs.

Furthermore, the fate of retired or scrapped vehicles, engines, and parts that end up in emerging economies needs to be considered. Aside from scrapping for metal recycling, old engines, parts, or even entire vehicles may re-enter the market as used or second-hand commodities targeting lower-income users.

There is a gap in international and regional export/ importation standards or restrictions, re-entry of used or second-hand engines into the spare parts market, and transboundary movement of retired vehicles or their engines. Engines and vehicles are being resold into secondary markets because scrapping countries do not insist on assured scrapping, and may even encourage export of end-of-life engines and vehicles, thereby cancelling out the emission reduction potential that can be achieved through this strategy.

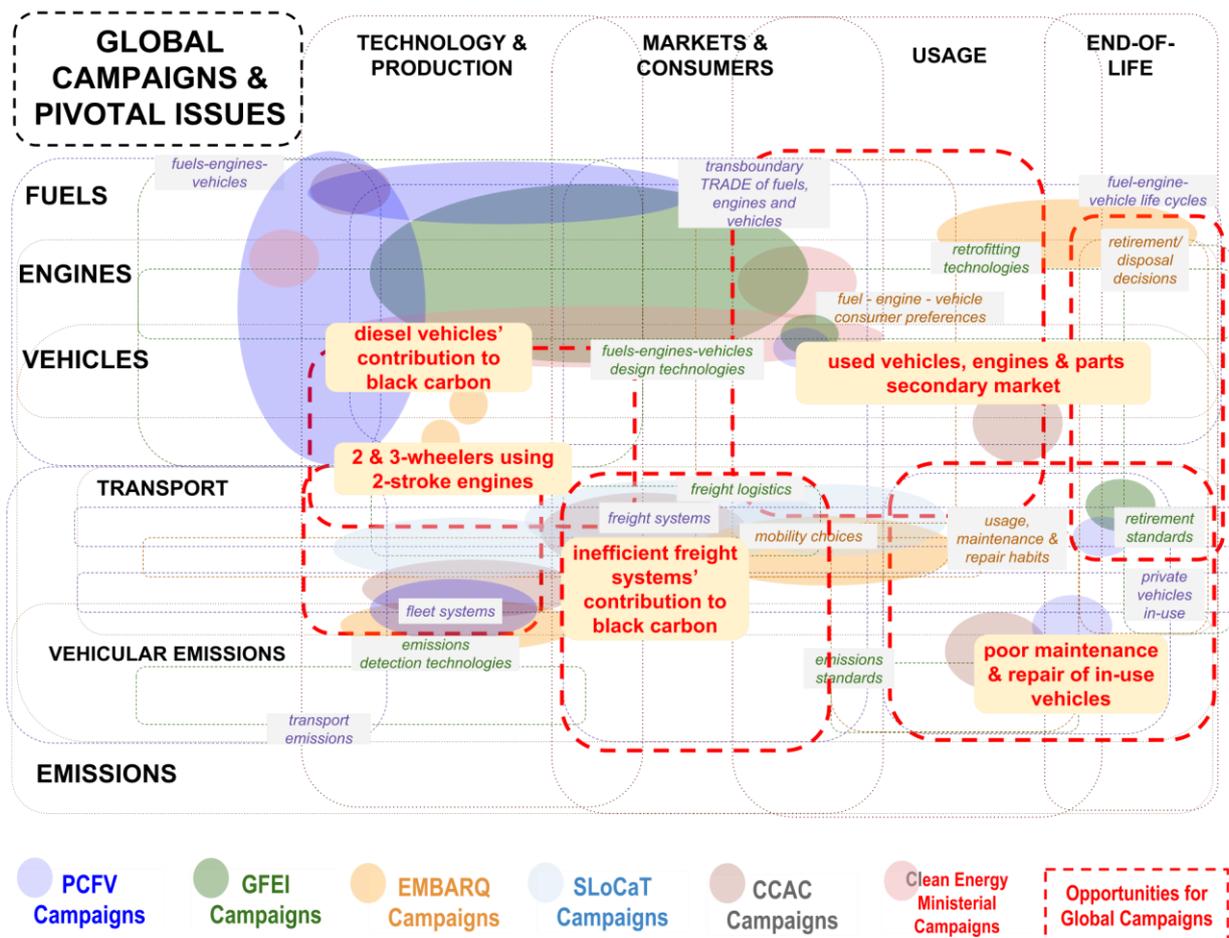
Since the movement of used consumer goods is influenced by policies and trade agreements between importing and exporting countries, the movement of outdated vehicles and engines necessitates action at the regional or global level.

# CURRENT CAMPAIGNS

The success of global campaigns is limited to the extent that these are adopted by and implemented in other countries.

