FUEL ECONOMY OF LIGHT DUTY VEHICLES IN SRI LANKA

THE BASELINE

Prepared by

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Clean Air Sri Lanka

August 2015

ACRONYMS

ACEA	European Automobile Manufacturers Association
AirMAC	Air Resource Management Centre
CA2AP	Clean Air 2000 - An Action Plan
CAA	Clean Air Asia
CAASL	Civil Aviation Authority of Sri Lanka
CAI-Asia	Clean Air Initiative for Asian Cities
CBSL	Central Bank of Sri Lanka
CEA	Central Environmental Authority
CEB	Ceylon Electricity Board
CEYPETCO	Ceylon Petroleum Corporation
CI	Compression ignition
CISIR	Ceylon Institute for Scientific and Industrial Research
Clean Air SL	Clean Air Sri Lanka
CPSTL	Ceylon Petroleum Terminals Ltd
CSE	Centre for Science and Environment
CUTP	Colombo Urban Transport Project
DMT	Department of Motor Traffic
E3ST	Energy Efficient and Environmentally Sustainable Transport
EECA	Energy Efficiency and Conservation Authority, New Zealand
EIA	Environmental Impact Assessment
EPL	Environmental Protection Licence
EU	European Union
EV	Electric vehicles
FCV	Fuel cell vehicle
GHG	Greenhouse gas
GTZ	German Development Cooperation
HEV	Hybrid-electric vehicle
HOV	High occupancy vehicle
IC	Internal combustion
ICCT	International Council on Clean Transportation
IEA	International Energy Agency
IIASA	International Institute for Applied Systems Analysis

IPCC	Intergovernmental Panel on Climate Change
kgOE	kg of Oil Equivalent
LCA	Life cycle analyse
LDV	Light-duty vehicle
LECO	Lanka Electricity Company
LIOC	Lanka Indian Oil Company
LPG	Liquefied Petroleum Gas
MEIP	Metropolitan Environmental Improvement Programme
MIT	Massachusetts Institute of Technology
MJ	Mega Joule
NAAQS	National ambient air quality standards
NBRO	National Building Research Organisation
NEA	National Environment Act No 47 of 1980
NEDC	New European Driving Cycle
NMT	Non-motorized transport
NTC	National Transport Commission
NTMI	National Transport Medical Institute
OECD	Organisation for Economic Co-operation and Development
RDA	Road Development Authority
SE4ALL	Sustainable Energy for All
SI	Spark-ignition
SLSEA	Sri Lanka Sustainable Energy Authority
SLPA	Sri Lanka Ports Authority
SLR	Sri Lanka Railways
SLTB	Sri Lanka Transport Board
SLVET	Sri Lanka Vehicle Emission Testing
TOE	Tonnes of Oil Equivalent
UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
VET	Vehicle Emission Testing
ZEV	Zero Emission Vehicle

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SECTION 01: INTRODUCTION

1.1 Development, Energy and Transport

Energy is the prominent driver of the economic development. Globally, the energy demand is catered primarily by fossil fuels, contributing to over 81% of primary energy supply in 2012 [1]. However, the utilization of such resource, having issues related to both quantity and quality, has led to severe energy and environment related challenges. Not only that they are depleting resources but also are responsible for much spoken environmental impacts, from local level indoor & outdoor ambient air quality degradation to global level climate change issues. Particularly, global warming due to emission of greenhouse gasses (GHGs) challenges the present unsustainable economic development models followed and thus becomes decisive factor of the future development pathways. The 5th Assessment Report of Intergovernmental Panel on Climate Change (IPCC) highlights that, despite the variety of existing policy efforts and the existence of the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol, emissions of GHGs have grown at a higher rate [2].

Among the energy end-use sectors, demand for fossil oil (petroleum) primarily driven by growth in the vehicle population, especially private passenger vehicles, as well as total vehicle distance travelled. This is largely due to rapid motorisation taking place in developing countries and emerging economies. The transportation sector is responsible for approximately 28% (91 EJ) of global final energy demand in 2012. Road transport accounts for more than 70% of that total and 95% of transport energy comes from oil-based fuels [3]. Present global vehicle population exceeds 1 billion and estimated to reach 2 billion by 2035. It is estimated that the transport sector will account for 97% of the increase in world primary oil use between 2007 and 2030 [4].

The transport sector produced 7.0 Gt CO_{2eq} of direct GHG emissions (including non-CO_2 gases) in 2010 and hence was responsible for approximately 23% of total energy-related CO_2 emissions (6.7 Gt CO_2). Growth in GHG emissions has continued in spite of more efficient vehicles and policies being adopted last few decades. Without aggressive and sustained mitigation policies being implemented, transport emissions could increase at a faster rate than emissions from the other energy end-use sectors and reach around 12 Gt CO_{2eq} per year by 2050 [2]. Therefore, consequent energy security and GHG emission implications mean that reducing the fuel used in this sector is one of the highest priorities for all countries.

1.2 GHG Mitigation in Transport Sector

Transport demand per capita in developing and emerging economies is far lower than in Organisation for Economic Co-operation and Development (OECD) countries but is expected to increase at a much faster rate in the next decades due to rising incomes and development of infrastructure. Current models of development promote the personal vehicle as symbol of well-being and societal advance. However, this socio-economic development model is deemed to be unsustainable in many aspects, especially for cities that have never evolved around the personal vehicles. At present, many OECD countries struggle to overcome the dependence on personal vehicles and face strong difficulties to turn back, while an increasing number of industrialized cities are in the process of breaking the trend. Unfortunately, majority of the developing countries and emerging economies seem to follow the conventional development path [5]. Consequently, the continuing growth in passenger and freight activity could outweigh all mitigation measures and reduction of global GHG emissions in the transport sector would become a very challenging task, unless transport emissions is strongly decoupled from gross domestic product (GDP) growth. Nevertheless, analyses of both sectoral and integrated model scenarios suggest that a substantial decoupling of transport GHG emissions from GDP growth seems possible. A strong slowing of light-duty vehicle (LDV) travel growth per capita has already been observed in several OECD cities, suggesting the possibility [2].

Under the above circumstances, novel and innovative approaches are required to realize GHG mitigation targets in the transport sector. In general, there is a number of fundamental approaches, but has to be implemented simultaneously by considering all the governing factors in order to best achieve the mitigation targets. It is also important to highlight that, although several instruments and tools are available, political action and good management at all levels are also required for the successful implementation. In particular, rather than focusing on specific technological options, a systemic approach can facilitate enduring transport systems and realize several co-benefits. The main framework for this strategic action is commonly referred to as Avoid/Reduce-Shift-Improve approach [5]. For example, direct GHG emissions in the transport sector can be reduced by the following [2]:

- <u>Avoid/reduce journeys</u>: by, densifying urban landscapes, sourcing localized products, internet shopping, restructuring freight logistics systems, and utilizing advanced information and communication technologies (ICT);
- <u>Modal shift</u>: to lower-carbon transport systems, encouraged by increasing investment in public transport, walking and cycling infrastructure, and modifying roads, airports, ports, and railways to become more attractive for users and minimize travel time and distance;
- <u>Improve energy efficiency of transport modes and vehicle technology</u>: in lowering energy intensity of transport (MJ/passenger-km or MJ/tonne-km) by enhancing vehicle and engine performance, using lightweight materials, increasing freight load factors and passenger occupancy rates, deploying new technologies such as electric 3-wheelers;
- <u>Improve fuel</u>: in reducing carbon intensity of fuels (CO_{2eq}/MJ) by substituting petroleum-based products with natural gas, bio-methane, or biofuels, electricity or hydrogen produced from low GHG sources;

In addition, reduction of indirect GHG emissions arisen during the construction of infrastructure, manufacture of vehicles, and provision of fuels should also be considered.

The above synergistic approach is an important agenda for both developed and developing countries, but the local context has to be well-recognized in adopting and prioritizing programmes and activities. In particular, developing countries often have the better opportunity to implement most of the interventions given above in their growing cities, while "leapfrog" to sustainable transport systems. The present study is focused on energy efficiency in transportation, particularly on LDVs as the transport sectors in developing countries including Sri Lanka are experiencing rapid increase on personal vehicle ownerships.

1.3 Fuel Economy in the Transport Sector

The demand for fuel (or energy) in the road transport sector depends on the modal share and vehicle fleet characteristics including fuel usage of each mode of transport. For a given vehicle category, the fuel demand could be estimated by three key factors viz fuel efficiency of the vehicle (which is determined by the technical energy efficiency), vehicle travel (which denotes the type of travel/driving and the number of distance driven) and the vehicle population (which is the number of vehicles on the road). The fuel efficiency of a vehicle is usually described by different terms such as fuel economy, fuel consumption, energy efficiency, etc., which are used with different definitions and measurement units around the world, thus sometime causing linguistic confusion. Therefore, it is important to use the relevant parameters with clear definitions. Typically, fuel economy refers to fuel consumption per unit distance travelled or distance travelled per unit amount of fuel consumed of a vehicle under given under a given driving pattern or conditions (refers to as the driving cycle). More details on definitions of fuel economy is given in Section 1.6.

In the estimation of energy demand in the transport sector, an average figure for the fuel economy has to be used at-least for a given category of vehicles. In addition, the annual distance travelled can vary markedly from vehicle to vehicle and moreover tends to, on average, decline as the vehicle ages. It is also important to highlight at this juncture that the definition used for the fuel economy above has a shortcoming , as the number of passengers and/or the load carried by the vehicle is not reflected, thus failing to depict the effectiveness of using fuel for mobility in a particular transport mode. Therefore, another way of defining the fuel economy is fuel consumption per each passenger-kilometre or tonne-kilometre travelled. Such figures could be used to compare the fuel efficiency of different transport modes. For example, Table 1.1 presents average fuel economy of some common passenger transport modes together with their corrido capacities [3].

Table 1.1: Corridor capacity and energy efficiency of different modes of transportation

Performance Parameter	Transport Mode						
	Mixed traffic	Regular Bus	BRT single-lane	Cyclists	Pedestrians	Light Rail	Heavy Rail
Corridor Capacity(1)	2,000	9,000	17,000	14,000	19,000	22,000	80,000
Energy Efficiency (MJ/p-km)	1.65 to 2.45	0.32 to 0.91	0.24	0.1	0.2	0.53 to 0.65	0.15 to 0.35
Fuel	Fossil			Food		Electricity	

(1) People per hour on 35m wide lane in the city.

When transport choices are made, in addition to the above, comparison of different transport modes and technologies needs to incorporate life cycle analyse (LCA) together with financial, social and environmental impacts. Modal shares could move to modes that are less energy-intensive, both for passenger and freight transport. In cities, a combination of push and-pull measures through traffic-demand management can induce shifts from personal vehicles (such as motor-bicycles, three-wheelers and cars) to public transit and non-motorized transport (NMT) modes (i.e. walking and cycling), which can provide multiple socio-economic and environment benefits. In particular, NMT could be promoted everywhere as there is wide agreement about its benefits to transportation and people's health [3]. Estimates on annual distance travelled as well as vehicle occupancy and load factor are critical for calculating passenger-kilometres and tonne-kilometres travelled in each mode of transport. Generally, data on these parameters in different modes is sparse, but needed for the analysis of energy (or fuel) demand characteristics in the transport sector.

Although all transport modes are expected to show substantial increases in activity, private vehicles in particular will continue to have dominant effects on the overall transport energy and petroleum use the future. This in turn will provide greater opportunity for the mitigation of GHG emissions in the transport sector, as discussed in the following two sections.

1.4 Clean and Efficient Vehicle Technologies

Presently, energy conversion technologies of ground vehicles are dominated by petroleum fuelled IC engines. Overall energy conversion efficiencies of these vehicles are quite low, particularly in urban driving environments. Figure 1.1 illustrates the energy balance and losses in a typical IC engine vehicle under urban driving cycle [6]. Note that the percentage losses given are some indicative values and could vary depending on the vehicle technology and the driving cycle.

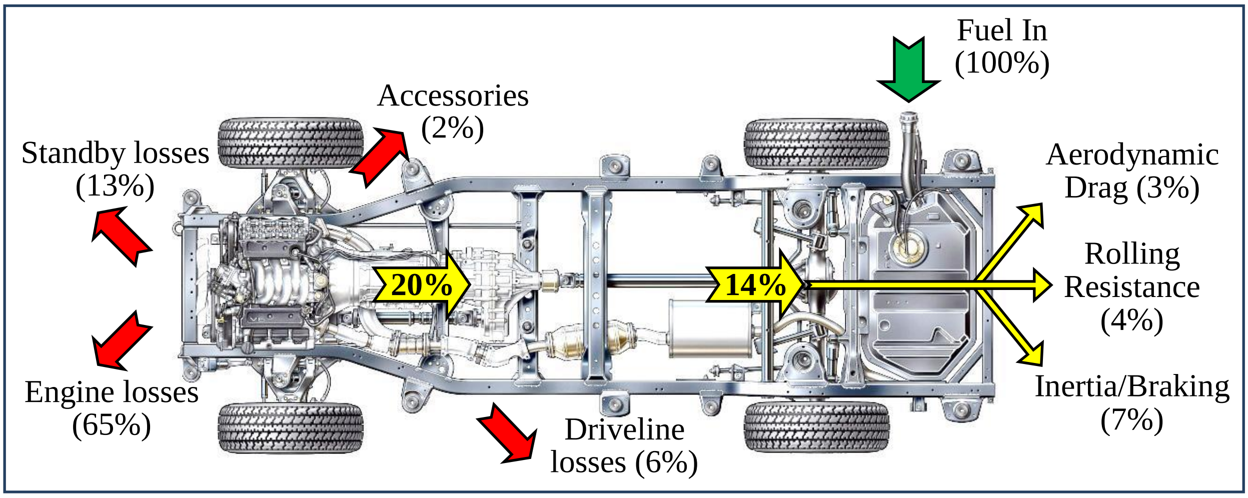


Figure 1.1: Energy balance and losses in a vehicle

IC engine technology has improved steadily over the years; yet there are many more opportunities to improve further. In fact, a major transformation of transportation is expected over the next 20–35 years and, in case of LDVs, the major improvement would be through evolution of vehicle propulsion systems towards more advanced and efficient alternatives (see Figure 1.2) [7].