Many current campaigns employ “improve” strategies that correspond to technical or technological actions, i.e. fuel quality or fuel efficiency standards, design and development of alternative fuels-engines-vehicles, among others. Notable campaigns are efforts by Global Fuel Economy Initiative (GFEI) and the Partnership for Clean Fuels and Vehicles (PCFV) and EMBARQ’s Sustainable Urban Transport Fuels and Vehicles (SUTFV) Program, which advocate for more stringent fuel and economy standards highlight technologies and policies that improve current emission reduction efforts. The Clean Energy Ministerial’s Electric Vehicles Initiative (EVI), supported by the International Energy Agency (IEA), aims to accelerate the introduction and adoption of electric vehicles worldwide towards diversification of fuel mix and reduce dependence on fossil fuels.

Other campaigns, such as “Transport Delivers” initiated by the Partnership for Sustainable Low Carbon Transport (SLoCaT), focus on environmentally sustainable transport issues at the global level; it incorporates “avoid” and “shift” measures with “improve” strategies. Some campaigns that Avoid or reduce the need to travel include advocacies for integrated urban planning or increasing the walkability of cities, thereby avoiding the need for motorized transport. Others promote Shift of activities to more environment-friendly modes of transport and integrate considerations towards low carbon consumption. Since these consider other elements that are outside the scope of motorized transport, these campaigns are treated as beyond the scope of this paper.



The Climate and Clean Air Coalition (CCAC) to Reduce Short-Lived Climate Pollutants (SLCPs) is another global initiative facilitated by UNEP and the governments of Bangladesh, Canada, Ghana, Mexico, Sweden, and the United States. CCAC has 46 state partners and 54 non state partners. This includes an initiative on reducing black carbon emissions from heavy duty diesel vehicles and engines, which works with several countries in Latin America, Africa and Asia to produce black carbon inventories, form national task forces and regional coalitions for harmonized black carbon reduction strategies and policies, and set target dates for introduction of 50 ppm fuel sulphur content standards.

From the mapping of current issues and campaigns, the following generalizations can be derived:

- Some subsystems such as fuels, engines, and vehicular emissions are covered by global campaigns, but others that occur post-production or involve in-use vehicles (such as fleet systems thinking, green freight, markets and consumers, and fuel-engine-vehicle lifecycles) are not;
- There appear to be limited global or regional campaigns for issues that prevail in specific geographic regions but have global impact (i.e. 2- & 3-wheelers and 2-stroke engines);
- There are opportunities for campaigns at the global level employing behavioural approaches (or avoid and shift strategies) to encourage consumers and users to make informed choices and develop positive attitudes towards vehicle maintenance and repair;
- I/M programs, despite their strategic contact with in-use vehicles and hence their major role in global campaigns on transport emissions reduction, are entrusted at the local or national levels and would benefit greatly from a global campaign push;
- Movement of obsolete technologies from emissions-stringent economies to emissions-lenient areas, whether at the inter-city, inter-region, or international levels, should be a global concern.



# CONCLUSIONS AND RECOMMENDATIONS

On this evidence, there are certain topics that need far greater attention and action.

## 1. RENEWED EFFORTS TO CURB ULTRAFINE PARTICLES AND BLACK CARBON EMISSIONS, SPECIFICALLY FROM DIESEL ENGINES.

This cuts across many other priority issues: sulphur content in fuel, road freight that rely on heavy duty diesel vehicles for delivery of goods, two-stroke engines, even used vehicles, and climate change mitigation efforts. The audience for current and future campaigns on PM2.5 and black carbon reduction should include actors in the fuel refining and automotive sectors, consumers, and stakeholders from other sectors that address or work towards the mitigation of the effects of climate change, to which these emissions are significant contributors. Further support is needed for research and development of more effective but affordable pollution control devices that do not interfere with engine performance, as well as other technical aspects involved in emissions detection and formulation of standards on ultrafine particulate matter.

## 2. TAKE ACTION ON 2- AND 3-WHEEL MOTOR VEHICLES.

These vehicles are inexpensive and provide high levels of mobility. They represent one of the fastest growing populations of vehicles in the planet. While some countries have adopted standards that require catalytic converters on 2- and 3-wheeled vehicles in order to dramatically decrease emissions, global standards are inconsistent.

This represents an excellent opportunity to clean up these otherwise efficient personal vehicles through harmonization and tightening of emission standards. The European Union has started on a pathway towards cleaner motorcycles, which will see hydrocarbon emission limits reduced by more than an order of magnitude from motorcycles from 2006, and bringing motorcycles to a closer technological pathway as vehicles. A campaign could push for 2- and 3-wheeled motor vehicles around the world to be sold at Euro 4 or equivalent motorcycle standards by 2020. The increasing use of alternative fuel motorcycles, including electric bikes, also offer new possibilities.



## 3. A GLOBAL GREEN FREIGHT AND LOGISTICS CAMPAIGN

Countries, international agencies, and multilateral development banks are beginning to see that the freight and logistics industry has a heavy impact on the environment, fuel consumption, and their economies. Green freight, as a concept is in its nascent stages, with projects beginning to spread around the world that focus on improving truck technologies including tires, aerodynamic improvements, and telematics technologies. In China, there is an increasing focus on transforming fleets of fixed-form trucks into tractor-trailer systems that allow for logistics systems to take on greater efficiencies.

As pilot projects offer insight into technologies that are effective at making in-use trucks more efficient, there will be need to evaluate data from projects and in the first instance to promote such pilot project results data around the world, but in the second instance to scale up those pilot projects through national programs, finance for the private sector, and eventually vehicle and logistics practice standards will need to improve from this pilot experience. A green freight and logistics campaign would aim to see national programs initiated in every country around the world, with experience and data being reported and disseminated globally. The campaign would not only focus on reduction of GHGs, but also on the reduction of pollutants, black carbon, as well as fuel consumption and road safety.

To date, green freight is an issue that is being addressed at the national level, particularly in the US and Canada through the voluntary, public-private SmartWay program, as well as in Europe through programs such as ObjectifCO2, ECOStars, and Lean and Green, which are either government-initiated Public-Private Partnerships or NGO-initiated multi-stakeholder initiatives that provide labeling incentives to both manufacturers of goods, as well as to providers of transport and logistics services. Green Freight Europe and Green Freight Asia are completely private-sector initiatives with the same goals across their respective regions, and developing countries around the world are starting national green freight programs, with countries such as Mexico and China taking a lead in organizing public and private sectors to begin addressing emissions from the freight sector. Regional programs such as the Greater Mekong Sub-region (GMS) Green Freight Initiative are also being implemented. These initiatives, however, primarily focus on reducing CO2 emissions from the freight sector, leaving PM2.5 and Black Carbon, along with NOx pollution as a remaining major topic requiring attention.

The Climate and Clean Air Coalition (CCAC) is developing a Green Freight Action Plan for governments and the private sector, and is developing guidelines for reducing the emission of Black Carbon and PM2.5 from the freight sector, but will require the support of NGOs and other action groups around the world to monitor and implement into the future. Organizations including the Smart Freight Center, GIZ, ICCT, Green Freight Asia and Green Freight Europe, in addition to traditional funders such as Multilateral Development Banks can all be suitable global partners in this effort to improve the emissions profile of freight.

#### **4. OPTIMIZING AUTOMOTIVE PERFORMANCE AND REDUCE HEALTH IMPACTS THROUGH INSPECTION AND MAINTENANCE OF MOTOR VEHICLES (I/M).**

Vehicle fuel economy and emissions performance decreases with time and use. However, the decline in performance can be minimized by maintaining vehicles according to a regular schedule and need. Vehicle inspection programs help to identify units that require maintenance in order to improve their performance and maintenance programs ensure that the vehicles actually receive the repairs needed. Globally, I/M programs have had varied success, but where they are successful, they have high potential to avoid PM (including black carbon), NOx, CO, HC, and other emissions.

- a. There is a need for more information about emissions and health impacts, fuel costs for drivers from poorly-maintained vehicles, and incentives for drivers to properly maintain their vehicles;
- b. There is a need for a platform for best practices and experiences for regulators around the world to gain knowledge on how to design and implement I/M programs, and customize these programs properly for their local conditions; and
- c. There is potential to link vehicle inspection to yellow-labelling of non-compliant vehicles. While not explicitly requiring maintenance, these yellow-label vehicles could be banned from entering low-emission zones established by cities.

## 5. STRONG EMISSION STANDARDS FOR IMPORTED SECOND HAND VEHICLES.

Developing countries across Southeast Asia, Africa, and Latin America are littered with old vehicles and engines that were “scrapped” in developed countries. These “scrapped” vehicles have helped improve air quality in the countries they left, but in fact have provided low-cost but heavily polluting forms of transportation in less-developed countries, essentially exporting pollution from wealthy to poorer nations.



A global campaign on the development and enforcement of emission standards for imported second-hand vehicles could raise the awareness of this issue and ensure that importing countries do not increase their exposure to automotive pollution nor to fuel prices that come as a result of unnecessary fuel consumption in inefficient vehicles. It will also cause “scrapping” countries to consider the impacts of their vehicle scrappage programs and ensure that industries are in place to actually recycle their vehicles in-country.

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