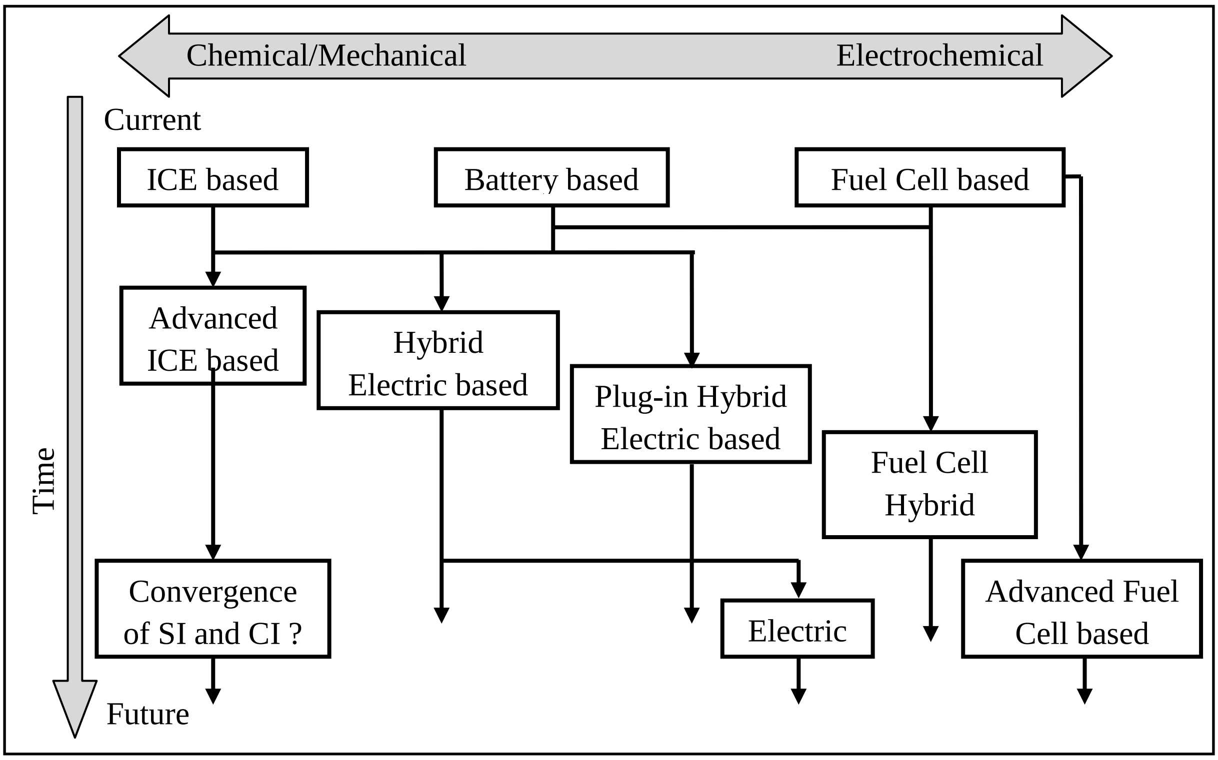


Figure 1.2: Vehicle propulsion system pathways

The current vehicle propulsion system is dominated by IC engines, where the basic energy conversion process is the combustion of fuel. There are two distinct methods of combustion spark-ignition (SI) employed with gasoline engines and compression ignition (CI) employed with diesel engines. Advances in these two technologies and fuels are expected to contribute greatly toward reducing use of petroleum and GHG emissions from transportation. Further, electric drives will act as a bridging technology to other alternative propulsion technologies such as all-electric battery vehicles (EBVs), hybrid-electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs) and hydrogen fuel cell vehicles (FCVs). Although the penetration of these propulsion systems is still low, significant increasing trends are seen in the recent past, in particular, due to advances in battery technologies.

Among the different pathways shown in Figure 1.2 above, it is not yet clear which one would dominate in the future. However, it could be expected that mainstream ICEs will continue to dominate light-duty vehicle propulsion systems for the next few decades.

1.5 Fuel Economy in Light Duty Vehicles

There are a number of factors that affect the fuel economy of any vehicle, such as:

- Vehicle type/size
- Vehicle age and accumulated distance travelled
- Fuel used

- Tire type and maintenance
- Maintenance condition of the vehicle
- Traffic conditions (or driving cycle) and how the vehicle is driven
- Road conditions
- Ambient weather conditions.

Considerable progress in performance improvements of fuel economy (and CO_2 emissions) in vehicles has been achieved with technology innovation and deployment, and further improvements are stipulated in the future through variety of interventions for reducing losses across propulsion and non-propulsion systems, as listed in Table 1.2 [6], [7].

Table 1.2: Energy loss reduction opportunities in ICE vehicles

<table>
<tr><th>Category</th><th colspan="2">Field of improvement</th></tr>
<tr><td rowspan="11">Propulsion Systems</td><td colspan="2">Friction reduction opportunities (include improved materials and designs)</td></tr>
<tr><td colspan="2">Smart cooling systems, which can reduce engine heat losses</td></tr>
<tr><td>Variable valve lift & timing systems</td><td>Variable compression ratio engines</td></tr>
<tr><td>Gasoline direct-injection</td><td>Transmission system improvements</td></tr>
<tr><td colspan="2">Cylinder deactivation or cut-out system</td></tr>
<tr><td colspan="2">Camless valve-trains for improved valve timing control</td></tr>
<tr><td colspan="2">Higher pressure fuel injection in diesel engines</td></tr>
<tr><td colspan="2">Improved thermal and exhaust gas recirculation management</td></tr>
<tr><td colspan="2">Homogeneous charge compression ignition</td></tr>
<tr><td>Secondary Air Injection</td><td>Pre-chamber / Swirl Chamber</td></tr>
<tr><td>Controlled Auto-ignition</td><td>Advanced Turbochargers</td></tr>
<tr><td rowspan="3">Non-propulsion Systems</td><td colspan="2">Improvements in vehicle aerodynamics for reduction of drag</td></tr>
<tr><td colspan="2">Improvements in tire rolling friction</td></tr>
<tr><td colspan="2">Vehicle weight reduction</td></tr>
</table>

It is important to recognize that, even for modern vehicles with much improved performance capabilities, on the road fuel consumption and emissions are highly dependent on several other factors related to operational environment of the vehicles. In particular, the traffic conditions and the how the vehicle is driven could significantly affect the fuel economy. Under these circumstances, the concept of eco-driving has been emerged. Several eco-driving schemes have been developed worldwide, which are in general multi-faceted and include both training and communications components [8]. Typically, eco-driving provides techniques/behaviours associated with the following attributes [9]:

- Accelerate moderately
- Anticipation of traffic flow and signals thereby avoiding sudden starts and stops
- Maintain an even driving pace
- Drive at (or safely below) the speed limit
- Eliminate excessive idling.

Non-compliance of eco-driving practices could result in considerable reduction in fuel economy of a fuel-efficient vehicle. For example, Table 1.3 presents cumulative effects of fuel economy performance in a passenger car, indicating a total improvement of 45% [10].

Table 1.3: Measures to promote fuel-efficient vehicles

Factor (effect on performance)	Fuel Economy Improvement (%)	Fuel economy (km/litre)
Nominal performance	-	15.00
Aggressive driving(1)	25%	11.25
Driving at excessively high speeds(2)	6%	10.58
Route selection (road type, grade & congestion) (3)	6%	9.94
Out-of-tune engine(4)	4%	9.54
Tires with increased rolling resistance(5)	4%	9.16
Using air conditioner(6)	4%	8.79
Excessive idling(7)	2%	8.62
Extra weight(8)	1.5%	8.49
Improper oil	1.5%	8.36
Under-inflated tires(9)	1.5%	8.24

(1) Not using cruise control included.
(2) Driving at very high speeds on 20% of the total distances driven.
(3) Two possible routes (with different road types, grade profiles, and/or levels of congestion) are available 20% of the total distance driven.
(4) Faulty oxygen sensor (infrequent in relatively new vehicles) could result in a fuel economy drop of 40%.
(5) Replacement tires with 25% higher rolling resistance than originally equipped tires.
(6) Used during 25% of the total distance driven. At very high speeds the windows are up.
(7) Turning off the engine during two 1-minute idle periods per each 15 km.
(8) Extra 50 kg of cargo.
(9) Under-inflation of all four tires by 5 psi.

The achievements in technology advancements in ICEs (with both conventional and hybrid drive-trains) have been persuaded by the strong regulatory efforts in number of countries including Japan, Europe, and the United States. In addition, several other measures could be implemented to promote fuel-efficient vehicles usage in a country. For example, Table 1.4 summarizes such major approaches to reduce fuel consumption and GHG emissions from LDVs [11].

Recent estimates suggest substantial additional, unrealized potentials exist with up to 50% improvements in vehicle fuel economy in MJ/km or litres/100 km units (or equal to 100% when measured as km/MJ, km/litre). Although most countries have emission regulations in road vehicles, they usually deal with air pollutants than GHG emissions. However, most OECD countries have established programmes to address transportation related GHG emissions [2]. Fuel economy programmes and GHG emission targets, either mandatory or voluntary, have proven to be among the most cost-effective tools in controlling oil demand and GHG emissions from vehicles, thus could be adopted worldwide. The overall effectiveness of standards can be significantly enhanced if combined with fiscal incentives and consumer information. Taxes on vehicle purchase, registration, use, and motor fuels, as well as road and parking pricing policies, are important determinants of vehicle energy use and emissions. More details of fuel economy standards are discussed in the next section.

Table 1.4: Measures to promote fuel-efficient vehicles

Approach		Measures/forms	Country/region
Standards	Fuel economy	Numeric standard averaged over fleets or based on vehicle weight-bins or sub-classes	US, Japan, Canada, Australia, China, Republic of Korea
	GHG emissions	g CO_2/km or g CO_2/mile	EU, California (US)
Consumer Awareness	Fuel Economy/ GHG emission labels	mpg, km/l, l/100 km, g CO_2/km	Brazil, Chile, Republic of Korea, US and others
Fiscal Incentives	High fuel taxes	Fuel taxes at least 50% greater than crude price	EU, Japan
	Differential vehicle fees and taxes	Tax or registration fee based on engine size, efficiency & CO_2 emissions	EU, Japan, China
	Economic penalties	Gas guzzler tax	US
Support for new technologies	R&D programmes	Funding for advanced technology research	US, Japan, EU, China
	Technology mandates and targets	Sales requirement for Zero Emission Vehicles (ZEVs), Plug-in HEVs and EVs	California (US), China
Traffic control measures	Incentives	Allowing hybrids to use high occupancy vehicle (HOV) lanes	California, Virginia and others states in the US
	Disincentives	Banning SUVs on City Streets Inner city congestion charges	Paris, London

1.6 Fuel Economy Standards

In case of a vehicle, the fuel economy could be defined as the fuel efficiency relationship between the distance travelled and the amount of fuel consumed by the vehicle under typical driving pattern or conditions (refers to as the driving cycle). Certification of fuel economy performance (and GHG emission) and for new vehicles is based on test procedures intended to reflect real world driving conditions and behaviour in each country. Accordingly, fuel economy standards are specified in terms of volume of fuel to travel a given distance (e.g. litres/100 km), or the distance travelled per unit volume of fuel consumed (e.g. km/litre) under a specific driving cycle. Automobile GHG emission standards are usually expressed as mass per unit distance (e.g. g CO_2/km).

It should be noted that, as the fuel-base or energy source of transportation is becoming more diverse, use of volume of fuel (which refers to liquid only) has limitation for comparison of fuel economy (or energy efficiency) between different types of vehicles, technologies or fuels (for instance IC engine vs electric or plug-in hybrid. Even among liquid fuels, the energy content (i.e. calorific value) varies, and thus energy input per unit volume may have significant differences. For example, the calorific value of diesel fuel is roughly 45.5 MJ/kg, slightly lower than petrol which is 45.8 MJ/kg. However, diesel fuel is denser than petrol and contains about 15% more energy by volume (roughly 36.9 MJ/litre compared to 33.7 MJ/litre) [12]. Therefore, use of an energy unit (e.g. MJ or kWh) than the volume to specify fuel economy (or more precisely energy efficiency) becomes more logical. Yet, most commonly used unit for fuel economy is volume based, expressed in terms of gasoline equivalent.

More significantly, most countries with large auto markets (in particular US, EU, China and Japan) regulate passenger vehicle fuel efficiency (or CO_2 emissions) with different approaches in designing regulations, and use different underlying drive cycles and test procedures to certify that a vehicle complies with the standards. US used to regulate vehicles based on corporate average fuel economy (CAFE) standards, which required each manufacturer to meet two specified fleet average fuel economy levels for cars and light trucks, respectively. However policy makers are now shifting to a “footprint-based” approach, which regulates GHG emissions instead of fuel economy. Canada has implemented a voluntary agreement with automakers, and intends to reduce GHG emissions from new and in-use vehicles. EU is also in the midst of dramatic changes in its fuel economy policies. Until 2009, the EU promoted a voluntary standard. However, as it became increasingly evident that automakers were not going to achieve the voluntary standard, it was made mandatory and is now based on a weight-based limit value curve. China and Japan have set tiered, weight-based fuel economy standards. Japan’s standards allow for credits and trading between weight classes, while China sets minimum standards that every vehicle must achieve or exceed. Fuel economy standards in the Republic of Korea are based on an engine size classification system [11], [13].

Testing methods followed also differ from country to country, and include different driving cycles. In general, driving cycles are used to assess the fuel economy and emission performance (both GHG and air pollutants) of vehicles as well as traffic impact. There are two main categories of test cycles: legislative cycles employed in type-approval tests for vehicles emissions certification and non-legislative cycles mainly used in research. EU, Japan, and US have established their own test procedures/driving cycles, viz the new European drive cycle (NEDC), newly established JC08 cycle tests, and US city and highway cycles (US CAFE procedure represents 55/45 split of the city and highway cycles), respectively. China and Australia follows EU NEDC testing procedure, while the Republic of Korea is following testing methods that are similar to US CAFE testing procedure. Each of these driving cycles has advantages and drawbacks. For example, EU NEDC, which consists of several steady-steady test modes, is quite simple to drive and thus repeatable. However, NEDC does not represent real driving behavior of a vehicle in actual traffic thus, does not necessarily reflect pollutant emissions and fuel consumption. JC08 represents real driving behavior but only in congested city traffic situations and does not cover other driving conditions and road types. In order to address this issue, the World-wide Harmonized Light-duty Test Cycle (WLTC) is been developed to represent typical driving characteristics around the world. WLTC is not yet officially in use anywhere but expected to be adopted in the EU and Japan (and probably by other governments as well) beginning in 2017 [11], [13], [14].

Table 1.5 summarizes the specific LDV fuel efficiency and GHG emission policy approaches together with the driving cycles adopted by different countries and regions [15].

Table 1.5: Overview of LDV fuel efficiency and GHG emission policy approaches

Country or Region	Target year	Standard type	Unadjusted fleet target/ measure	Structure	Targeted fleet	Test cycle
US (include California) (enacted)	2016	Fuel economy/ GHG	34.1 mpg(1) or 250 gCO_2/mile	Size-based corporate avg.	Cars/Light trucks	US CAFE
US (enacted)	2025		49.1 mpg(2) or 165 gCO_2/mile			
Canada (enacted)	2016	GHG	153 (157) (3) gCO_2/km	Size-based corporate avg.	Cars/Light trucks	US CAFE
EU (enacted)	2015	CO_2	130 gCO_2/km	Weight-based corporate average	Cars/SUVs	EU NEDC
EU (proposed)	2020		95 gCO_2/km			
Japan (enacted)	2015	Fuel economy	16.8 km/l	Weight-class based corporate average	Cars	JC08
Japan (enacted)	2020		20.3 km/l			
China (enacted)	2015	Fuel economy	6.9 l/100-km	Eight-class based per vehicle and corporate average	Cars/SUVs	EU NEDC
China (under study)	2020		5 l/100-km			
South Korea (enacted)	2015	Fuel economy/ GHG	17 km/l or 140 gCO_2/km	Weight-based corporate average	Cars/SUVs	US CAFE
Mexico (enacted)	2016	Fuel economy/ GHG	35.1 mpg or 157 g/ km	Size-based corporate avg.	Cars/Light trucks	US CAFE
Brazil (enacted)	2017	Fuel economy	1.82 MJ/km	Weight-based corporate average	Cars	US CAFE
India (proposed)	2016	CO_2	130 g/km	Weight-based corporate average	Cars/SUVs	EU NEDC
	2021		113 g/km			

(1) Assumes manufacturers fully use A/C credit.
(2) Proposed CAFE standard by NHTSA. It is equivalent to 163 g/mile plus CO_2 credits for using low-GWP A/C refrigerants.
(3) In April 2010, Canada announced a target of 153 g/km for MY2016. Value in brackets is estimated target for MY2016, assuming that during 2008 and 2016 the fuel efficiency of the light-duty fleet in Canada will achieve a 5.5% annual improvement rate (the same rate as the US).

Figure 1.3 presents the estimated historical fleet fuel economy and CO_2 emissions performance and current or proposed passenger vehicle standards in different countries and regions. Note that, as there is a great deal of diversity in the standards and test procedures across different countries, the standard values have to be normalized to a single test cycle for comparison. The data presented in Figure 1.3 represents the values normalized to EU NEDC [16].

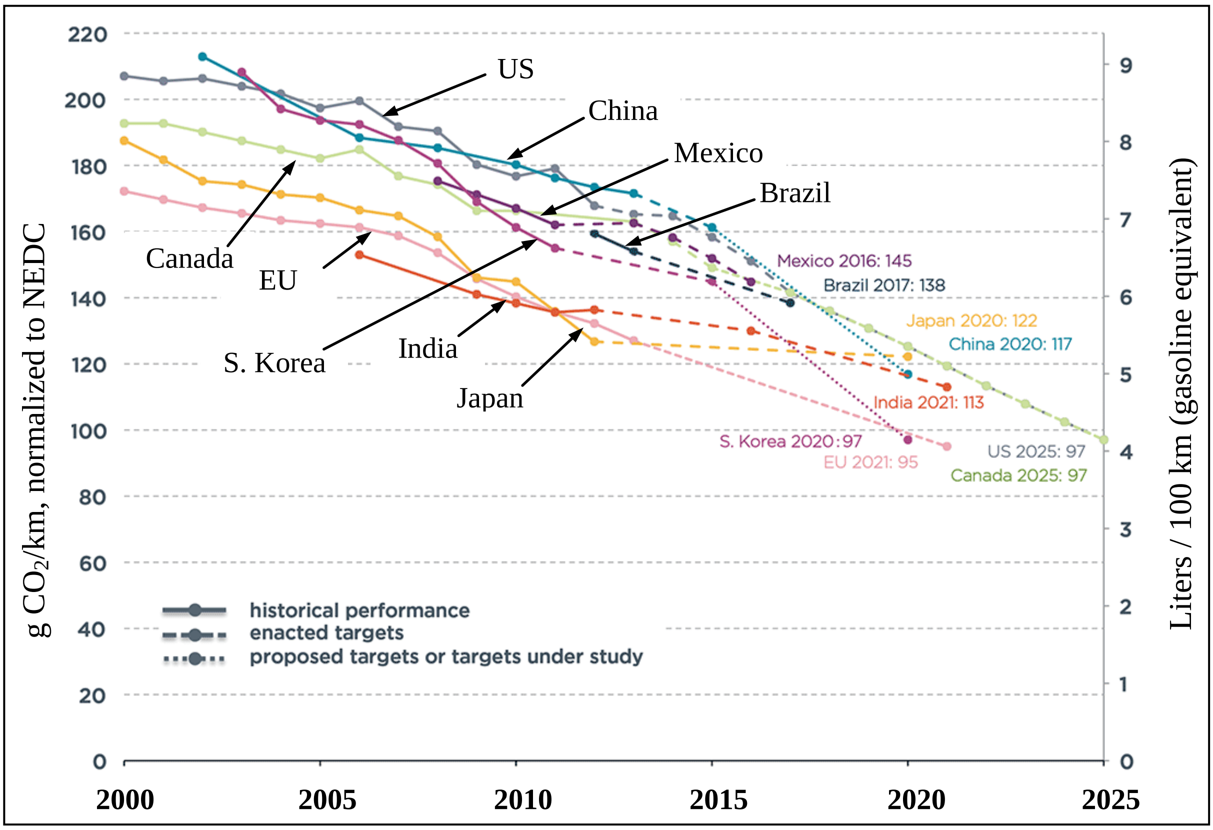


Figure 1.3: Fuel economy and CO_2 emissions performance passenger vehicles

Table 1.6 presents fuel economy averages of passenger cars in selected counties and regions together with global average in 2005, 2008 and 2011 [15].

Table 1.6: Evolution of fuel economy in passenger cars / light-duty vehicles

<table>
<tr><th rowspan="2">Region</th><th rowspan="2">Performance Parameter</th><th colspan="3">Year</th></tr>
<tr><th>2005</th><th>2008</th><th>2011</th></tr>
<tr><td rowspan="3">OECD average</td><td>Average fuel economy (l/100km)</td><td>8.1</td><td>7.6</td><td>7.0</td></tr>
<tr><td rowspan="2">Annual improvement rate (% per year)</td><td colspan="2">-2.2%</td><td>-2.7%</td></tr>
<tr><td colspan="3">-2.4%</td></tr>
<tr><td rowspan="3">Non-OECD average</td><td>Average fuel economy (l/100km)</td><td>7.5</td><td>7.6</td><td>7.5</td></tr>
<tr><td rowspan="2">Annual improvement rate (% per year)</td><td colspan="2">0.4%</td><td>-0.6%</td></tr>
<tr><td colspan="3">-0.1%</td></tr>
<tr><td rowspan="3">Global average</td><td>Average fuel economy (l/100km)</td><td>8.0</td><td>7.6</td><td>7.2</td></tr>
<tr><td rowspan="2">Annual improvement rate (% per year)</td><td colspan="2">-1.7%</td><td>-1.8%</td></tr>
<tr><td colspan="3">-1.8%</td></tr>
</table>

As shown in Table 1.3, the global average annual improvement rate during the period 2005 to 2008 and 2008 to 2011 were about 1.7% and 1.8%, respectively, indicating that the pace of improvement has slightly accelerated. OECD countries show much faster improvements than that of non-OECD countries, and now become better in fuel economy (i.e. 7.0 vs 7.5 l/100-km) on average. As the LDV sales in non-OECD are rising much faster than OECD sales, fuel economy interventions in non-OECD countries would be the key determinant in the future global fuel economy status of the transport sector.

1.7 Global Fuel Economy Initiative Project

1.7.1 Background

Sustainable Energy for All (SE4ALL), an initiative led by the UN Secretary-General and the President of the World Bank, has three objectives for 2030:

- Universal access to modern energy services
- Doubling global rate of improvement of energy efficiency
- Doubling share of renewable energy in global energy mix.

The second objective plays a major role in realizing sustainable socio-economic development, as greater energy efficiency provides a triple rationale for action through advancement towards achieving global climate goals in the form of emissions reductions, economic benefits (increased productivity, lower costs, net job creation) and improvement of people's well-being. In order to assist the national and local governments in reaching the objective of doubling of the global rate of improvement in energy efficiency, the Global Energy Efficiency Accelerator Platform was established, under which a unique alliance of partners are committing to new and expanded actions to accelerate energy efficiency [17]. The Accelerator Platform was established to support five specific sector-based energy efficiency accelerators viz:

- Lighting: Global market transformation to efficient lighting
- Appliances & Equipment: Global market transformation to efficient appliances & equipment
- Vehicle Fuel Efficiency: Improve the fuel economy capacity of the global car fleet
- Buildings: Promote sustainable building policies & practices worldwide
- District Energy: Support national & municipal governments to develop or scale-up district energy systems
- Industry: Implementing Energy Management Systems, technologies & practices.

The Accelerator Platform drives and supports action and commitments by national and sub-national leaders at the country, city, state, regional, or business and sector level as well as by donors, funders and supporters of this initiative. One of the key deliverables of the Accelerator Platform in each sector will be a roadmap, which describes the policies and projects that will be taken in order to achieve the energy efficiency improvements. The Global Fuel Economy Initiative (GFEI) is one of five energy efficiency projects within the Accelerator, which works on the vehicle fuel economy improvements.

The Global Fuel Economy Initiative (GFEI) was launched on 4 March 2009 in Geneva by the United Nations Environment Programme (UNEP) and its partners, namely the International Energy Agency (IEA), the International Transport Forum (ITF), the "Fédération Internationale des Automobiles" (FIA Foundation), the International Council on Clean Transportation (ICCT) and the UC Davis Institute of Transportation Studies (ITS). GFEI works to secure real improvements in fuel economy, and the maximum deployment of existing fuel economy technologies in vehicles across the world through in-country policy support, analysis and advocacy.

1.7.2 GFEI Fuel Efficiency Targets

The overall objective of the GFEI is to stabilize greenhouse gas emissions from the global light duty vehicles fleet through a 50% improvement of vehicles fuel efficiency worldwide by 2050 (thus referred to as "50 by 50" campaign) with respect to the base-year of 2005 (see Table 1.7). The GFEI target is to double the efficiency of all new vehicles by 2030 from 8 l/100 km to 4 l/100 km and to achieve the same for the complete global vehicle fleet by 2050. The corresponding drop in CO_2 emissions would be from an average of around 180 g/km to 90 g/km. This would save over 1 Gt of CO_2 a year by 2025 and over 2 Gt/yr by 2050, and result in savings in annual oil import bills alone worth over US$ 300 billion in 2025 and US$ 600 billion in 2050 [18].

Table 1.7: GFEI Fuel Efficiency Targets (relative to a 2005 baseline)

Vehicle category	Year		
	2020	**2030**	**2050**
New cars	30% reduction in l/100km compared to 2005 Mainly from incremental efficiency improvements to engines, drive-trains, weight, aerodynamics and accessories(1)	50% average improvement globally Mainly from incremental improvements and full hybridisation of most models of vehicles(1)	50%+ globally (currently unspecified target) Additional improvements in new car fuel economy from light-weighting, shifts to electric motor drive, possible adoption of fuel cell vehicles
Total Fleet	20% reduction Improvements in new car fuel economy (with some lag time for stock-turnover) and additional measures such as eco-driving, improved aftermarket components, better vehicle maintenance, etc.	35% reduction From new car improvements and on-road improvement measures	50% reduction (50 by 50: the Ultimate Goal) Following the new car improvement in 2030 and with in-use improvement measures

(1) Plug-in hybrids, electric and fuel cell vehicles are not required to meet these targets but certainly may help to reach it (reach it faster or even exceed it).

Table 1.8 presents the fuel economy status of LDV and personal cars worldwide and long-term GFEI target comparison. The global average of fleet fuel economy in 2013 was at about 7.1 l/100 km (gasoline equivalent), with countries in OECD averaging 6.9 l/100 km and countries in non-OECD averaging 7.2 l/100 km. The annual rates of improvement for both OECD (2.6%) and non-OECD countries (0.2%) from 2005 to 2013 are lower than what is expected in order to reach the GFEI target of halving fuel for new light-duty vehicles and personal cars consumption by 2030 (see Table 1). As such, there will be a need to accelerate annual improvements by about 3.1% per year from 2012 to 2030 to reach the target [19].

Table 1.8: Fuel economy status worldwide and long-term GFEI target comparison

<table>
<tr><th rowspan="2">Region</th><th rowspan="2">Performance Parameter</th><th colspan="5">Year</th></tr>
<tr><th>2005</th><th>2008</th><th>2011</th><th>2013</th><th>2030</th></tr>
<tr><td rowspan="3">Global average</td><td>Average fuel economy (l/100km)</td><td>8.0</td><td>7.6</td><td>7.2</td><td>7.1</td><td></td></tr>
<tr><td rowspan="2">Annual improvement rate (% per year)</td><td colspan="2">-1.7%</td><td>-1.8%</td><td></td><td></td></tr>
<tr><td colspan="4">-1.7%</td><td></td></tr>
<tr><td rowspan="3">GFEI target</td><td>Average fuel economy (l/100km)</td><td>8.0</td><td colspan="3"></td><td>4.0</td></tr>
<tr><td rowspan="2">Required improvement rate (% per year)</td><td colspan="5">-2.7%</td></tr>
<tr><td colspan="4">2012 base year →</td><td>-3.1%</td></tr>
</table>

1.7.3 GFEI Programmes

The main activities conducted by GFEI include the following [20]:

- Development of improved data and analysis on fuel economy around the world, monitoring trends/progress over time and assessing the potential for improvement;
- Work with governments to develop policies to encourage fuel economy improvement for vehicles produced or sold in their countries and to improve the consistency and alignment in policies across regions in order to lower the cost and maximize the benefits of improving vehicle fuel economy;
- Work with stakeholders including auto makers to better understand the potential for fuel economy improvement and solicit their input and support in working toward improved fuel economy;
- Support regional awareness initiatives to provide consumers and decision makers with the information they need to make informed choices.

The strategy development and implementation of automotive fuel economy policies, strategies and standards are planned in three phases, as illustrated in Figure 1.4. Phase I of the GFEI project is a preparatory stage where the essential approaches and tools are developed for a global roll out of national actions, having the following planned outcomes [21]:

- National-level strategies and plans prepared in 4 GFEI pilot countries with supporting expertise and resources from the GFEI;
- A global database including auto fuel efficiency information at the national level for developing and transitional countries;
- The Auto Fuel Efficiency and Climate Change: a tool for national strategy development tool finalized, field tested and ready for roll out in Phase II to additional countries, available in online and CD versions;

- Methodology for creating a baseline for emissions and basic data for existing fleets in developing countries, to be used in the pilot countries and toward building greater regional and global tracking of emissions and reductions from the light duty vehicle sector toward 50by50.

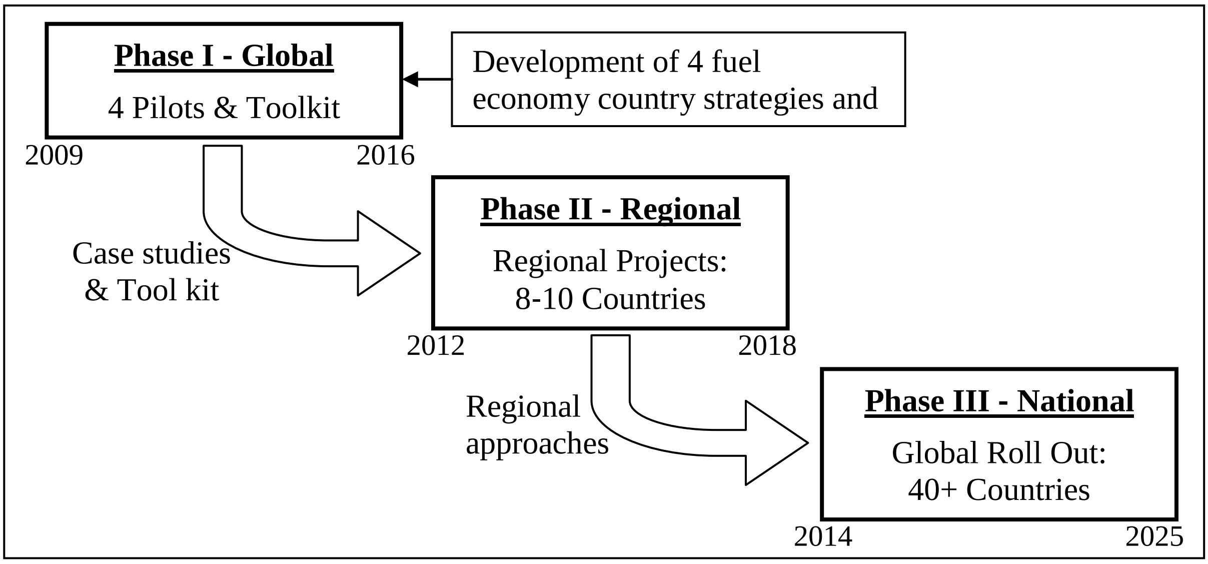


Figure 1.4: GFEI strategy development and implementation phases [21]

The results of Phase I will be used for Phase II and Phase III rolling out the GFEI to the global level. Presently, this initiative is being implemented in 25 countries across Asia (including Sri Lanka), Europe, Latin America and Africa, which is higher than the number of countries planned in the project proposal. Further, GFEI has launched ‘100 for 50by50’ - an ambitious pledge ahead of the COP21 Climate Summit in Paris in December 2015, with the target to involve 100 countries in its fuel economy capacity-building work by 2016 [22].

1.7.4 GFEI Toolkit

The GFEI toolkit is aimed at policy makers seeking to understand and design effective policies to improve energy efficiency and lower greenhouse gas emissions in their countries. It contains guidance coupled with case studies describing what is being done to improve automotive fuel economy around the world. The toolkit is made up of five sections [19]:

- Introduction to GFEI;
- Explanation of different Instruments that countries can use, such as standards, taxes or labelling schemes;
- Case studies from different countries;
- Resources, such as a step by step guide to developing a data baseline;
- Global overview, which shows which countries have different instruments in place.

Upcoming updated to the GFEI Toolkit will include additional country content and case studies, expanded content on fee-bate design, and a GFEI fuel economy projection feature that will allow countries to estimate future vehicle stock efficiency based on current data and the baseline exercise that is at the core of the GFEI approach.

Within the section on resources, GFEI Toolkit provides a tool, referred to as the Fuel Economy Policies Impact Tool (FEPIt), developed by IEA on estimation of impact of fuel economy policies in a country. FEPIt builds on the data gathered for the national fuel economy baseline, in which the projections are based on the newest trends of the average fuel economy of all newly registered vehicles (both new and second hand) and on the vehicle market structure. Based on the vehicle registration data and a fuel economy target, this tool estimates what a set of fuel economy policies (and their level of ambition) can deliver in terms of average auto fuel economy in the future [23].

GFEI formulated a four-step process to support the development of policies to improve fuel economy of vehicles: Plan, Implement, Monitor, and Evaluate, as given in Table 1.9 [19].

Table 1.9: Development process for fuel efficiency policies

Phases	Critical steps	Actions
Plan	Decide scope, type and schedule of policies	Gather information; Determine scope and type of fuel economy measures; Consult on policy schedule and stakeholders; Decide target year aligned with national goals.
	Decide measurement method	Gather information about traffic conditions; Determine measurement approach; Develop driving cycle.
	Secure resources	Allocate fiscal and human resources; Develop system for gathering and certifying essential information; Engage in broad consultation.
	Design policies	Fuel economy labelling and information; Fuel economy standards; Fiscal measures
Implement	Certify fuel economy	Decide fuel economy certification process, utilizing existing vehicle certification schemes; Define certification vehicle category
	Make information accessible to public	Require manufacturers to display fuel economy information; Public fuel economy information on government website; Time release of information when introducing fiscal incentives.
Monitor	Check compliance with fuel economy policies	Check data to monitor fuel economy; Check conformity of vehicle sold; Check compliance with policies.
	Publish monitoring data	Publish information on trends of average fuel efficiency to fulfil government's accountability; Publish information on most fuel-efficient vehicles to attract public's attention.
Evaluate	Evaluate and enforce policies	Evaluate level of compliance and enforce penalties; Evaluate impacts of fuel economy policies.
	Revise policies	Change design and mix of fuel economy policies, if needed; Develop new target values as technology improves.

Sri Lanka intends to follow the above procedure in developing the national programme on fuel economy.

SECTION 02: TRANSPORT SECTOR IN SRI LANKA - AN OVERVIEW

2.1 Country Profile

2.1.1 Geography and Demography

Sri Lanka (officially the Democratic Socialist Republic of Sri Lanka) is an island located in Indian Ocean. The maximum length and width of Sri Lanka is 432 km North to South and 224 km West to East, respectively. Total area of Sri Lanka is 65,610 km^2, which comprised of 62,705 km^2 land area and 2,905 km^2 inland water area. The total forest cover is 16,598 km^2. The island consists mostly of flat-to-rolling coastal plains, with a mountainous area in the south-central part. The climate of Sri Lanka can be described as tropical and warm. The mean temperature ranges from about 17 °C in the central highlands to a maximum of approximately 33 °C in other low-altitude areas. Rainfall pattern of the country is influenced by Monsoon winds from the Indian Ocean and Bay of Bengal [24].

In 2014, the estimated mid-year population of Sri Lanka was about 20.77 million and population growth rate was 0.9%, with a population density of 331 persons/km^2. The Colombo District has the highest population of about 2.36 million, while over 750,000 people living in the Colombo City. In 2013, the literacy rate in local languages is about 92.5% and life expectancy is 74.3 years [25].

2.1.2 Economy

Sri Lanka is a lower-middle income developing nation with a GDP of about US$ 74.9 billion in 2014 and per capita GDP of about US$ 3,608. The currency is the Sri Lankan Rupee (LKR), and the average exchange rate of which during 2014 was about 130.6 LKR/US$. Sri Lanka has seen strong economic growth of 7.4 per cent in 2014. During last three decades or so, Sri Lanka's export-oriented policies have seen a shift from agricultural exports (tea, rubber, coconut and several varieties of spices) to the services and manufacturing sectors. In 2014, the services sector accounted for almost 57.6% of GDP, while that of industrial sector was 32.3%. The agriculture sector, though decreasing in importance to the economy, accounts for around 10.1 % of GDP [25], [26]. Industrial development in Sri Lanka is still at a stage where only a handful of large-scale industries exist but a large number of industries operate on micro, small and medium scales. Human Development Index of Sri Lanka in 2013 was 0.75 with a rank of 73 among 187 countries, which is a gain in the rank by five within a 5-year period [27].

2.1.2 Constitutional Structure

The national constitution of 1978 forms the supreme law under the Executive Presidency and a single House of Parliament. The country is divided for administrative purposes into nine provinces. The provinces are divided into 25 districts, each headed by a Government Agent and districts are divided into 280 divisions each headed by a Divisional Secretary. The 13th amendment to the Constitution in 1987 provided for the devolution of power to the provinces and provinces are now the fundamental administrative units of regional governance. Local government is in the hands of Municipal Councils, Urban Councils in urban areas and the Pradeshiya Sabhas at the Divisional level. Colombo is the commercial capital of Sri Lanka, and the administrative capital is Sri Jayewardenepura-Kotte, a suburb east of the city.

2.1.4 Energy Sector

The primary energy supply in Sri Lanka is mainly based on four sources: biomass, petroleum oil, coal and hydroelectricity. In 2014, the total primary energy supply was approximately 11,631.4 thousand Tonnes of Oil Equivalent (TOE), in which biomass accounted for 42.2%, petroleum 39.8%, major hydro-electricity 7.5%, coal 7.9% and the balance 2.6% is new renewable energy (NRE) resources (including small hydro, wind, biomass and solar). In the same year, domestic & commercial sector contribute to about 44.7% of the total energy demand, while transport and industrial sectors contribute to 29.4% and 25.9%, respectively. Figure 2.1 presents historical total energy demand by sector from 1976 to 2014 [28], [29]. It can be seen that the percentage share of transport sector on the energy demand has been in increase throughout.

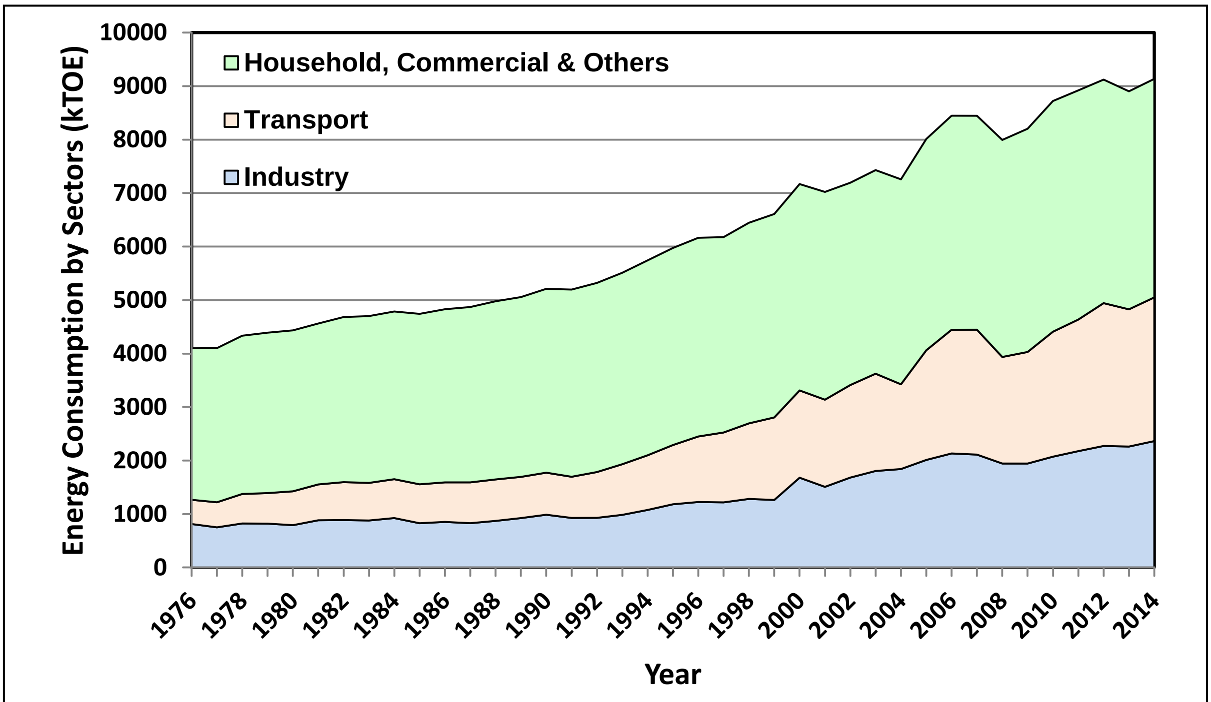


Figure 2.1: Total energy demand by sector

In 2014, per capita primary energy consumption was about of 440 kg of Oil Equivalent (kgOE), while per capita electricity consumption was 530 kWh. By the end of 2014, the total installed capacity of grid-electricity generation plants was 3,932 MW, which comprised of major hydro - 1377 MW, oil - 1215 MW, coal - 900 MW and NRE - 440 MW. The gross grid electricity generation was 12,357 GWh. Figure 2.2 presents gross electricity generation by source since 1977, where the increase in the contribution from thermal generation (oil and more recently coal) is evident. Presently, NRE contributes to about 10% of grid electricity generation, and the government target is to reach 20% by 2020. The household access to grid electricity has reached 98% in 2014 and the target is to reach 100% by 2016 [28], [30].

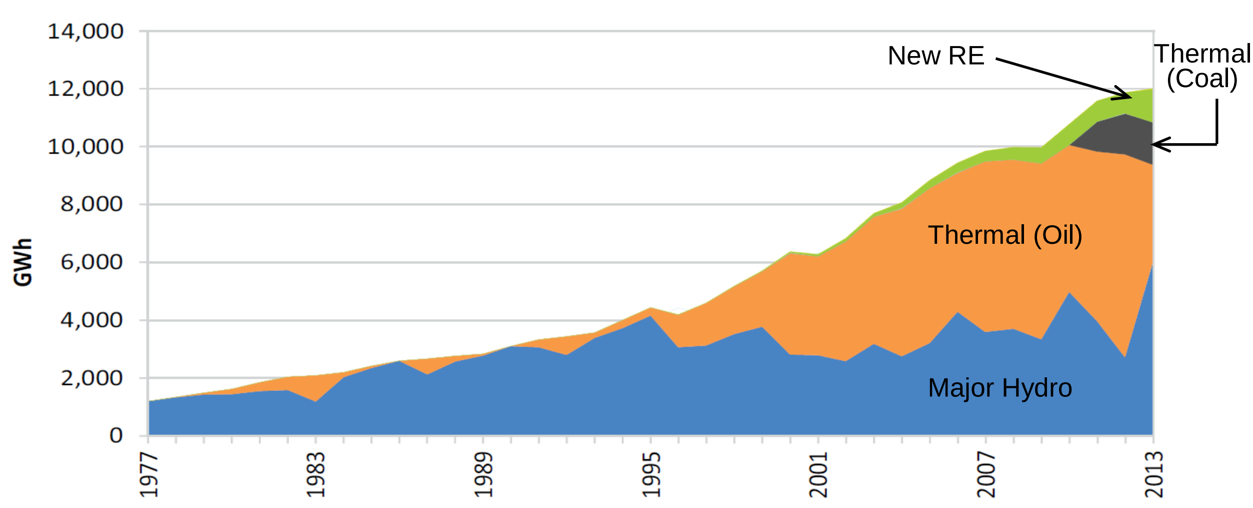


Figure 2.2: Gross electricity generation by source

The energy sector comes under the purview of Ministry of Power & Energy and number of institutions under the ministry manages the different energy sub-sectors. Ceylon Electricity Board (CEB) and several independent power producers generate electricity in Sri Lanka. CEB operates the transmission system and grid substations. Both CEB and Lanka Electricity Company (LECO) distribute electricity. New renewable energy (small hydro, wind, solar, biomass, etc.) sector development and energy management are administered by Sri Lanka Sustainable Energy Authority (SLSEA). Public Utilities Commission of Sri Lanka (PUCSL) is the electricity sector regulator.

2.1.5 Petroleum Sector

Sri Lanka does not have fossil fuel resources, but recent explorations indicate presence of gas reserves (most probable). More detailed investigations are required to identify technical and economic potentials. The country has long been an importer of refined products for domestic consumption. But, after the refinery was commissioned in 1969 (the only refinery in the country is owned and operated presently by the state-owned Ceylon Petroleum Corporation - CEYPETCO), the dependence on imported refined products came down drastically for many categories of petroleum products. However, this situation has changed since the late 1980s, as country's demand for petroleum products has been rising at a rapid rate. The refinery, having a capacity of processing 50,000 barrels of crude oil per day, converts imported crude oil to refined products to supply approximately one-third of the petroleum demand of the country. During the year 2014, the crude oil and refined petroleum products imports were 1,824 and 3,385 thousand metric tons, with annual expenditure of about 1.44 and 3.00 billion US$, respectively. At present, the government is in consideration to upgrade and expand the refinery in response to the issues arisen from fuel quality and also the declining trends in market share. The total expenditure for petroleum imports was about 6% of GDP [26]. The annual sales of petroleum products are presented in Figure 2.3. About 70% of the petroleum is consumed by the transport sector, where the main fuel is diesel [29].

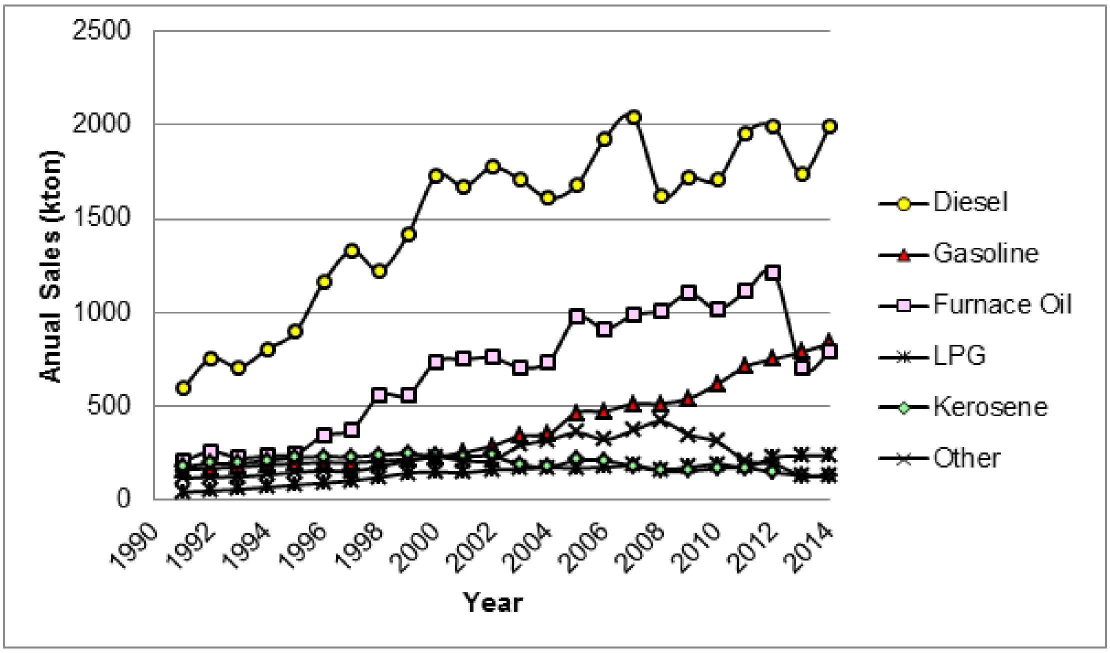


Figure 2.3: Annual sales of petroleum products

The contribution of the refinery to meet the local demand has come down over the years. Hence, the increase of domestic demand has basically met from the imported products. Accordingly, the country has spent an increasing proportion of its import bill on the importation of refined petroleum products. The high expenditure for the importation of petroleum has become a major factor affecting adversely the economy of the country, thus improvement of energy efficiency/fuel economy in the transport sector has become a national priority. Table 2.1 provides data on expenditure for the importation of petroleum (both crude oil and refined products including Liquefied Petroleum Gas - LPG), in comparison with country's total export and import values [26], [31], [32].

Table 2.1: Petroleum imports and its impacts on economy

Year	Expenditure (Million US$)	% of Exports	% of Imports
1980	449	42.7	21.9
1985	398	37.4	20.4
1990	357	18.0	13.2
1995	387	10.2	7.3
2000	901	16.3	12.3
2005	1655	26.1	18.7
2010	3041	35.4	22.6
2011	4795	45.4	23.7
2012	5,141	52.6	26.8
2013	4,355	41.9	24.2
2014	4,636	41.7	23.9

At present the Ministry of Power & Energy regulates the petroleum industry. The CEYPETCO, in addition to the refinery operation, markets the products in bulk and through retail outlets. Lanka Indian Oil Company (LIOC) imports products and markets them in bulk and through its own retail outlets. Ceylon Petroleum Terminals Ltd (CPSTL), jointly owned by CEYPETCO and LIOC, operate the two main petroleum storage facilities. The LPG industry has two suppliers.

2.2 Administration and Institutions in the Transport Sector

The transport is a subject of national government, as 13th Amendment to the Constitution, Provincial Councils are not vested with power to make statues with respect to the functions set out in the Reserved List. Hence in addition to policy formulation and enactment, the implementation of any subject or function (which has not been explicitly included in the Provincial Council List or Concurrent List) can be enforced by the national government through Acts of Parliament.

Even with having the major responsibilities in transport sector in the country with the national government, they have traditionally been fragmented and are spread over several ministries and agencies. These administrative units used to handle their subjects in isolation, without adequate integration in policy development, planning and programme implementation. Figure 2.4 illustrates the institutional arrangement in the transport sector in Sri Lanka [33].

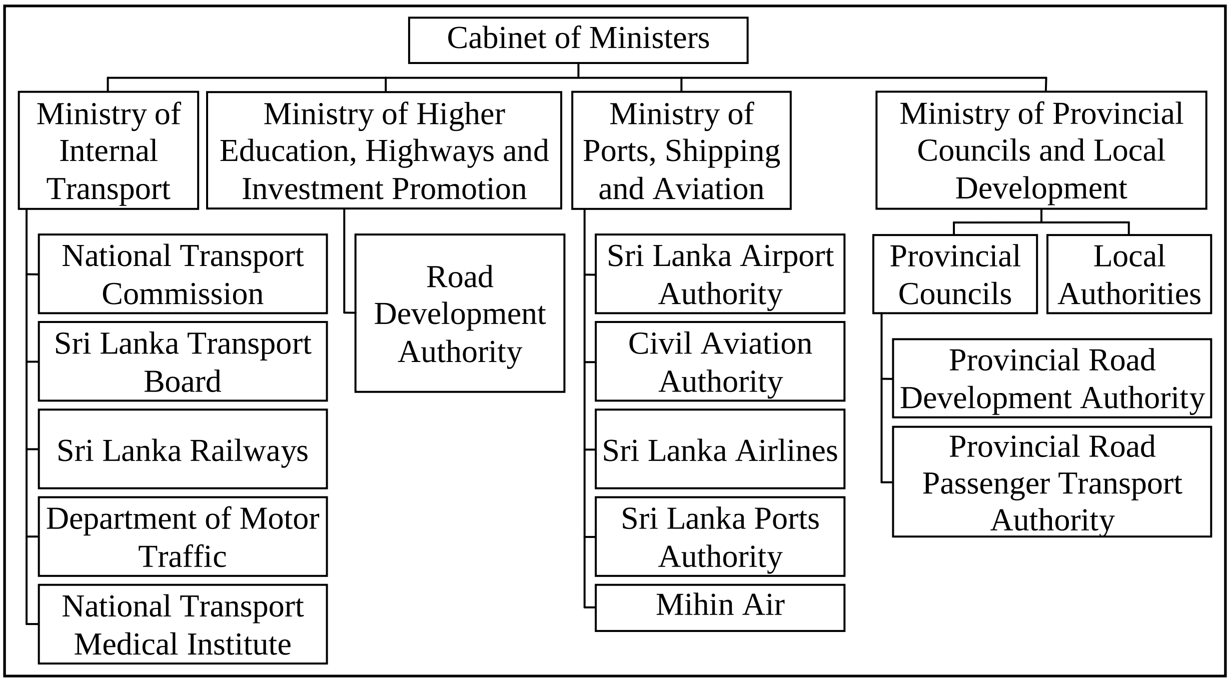


Figure 2.4: Transport sector organization

The public transport sector, except aviation, is managed by the Ministry of Internal Transport, which is responsible for national policy formulation and enactment on areas pertaining transport within national boundaries of the country. The agencies through which the ministry discharges these functions are National Transport Commission (NTC), Sri Lanka Transport Board (SLTB), Sri Lanka Railways (SLR), Department of Motor Traffic (DMT) and National Transport Medical Institute (NTMI).

The NTC has been set up under the NTC Act No 37 of 1991, with the functions advising the government on the national policy relating to passenger transport services by omnibuses. SLTB is given the task to provide bus transport services, and was reconstituted by Sri Lanka Transport Board Act No 25 of 2005, which is the successor to the Ceylon Transport Board (1958-1978), Sri Lanka Central Transport Board and Regional Boards (1978-2005), Peoplized Transport Service (1990-1997) and the Regional Transport Companies (1997-2005). SLR operates as a government department under the provisions of the Railway Ordinance, and provides both passenger and freight transport services. It is the only railway service provider in the country. DMT, established with a view of performing the functions stipulated under the Motor Traffic Act 1951 (and its amendments), has the responsibilities such as registrations of vehicles, issues of driving licenses and other services required by law to drive or use a vehicle on Sri Lankan roads. DMT is also the key organization involved with the implementation of the Sri Lanka vehicle emission testing programme of (SLVET).

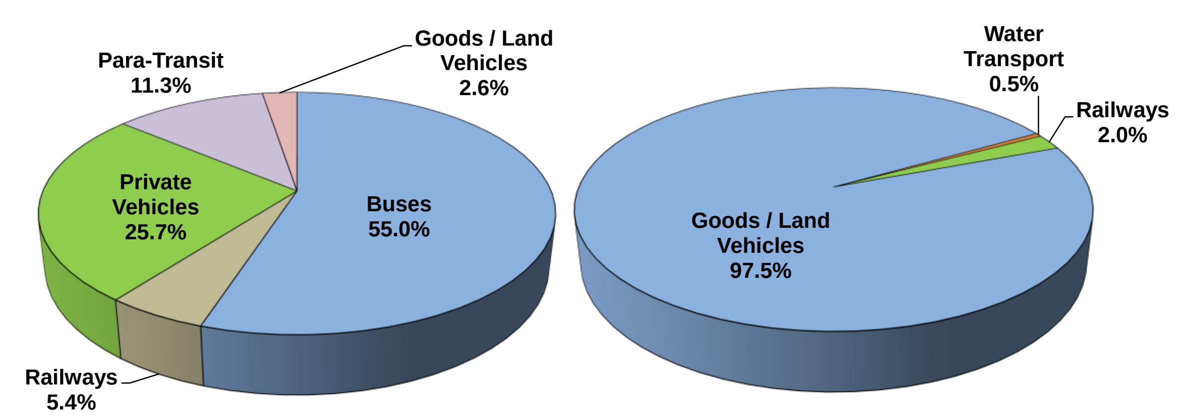
The national highway network, comprising of trunk roads (A Class - sub categorized as AA and AB) and Main roads (B Class), is presently managed by the Road Development Authority (RDA) which is a statutory body under the Ministry of Higher Education, Highways and Investment Promotion incorporated under the RDA Act No.73 of 1981. RDA is also responsible for the planning, designing and construction of new highways, bridges and expressways to augment the existing network. In the meantime, the provincial roads, and rural roads are administrated separately by the Ministry of Provincial Council and Local Government, and local authorities. The scope of activities include

- Local road infrastructure (Class C and D Roads, bridges and ferries within the province)
- Regulation of road passenger carriage services and the carriage of goods by motor vehicles within the province and the provisions of inter-provincial road transport services
- Issuance motor vehicle license.

The Ministry of Ports, Shipping and Aviation has three functional areas viz ports, shipping, and civil aviation. Several institutions operate under the ministry in executing the functions in the above areas, including Sri Lanka Ports Authority (SLPA), Directorate of Merchant Shipping, Ceylon Shipping Corporation Ltd, Central Freight Bureau, Ceylon Port Services Ltd, Civil Aviation Authority of Sri Lanka (CAASL), Air Port and Aviation Services Sri Lanka Ltd, Sri Lankan Airlines Ltd, and Mihin Lanka Ltd [33].

2.3 National Transport Statistics

Sri Lanka relies heavily on road transport, which, in year 2011 contributes to about 94.9 billion passenger-km/y (95.0%), while the rail contributes to the balance 5.4 billion passenger-km/y (5.0%). Major contribution to the passenger transport was from buses (55.0%), while private vehicles (including cars, two-wheelers, and duel-purpose vehicles) contributed to 25.7% and para-transit (mainly three-wheelers, office/school transport services, taxis offered through call centers) contributed to 11.3%. In case of freight, road transport contributes to 6436 million ton-km/y (97.5%), while rail 135 million ton-km/y (2.0%) and water transport 32 million ton-km/y (0.5%), as shown in Figure 2.5 [34]. Use of air transport within the country is very limited, and thus will not be analysed in this report.



(a) Passenger modal share (b) Freight modal share

Figure 2.5: Passenger and freight modal shares

Figure 2.6 presents the historical data on cumulative vehicle registrations in Sri Lanka from 2000 to 2014. During this period, total number of vehicles registered has increased from 1.69 million to 5.61 million (3.33 fold increase) [35]. The main contributions for this change are from three wheelers and two wheelers, where the numbers have increased 9.1 times and 3.6 times, respectively. The cars, dual-purpose vehicles and land vehicles have increased by approximately 2.5 times each, while number of buses has increased only by 50%, indicating shift from public transport modes to private vehicles.

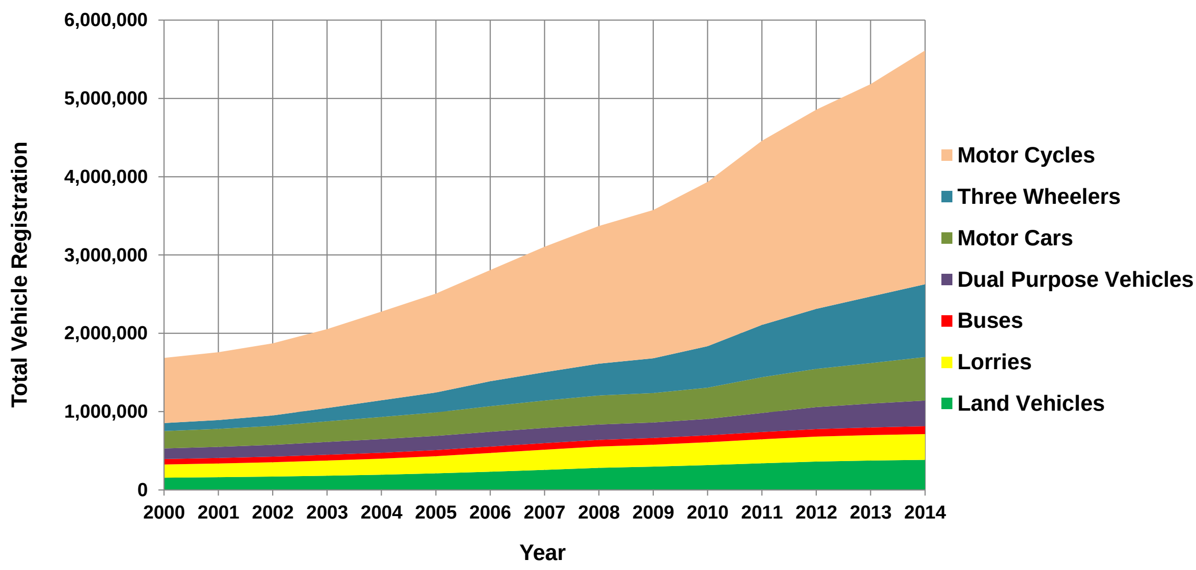


Figure 2.6: Cumulative vehicle registrations 2000 - 2014

Figure 2.7 presents the active vehicle fleet characteristics in 2013, where the total fleet was estimated to be 3.53 million (based on revenue licenses issued) [36].

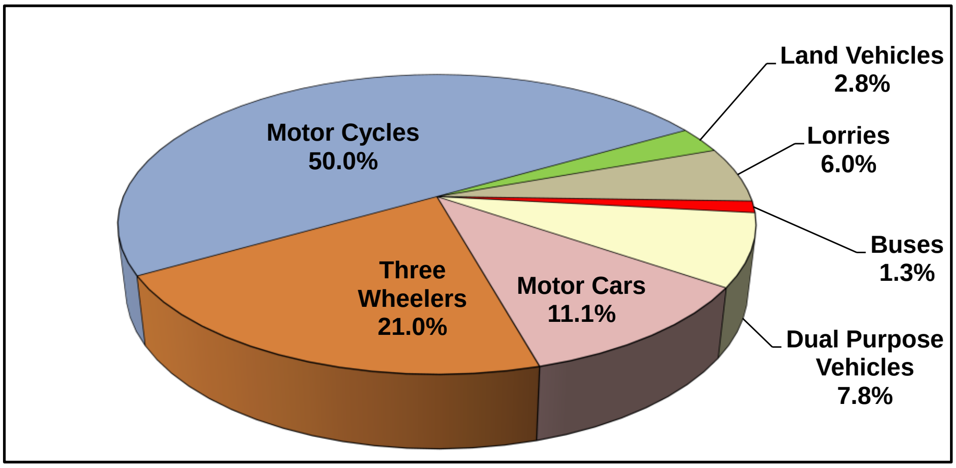


Figure 2.7: Active vehicle fleet in 2013 (based on revenue licenses issued)

The above data indicate that, as the total cumulative registration of vehicles up to 2013 was 5.18 million, the total survival percentage of vehicles was about 68%. It is also important to highlight here the contribution of buses on the passenger transport in Sri Lanka. About 1.3% buses in the active vehicle fleet contribute to 55% of the passenger transport (i.e. passenger-km), while more than 80% of the private vehicles contribute to only 26%.

During the year 2014, on average there were about 26,500 buses operated daily for passenger transport, out of which 18,534 (80%) are private buses and 4,596 (20%) by the state owned SLTB [26].

Another data source for active fleet is the SLVET programme database of VET Office in DMT. The test results during the year 2014 show that the total vehicles tested for emission certification was 3.33 million [37]. The percentages of vehicles tested under different categories are presented in Figure 2.8, which shows a close agreement with the data presented in Figure 2.7 above, which is based on the revenue licenses issued. Note that land vehicles are exempted from the emission testing, though there is a small number undergone the emission testing.

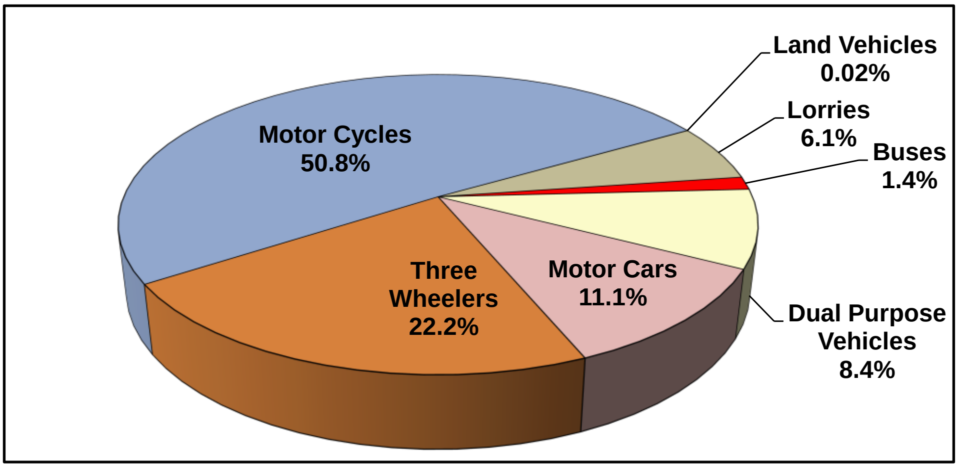


Figure 2.8: Active vehicle fleet in 2013 (based on SLVET data)

In Sri Lanka, the railway transport is a government monopoly, which is managed by SLR. SLR provides both passenger and freight transport services. In 2014, SLR had about 138 locomotives, 565 passenger coaches and 862 good wagons. The total track length of railway system is about 1450 km, with 167 main stations and 153 substations [25].

Contribution of non-motorized transport modes such as walking and cycling has not been quantified, though it is believed to be a significant amount. In Sri Lanka a bicycle is the most accessible multi-functional vehicle for poor families. Bicycles with trailers and extended frames are used to increase the load carrying capacity for passengers or goods. Luggage carriers are used at the front and back of the bicycle in order to carry commercial goods on a small scale such as bread, cigarettes, fish, and vegetables. Fuel wood and water are also carried by bicycle, often for long distances On average every 2 in 3 households in rural areas owns a bicycle, with an estimated 3.5 million cycles used throughout the country, and these bicycle users are serviced by approximately 3500 bicycle repair shops. It is also estimated that there are about 3.5 million bicycles in use, indicating a considerable contribution from non-motorized transport modes. The use of bicycles for recreation, leisure activities, exercise and races by an affluent urban crowd has renewed the interest in bicycles, which is further promoted as an environmentally sustainable transport mode in the recent past [38]. NTC also embarked on a project to promote the usage of bicycles amongst school children as a safe, reliable, and low cost transport option in light of the inadequate public transportation services in rural areas. Under this programme, 3,364 bicycles were distributed by end 2014 [26].

Several projects were carried out with a view to improving the quality of public transportation services in the recent past. NTC commenced a project to form private bus companies instead of having individually operated buses to streamline private bus services. Under this project, 16 companies have already been established. In addition, a bus tracking, monitoring and controlling system has been installed in around 2,095 buses to regulate operations. In spite of these efforts, both SLTB and private bus operators have failed to provide an efficient and good quality transportation service to the public, which has resulted in a loss of considerable amount of man hours in transit and a high fuel bill for the domestic economy [26].

2.4 Road Infrastructure

Total road network in Sri Lanka is about 113,000 km (with a road density is over 1.7 km per km^2), which in Sri Lanka are classified as express ways, national highways, provincial roads, local authority roads, depending on their functionality and ownership. National highways are categorized as Class A (trunk roads) that connects major cities or Class B (main roads) that connects major urban areas, which, together with their 4,200 bridges and other structures, are administered by the RDA. As at August 2014, total length of national highways is about 12,333 km, which comprised of 160 km of express ways (Class E), 4,217 km of Class A roads and 7,956 km of Class B roads [39]. There are about 16,000 km of provincial roads, which are managed by the respective provincial administrations and designated as Class C or D, and about 65,000 km of local authority roads in both the urban and rural sectors. The remaining roads, estimated to total 20,000 km, are owned or controlled by irrigation and wildlife authorities or other government agencies. Although road density and the proportion of roads that are paved are higher in Sri Lanka than in many developing countries, road conditions are reported to be inadequate and cannot handle rapidly growing freight and passenger traffic effectively [40]. In response to the need of road infrastructure developments, the construction of new roads and the rehabilitation of existing roads are considered as a national priority in line with the National Road Master Plan (2007-2017). In this context, several major highway projects and roads and bridge development projects are continued to implement in the recent past years. These efforts are further complemented by the rehabilitation of rural roads in several districts under the “Maga Neguma Rural Roads Development Programme” [26].

2.5 Environment Regulations

2.5.1 General Environment Regulations

There are well over 100 statutes directly or indirectly dealing with environmental matters, some dating back to more than 100 years. The National Environment Act No 47 of 1980 (NEA) and subsequent amendments is the main legislation that encompassed environmental management and protection in Sri Lanka. The enactment of NEA provided the platform to set up the necessary institutional framework to safeguard the environment. NEA facilitated the creation of the Central Environmental Authority (CEA) in 1980, which was mandated to function as the regulatory and coordinating agency in respect of all matters pertaining to the protection and management of the environment. The creation of a Ministry of Environment in 1991 was the next landmark event, which strengthened the government’s commitment to have an overriding influence on environmental concerns by bringing under its portfolio most of the state institutions responsible for subjects that have impacts on the environment [41]. This ministry is the main institution for the sectoral policy and decision making, which is presently designated as the Ministry of Mahaweli Development & Environment, a portfolio of HE the President.

The 13th Amendment to the Constitution of Sri Lanka empowered provincial councils with legislative and executive power over the environment within the jurisdiction of the respective provinces, provided such laws are not in conflict with those of the Central Government. Accordingly the North Western Provincial Council has set up its own environment statutes, while the Western Provincial Council has passed its own environmental statutes for Waste Management in 2004.

Environmental Impact Assessment (EIA) and Environmental Protection Licence (EPL) schemes have been made mandatory under the National Environment Act. The legal framework for the EIA process was laid down by the National Environmental (Amendment) Act No 56 of 1988. EIA process is mandated only for large scale development projects or projects which are located in environmental sensitive areas. The types of projects which require EIA have been prescribed in the Gazette No. 772/22 of 24.06.1993, where following are listed under transportation systems:

- Construction of national and provincial highways involving a length exceeding 10 km
- Construction of railway lines
- Construction of airports
- Construction of airstrips
- Expansion of airports or airstrips that increase capacity by 50% or more.

Industries and activities which required an EPL are listed in Gazette Notification No 1533/16 dated 25.01.2008. Industries are classified under 3 lists (A, B and C), depending on their pollution potential. Part A comprises of 80 significantly high polluting industrial activities and Part B comprises of 33 numbers of medium level polluting activities. Part C comprises of 25 low polluting industrial activities which have been delegated to Local Government Authorities. The prescribed activities related to the transport sector for which a license is required in each list are listed in Table 2.2.

Table 2.2: Prescribed activities in EPL related to transport sector

Category	Industrial activities related to the transport sector
Part A: High polluting industrial activities	Bulk petroleum liquid or liquefied petroleum gas storage or filling facilities having a total capacity of 150 or more metric tons excluding vehicle fuel filling stations.
	All types of tyres, tubes manufacturing or tyre retreading industries.
	Automobile or bicycle manufacturing or assembling industries.
	Vehicles service stations or container yards having vehicle service activities excluding three wheeler and motor cycles services and interior cleaning.
	All vehicle emission testing centres
Part B: Medium polluting industrial activities	Bulk petroleum liquid storage facilities excluding filling stations or liquefied petroleum gas (LP Gas) storage or filling facilities having a total capacity less than 150 metric tons
	Vehicle repairing and maintaining garages including spray painting or mobile air-conditioning activities.
	Three wheeler or motor cycle servicing activities or vehicle interior cleaning activities.
Part C: Low polluting industrial activities	All vehicle filling stations (liquid petroleum and liquefied petroleum gas).
	Vehicle repairing or maintaining garages excluding spray-painting or mobile air-conditioning activities.

In addition to the above, regulation of noise standards for vehicles has been under consideration and only regulation enforced so far is on the noise emanating from vehicular horns, which is cited as the National Environmental (Vehicle Horns) Regulations, No. 1 of 2011 (Gazette Notification No 1738/37 dated 29.12.2011).

2.5.2 Air Quality Regulations

As the air quality management needs interventions in diverse areas with an integrated effort by several institutions and agencies, a comprehensive programme of activities has been formulated by Sri Lanka, main element of which are illustrated in Figure 2.9.

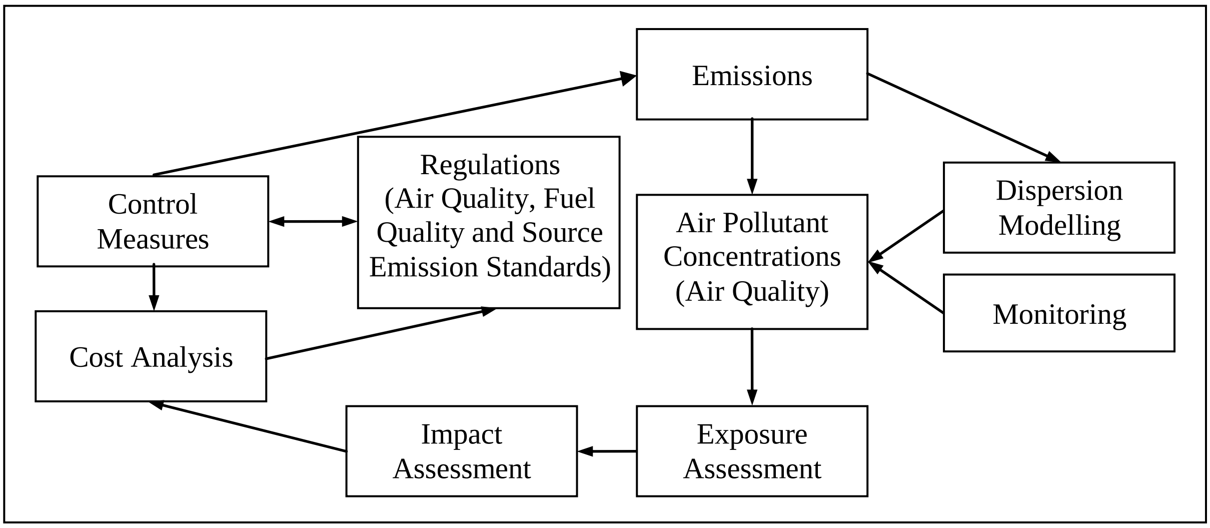


Figure 2.9: Main elements of the national air quality management (AQM) plan

Serous work on air quality degradation, especially in the urban sector due to growing industries and transportation, was begun in 1980's, particularly with series of air quality management related activities, as listed below:

- 1980: National Environment Act No 47 of 1980, subsequently amended by Act No. 56 of 1988.
- 1983: First formal monitoring of lead (Pb) in air in Colombo, carried out by the Department of Chemistry, University of Colombo.
- 1987: An inter-agency committee of experts, having recognized the growing problem of vehicular air pollution, made some twenty recommendations covering seven major issues with respect to environmental pollution.
- 1989 – 1994: Three separate research organisations, namely National Building Research Organisation (NBRO), CEA and Ceylon Institute for Scientific and Industrial Research (CISIR) carry out short-term studies and to contribute to the better understanding of the air quality situation in Colombo.
- 1991: The Metropolitan Environmental Improvement Programme (MEIP)-Colombo organises a workshop in August titled "Air Quality Management in Sri Lanka".
- 1992: Publication of "Clean Air 2000 - An Action Plan (CA2AP) for Air Quality Management in the Colombo Metropolitan Area" as Cabinet approved Government policy.
- 1993: Report on the air quality monitoring needs and future actions to be taken for Sri Lanka by the World Bank funded Colombo Urban Transport Project (CUTP) and MEIP.
- 1994: CEA gazetted the first national ambient air quality standards (NAAQS).
- 1994: Motor Traffic (emission control) Regulation Number 817/6 dated 3rd May 1994.
- 1996: Commencement of first ambient air quality monitoring station at Colombo Fort railway station.
- 2000: National policy on air quality management, to ensure sound environmental management within a framework of sustainable development in Sri Lanka.

- 2000: National Environmental (Air Emission, Fuel and Vehicle Importation Standards), Gazette notification number 1137/35 dated 23rd June 2000.
- 2001: Establishment of Air Resource Management Centre (AirMAC) as a multi-stakeholder partnership to manage air quality.
- 2001: Commencement of World Bank funded Colombo Urban Air Quality Management project.
- 2002: Introduction of lead-free gasoline.
- 2003: National Environment Policy.
- 2003: National Environmental (Air Emissions, Fuel & Vehicle Importation standards), Amended regulations no. 01 of 2013, Gazette notification number 1295/11 dated 30th June 2003.
- 2003: Commencement of the development of vehicle emission testing (VET) programme.
- 2004: Establishment of the Clean Air Sri Lanka (Clean Air SL) as a non-stock, non-profit organization to work on combating air pollution, in collaboration with AirMAC.
- 2004: Introduction of low sulphur diesel (3000 ppm).
- 2004: Development of Clean Air Action Plan – 2007.
- 2004: “Air that We Breathe” the first national symposium on Air Resource Management in Sri Lanka was held in December 2004.
- 2008: Commencement of Sri Lanka Vehicle Emission Testing (SLVET) programme (in Western province).
- 2008: National Environmental (Air Emissions, Fuel & Vehicle Importation standards), Amended regulations, Gazette notification number 1557/14 dated 09th July 2008.
- 2008: Prohibition of importation of 2-stroke three wheelers.
- 2009: Launch the National Action Plan for Haritha (Green) Lanka Programme of the National Council for Sustainable Development (NCSD).
- 2010: Development of Clean Air Action Plan – 2015.
- 2011: Prohibition of importation of spare parts for 2-stroke three wheelers.
- 2011: Commencement of the national programme in Energy Efficient & Environmentally Sustainable Transport (E^3ST) by Sri Lanka Sustainable Energy Authority (SLSEA).
- 2013: Implementation of SLVET programme in all provinces.
- 2013: Mobile ambient air quality monitoring station was provided to CEA by Vehicle Emission Test Trust fund.
- 2014: Government commitment for energy efficiency improvements in transport sector.
- 2014: Introduction of 10 ppm sulphur diesel as super diesel (on 1st August 2014).
- 2014: The Integrated Conference of BAQ 2014 and Intergovernmental 8th Regional EST Forum in Asia, in November 2014.

In particular, air quality related regulations were initiated with the publication of NAAQS, sited as the National Environmental (Ambient Air Quality) Regulation in 1994, developed under the National Environmental Act No. 47 of 1980 by the Ministry of Environment and Natural Resources. This regulation, amended in 2008, specifies the concentration limits for six air pollutants namely particulate matter PM_{10}, $PM_{2.5}$, carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen dioxide (SO_2) and ozone (O_3), as shown in Table 2.3.

Table 2.3: AQS of Sri Lanka (in μg/m^3)

Pollutant	Sri Lanka NAAQS	
	Standard	**Average**
Carbon monoxide	58,000	Any time
	30,000	1 hr
	10,000	8 hr
Sulphur dioxide	200	1 hr
	120	8 hr
	80	24 hr
Nitrogen dioxide	250	1 hr
	150	8 hr
	100	24 hr
Ozone	200	1 hr
PM_{10}	100	24 hr
	50	Annual
$PM_{2.5}$	50	24 hr
	25	Annual

The main intervention of controlling air pollution is also achieved through enforcement of emission standards at the source itself. There are two categories – mobile and stationary sources emission standards. In order to control emissions from mobile sources, SLVET programme was developed and implemented as a nationwide programme. This was made effective from November 2008, and presently covers all the nine provinces. The test procedures employed are no-load idle and fast-idle test for gasoline vehicles and snap acceleration test for diesel vehicles. The present emission standards are presented in Table 2.4. The values within the brackets represent the revised standards to be implemented in the next implementation phase of the SLVET programme.

Table 2.4: Vehicle emission standards in Sri Lanka

Type of Vehicles	Emission Standards		Remarks
	CO in% v/v	**HC in ppm v/v**	
Petrol Vehicles other than motor cycles and motor tricycles	4.5 (3.0)	1200 (1000)	Both idling and 2500 rpm / no load
Petrol Motor cycles and motor tricycles	6.0 (4.0)	9000 (6000)	
Diesel vehicles	Smoke Opacity on snap acceleration k factor (m^{-1})		
	8.0 (6.0)		

As per the regulation, all the vehicles registered in DMT are required to obtain the emission test certificate (with a pass rating) by paying a prescribed testing fee to secure the annual revenue licence from the divisional secretariat office annually. Failed vehicles are given three-month period to undergo a retest free-of-charge. Figure 2.10 illustrate the implementation structure of the emission certification process of the SLVET programme.

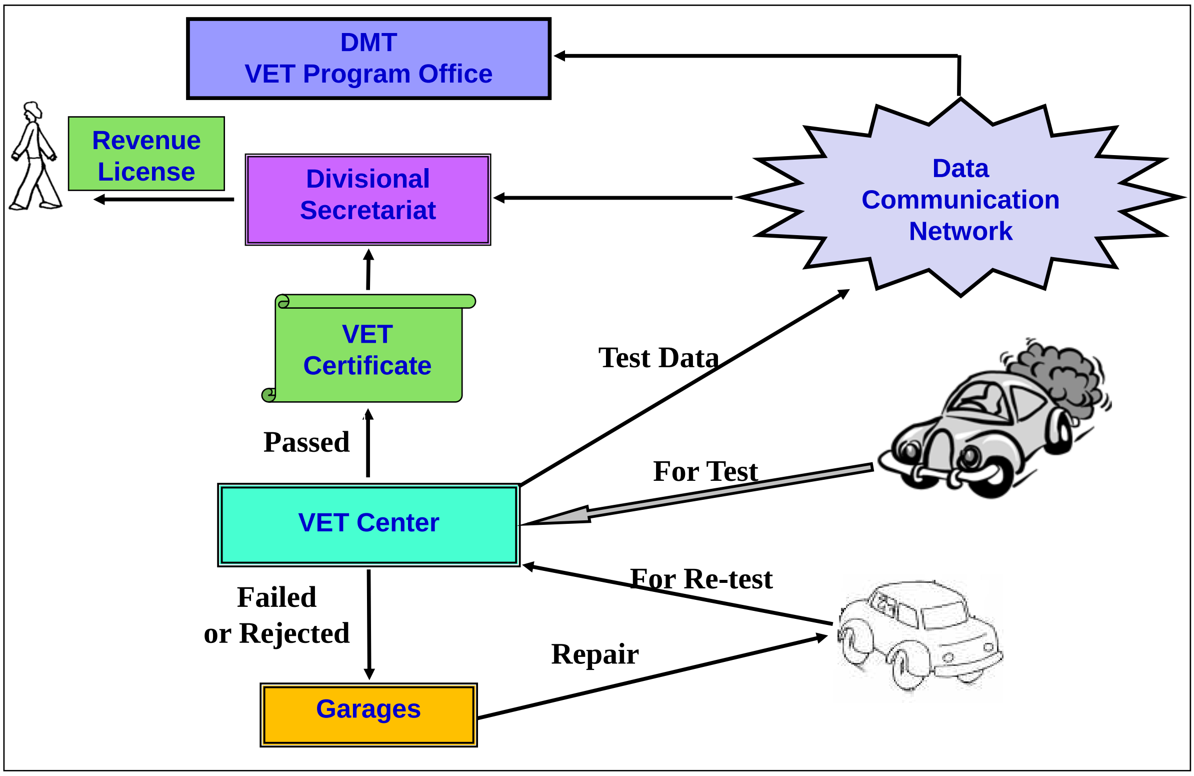


Figure 2.10: Emission certification process of the SLVET programme

The SLVET progeamme was formulated as a centralized, test-only system with on-line information transfer to a central database. There are about 230 centers available island-wide, operated by two private companies. These testing centres are classified as fixed, semi-fixed and mobile stations (see Figure 2.11). In year 2014, 3.33 million vehicles have been tested.

Figure 2.11: Types of emission testing centres in Sri Lanka

The impact of the implementation of SLVET programme could be illustrated through the improvement in the ambient air quality levels in Colombo, as shown in Figure 2.12. Even with the rapid increase in the number of vehicles as well as the vehicular traffic, the PM_{10} levels show a decreasing trend [42].

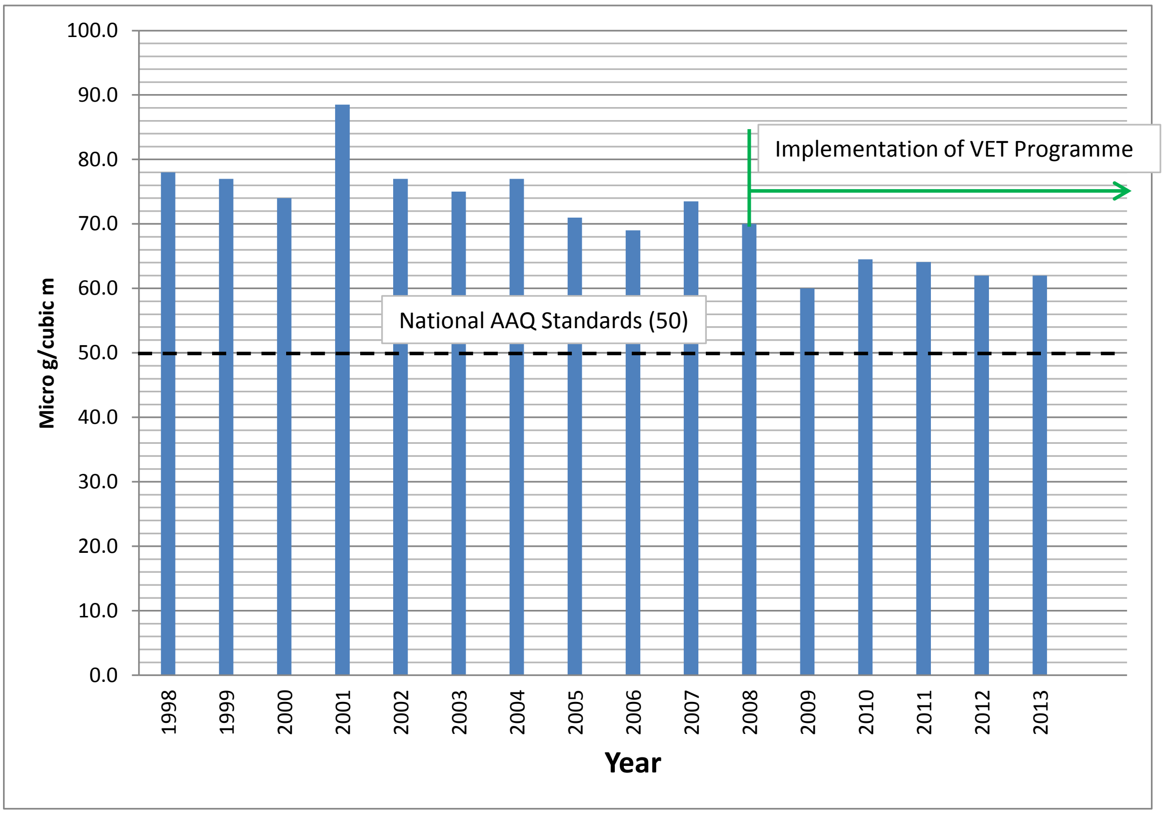


Figure 2.12: Annual average PM_{10} at Colombo Fort monitoring site

Emission standards for stationary sources have also been developed by CEA, and approved by its Board of Management for implementation as an intermediary measure. Once gazetted, the proposed standards will be mandatory and legally enforceable. In order to cover all the types of stationary sources, the standards adopt a two-tier approach. Tier 1 - equipment based standards is the primary one and covers stack emissions from commonly used equipment in industry including thermal power plants, boilers, thermic-fluid heaters, incinerators, crematorium, cupola, furnaces, ovens and cement kiln. In tier 2 – pollutant based standards, more than twenty pollutants, both combustion and non-combustion sources, are covered. Further, separate schedules for fugitive emissions are also included.

More recent initiatives in air quality management in Sri Lanka include the following:

- Development of Indoor Air Quality Guidelines: In 2013, a national expert committee was appointed to develop the guideline, and the work is still in progress.
- Cabinet memorandum on “Enhancing the Quality of Fossil Fuels for Managing Air Quality in Sri Lanka": In 2012, the Minister of Environment and Renewable Energy submitted this paper to the Cabinet of Ministers, and subsequently an Inter-Ministers Committee (comprising of Minister of Environment and Renewable Energy, Minister of Petroleum Industries, Minister of Technology and Research, Minister of Power and Energy and Minister of Transport) and to Technical Committee were appointed to

study all aspects pertaining to the enhancement of the quality of fossil fuels and make recommendations to the Cabinet on the management of the quality of air. The cabinet paper is now in the final stage of completion. The main recommendation of the paper could be summarized as:

(i) Introduction of low Sulphur diesel: 10 ppm Sulphur super diesel from July 2014, 1000 ppm Sulphur auto-diesel from 2015 to 2020 and 350 ppm Sulphur auto-diesel from 2020 to 2025.
(ii) Introduction of alternative fuels for transport (Electric and hybrid vehicles): Target for electric and hybrid vehicles is 10% by 2016 and 20% by 2020 of the total number of vehicles imported.
(iii) Introduction of alternative fuels for transport (biofuels): Endorse biofuel policy in 2015, Promotion of biogas for transport (particularly for three-wheelers, and introduction of biodiesel by 2016 and 1% by 2020 (through 3rd generation biofuels).
(iv) Development of fuel quality standards for industrial fuel - Furnace oil / heavy diesel: Maximum of 3% Sulphur from 2015 and 1,5% from 2020.
(v) Development of fuel quality standards for industrial fuel – Coal: 1.2% of maximum Sulphur content form 2015.
(vi) Expansion and modification of the CPC Petroleum Refinery: Maximum of 0.5% Sulphur diesel produced from 2018, 10 ppm from 2020, and establishment of Sulphur recovery plant by 2018.
(vii) Development of fuel quality standards for power sector – Furnace oil / heavy diesel: Maximum of 3% Sulphur fuel from 2015 and 1.5% by 2020.
(viii) Development of fuel quality standards for power sector – Coal: Maximum of 1.2% Sulphur coal by 2015.
(ix) Introducing LNG as a source of energy in all the sectors as a cleaner fuel.
(x) Railway electrification Plan: Three electric railway lines are established by 2025.
(xi) Establishment of an independent fuel quality testing laboratory/s.
(xii) Harmonize the fuel quality standards with source emission standards (both mobile and stationary sources) and ambient air quality standards, through development of a national air quality model.

- Acquisition of ambient air quality monitoring stations: Three ambient air quality monitoring stations (two fixed and one mobile) are to be acquired within this year by Vehicle Emission Test Trust fund to strengthen the air quality monitoring systems in the country.
- Revision of National Action Plan for Haritha (Green) Lanka Programme of NCSD: In 2014, revision of this policy document was initiated, and the revised programme is about to submit for the Cabinet approval. This action plan is considered to be the guidance document for environment management in all the sectors, categorized under ten broad thrust areas/missions. The mission for air quality management is titled as “Clean Air – Everywhere”, under which twelve strategies have been proposed including one covering the transport sector titled as “Energy efficient and

environmentally sustainable transport system established". The actions proposed under this strategy include:

(i) Enhance the customer friendly public transport system, especially rail system.
(ii) Introduce Water based transport with improved technologies.
(iii) Introduce proper traffic planning system.
(iv) Dedicated lane for public transport.
(v) Encourage to use bio-fuel and alternative fuel.
(vi) Introduce tax system for private vehicles to enter vehicles to city limits.
(vii) Introduce public parking.
(viii) Discourage road side parking.
(ix) Tax concession for the emission related spare parts.
(x) Encourage to use green vehicles with energy efficiency.
(xi) Introduction & Importation of euro engine standards.
(xii) Strengthen the activities of the VET programme.
(xiii) Implement the finalized emission standards.
(xiv) Introduce an effective road maintenance programme.
(xv) Introduce and encourage widespread use of international standards for road furniture.
(xvi) Introduce legislation to safeguard road users.
(xvii) Reduce entering of heavy vehicles to the city limits in the peak time.

- Development of Clean Air Action Plan 2025: The next phase of the Clean Air Action Plan, covering the next 10-year period, has been initiated in 2015. This action plan will be in line with the above list of activities presented under National Action Plan for Haritha (Green) Lanka Programme, but with more detailed activities and sub activities with specific time-bound targets.

2.6 Fuel Economy Regulations

Energy efficiency or fuel economy in the transport sector is a relatively new initiative in Sri Lanka and no specific regulation is in place yet. One main activity has been formulated by SLSEA as a national programme titled Energy Efficient and Environmentally Sustainable Transport (E^3ST) System in Sri Lanka, under which annual seminar/training programme has been organized since 2011. This activity has been assisted by number of international organizations, including Hong Kong Polytechnic University, Clean Air Asia (CAA) Centre, Philippines and Centre for Science and Environment (CSE), India. Further, SLSEA provided assistance to number of local Universities to develop driving cycles in urban cities. University of Moratuwa has completed the work to derive driving cycle in Colombo. Figure 2.13 presents the proposed driving cycle for Colombo and Table 2.15 provides the key parameters of it [43].

SLSEA is planning to develop driving cycles in few other urban areas. With the development of driving cycles to represent key urban areas in the country, SLSEA expects to introduce fuel economy labelling programme by 2016.

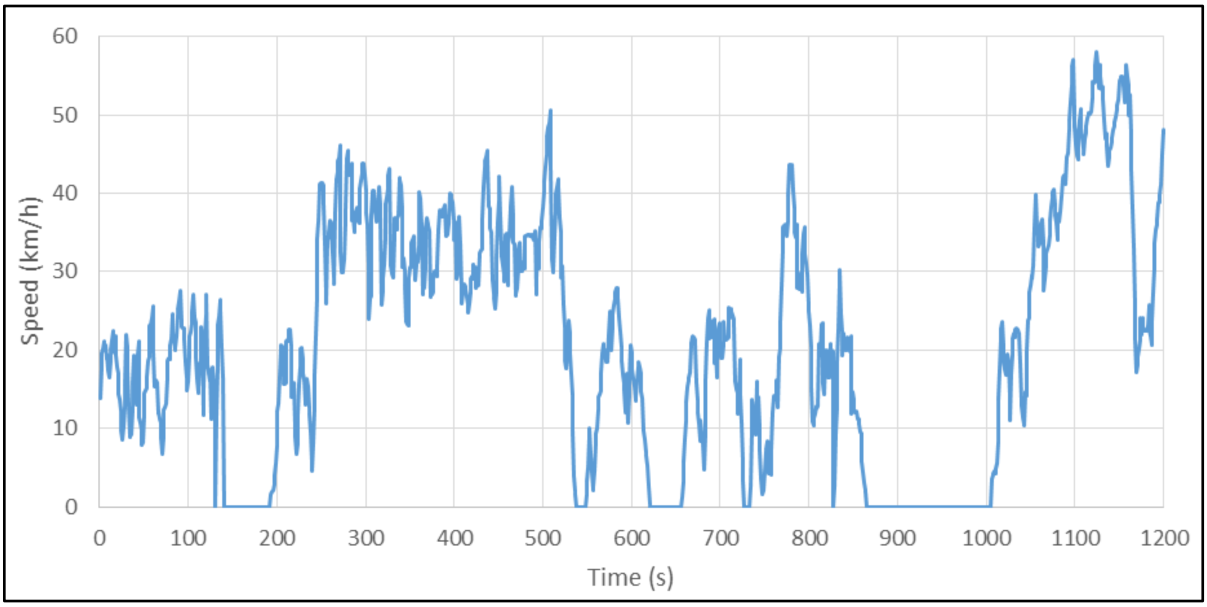


Figure 2.13: Proposed driving cycle for Colombo.

Table 2.5: Key parameters of the proposed Colombo driving cycle.

Parameters	Quantity
Average Speed (km/h)	20.3
Average Running Speed (km/h)	28.8
Average Acceleration (m/s^2)	0.23
Average Deceleration (m/s^2)	-0.22
Time Proportion for Idling	20.5
Time Proportion for cruising	12.8
Time Proportion for acceleration	36.1
Time Proportion for Deceleration	30.7

New government policies identify the importance of sustainable energy for the inclusive socio-economic development in the country. Thus, the energy sector development plan, which is set for a knowledge based economy, has primarily developed to meet energy demand through renewable and other indigenous energy resources, and their potentials towards a "green" economy, energy conservation measures for its sustainability, measures for energy security, financially and economically justifiable pricing policies for electricity and petroleum products, research and development initiatives, and importantly management and good governance practices for the sector. Accordingly, the government has set aggressive targets towards sustainable energy developments including the following [44]:

- To make Sri Lanka an energy self-sufficient nation by 2030.
- Increase the share of electricity generation from renewable energy sources from 50% in 2014 to 60% by 2020 and finally to meet the total demand from renewable and other indigenous energy resources by 2030.
- Reduce annual energy demand growth by 2% through conservation and efficient use

- Reduce the petroleum fuel use in the transport sub-sector by 5% by introducing efficient modes of transport and electrification of transport by 2020.
- Produce the total petroleum product demand of the country through the refinery by 2025.
- Upgrade quality of Gasoline and Diesel to EURO IV and EURO III, respectively by 2018.

The Ministry of Power & Energy has launched a national programme on energy conservation in the transport sector though awareness raising campaign for the drivers targeting 5% reduction of fuel consumption within 2015. This programme is being implemented by SLSEA. Further, the Ministry has directed the CEB and LECO to establish a network of charging infrastructure for the electric vehicles. Further, a time-of-use electric consumer tariff system in being developed to promote electric vehicles. Another initiative is related to promotion of electric three-wheelers, where a pilot project is being implemented by a private company on conversion to electric drive system and an international company has proposed to develop new electric three-wheelers to Sri Lankan market, especially as an inter-modal transport service.

In line with the government target of reaching 100% renewable energy by 2035, SLSEA has prepared a concept paper to illustrate the viability. The approach in the transport sector is to promote electrification of transport with the interventions in the following areas [45]:

- Most major cities will be predominantly pedestrian in character and will have only electric bicycles, scooters, E3Ws and E-taxis to support,
- Passenger transport dominated by electric trains and electric BRT supported by a fleet of EV taxis,
- Storage capacity of EVs used as a grid balancer,
- Hydrogen Fuel cell vehicles, Compressed air vehicles,
- Algae based biofuels and compressed biogas powering long haul transport.

Presently, SLSEA is in the process of developing a detailed policy document/roadmap for the realization of 100% renewable energy sector under four policy/strategic directions, as:

- Prevent unnecessary demand for mobility,
- Use transport infrastructure efficiently,
- Use Efficient technologies,
- Use cleaner fuels/renewable energy resources.

Under efficient technologies, which over both vehicle technology and operational efficiency, following actions have been proposed:

- Enforce fuel economy standards,
- Promote fuel-efficient vehicles (tax-incentives, subsidies, green-labels),
- Introduce electric rails,
- Promote electric / plug-in hybrid vehicles (tax-incentives, subsidies, green-labels),
- Promote efficient (energy and environmental) batteries (for EVs),
- Traffic management,

- Introduce fuel quality standards,
- Incentives for fuel efficient spare parts (including tyres),
- Improved road surfaces,
- Eco-driving programmes,
- Training for vehicle repair technicians,
- Awareness programmes for drivers and owners,
- Develop modelling and simulation tools for impact assessments,
- Promote R&D,
- Establish effective information management system.

These efforts of Sri Lanka are expected to be strengthened with the support from UNEP and GFEI, in setting the baseline, formulating appropriate policy interventions and developing roadmap for the fuel efficiency improvement in the transport sector, particularly of the LDVs.

2.7 Vehicle Taxation

Sri Lanka does not have a local vehicle manufacturing industry, and the cost of vehicles in the local market is heavily dependent on the importation taxes. The present tax system in the country has become very complicated, and there are frequent changes in coverage and rates leading to a further complexity. Another issue is the irrationality in formulating subsidies. While aimed at protecting consumers (or supplier), subsidies usually aggravate fiscal imbalances, and influence consumers (or suppliers) choices leading to wide-ranging economic consequences. Impacts of such issues are well recognised in the transport sector, particularly with subsidies imposed on fuels, vehicles, public transport fare / tariff, etc. Under these circumstances, subsidy reform has been a frequent topic of discussion all over the world, but implementation of such reforms is proven to be a very challenging task, particularly due to socio-political factors [46].

In relation to the importation of vehicles and parts / accessories thereof, there were nine taxes and levies in effect at national level prior to 2015, viz [47]:

- Customs Duty,
- Value Added Tax (VAT),
- Social Responsibility Levies (SRL),
- Ports and Airport Development Levies (PAL),
- Cess,
- Excise Duties,
- Nation Building Tax (NBT),
- Road Infrastructure Development Levies, and
- Surcharges.

As a measure to simplify the tax system the government has proposed to introduce Excise (Special Provisions) Duty as a single composite duty in lieu of VAT, NBT, Cess, Customs duty and PAL. Accordingly the present tax system for importation of motor vehicles includes only three items (with effect from 27th February 2015):

- Excise (Special Provisions) Duty,
- Preferential Duty, and
- General Custom Duty.

These taxes are applied to the custom valuation of the motor vehicle, which is the sum of Fee-on-Board (FOB) value and surcharges such as cost of transport and insurance to the port of Sri Lanka, cost of loading, unloading and handling, and brokerage and selling commissions incurred. The new taxes applicable for LDVs are presented in Table 2.6 [48].

Table 2.6: Vehicle importation taxes in Sri Lanka

Vehicle Category		Duty (%)			
		Excise (Spec. Prov.)	Preferential(1)	General	Total(2)
Three wheeler - Gasoline/Diesel		105	-	15	120
Three wheeler - LPG		95	-	15	110
Three wheeler - Electric	< 3 years old	05	-	7.5	12.5
	> 3 years old	05	-	15	20
Car - Gasoline	< 1000 cc	135	20	25	180
	1000 - 1600 cc	150	16.6	25	191.6
	1500 – 2000 cc	150	16.6	25	191.6
	2000 – 3000 cc	200	22.5	25	247.5
	> 3000 cc	220	22.5	25	267.5
Car - Diesel	< 1500 cc	200	20	25	245
	1500 - 2000 cc	220	16.6	25	262.6
	2000 – 2500 cc	240	22.5	25	287.5
	> 2500 cc	300	22.5	25	347.5
Hybrid electric vehicles - Gasoline	< 1500 cc	50	12	15	77
	1000 - 1600 cc	80	9.9	15	104.9
	1600 – 2000 cc	80	9.9	15	104.9
	2000 – 3000 cc	115	13.5	15	143.5
	> 3000 cc	160	13.5	15	188.5
Hybrid electric vehicles - Diesel	< 1500 cc	90	12	15	117
	1500 - 2000 cc	90	9.9	15	114.9
	2000 – 2500 cc	115	13.5	15	143.5
	> 2500 cc	160	13.5	15	188.5
Electric vehicles	< 3 years old	05	-	15	20
	> 3 years old	05	-	25	30

Notes: (1) Applicable for Imports under the Agreement on Global System of Trade Preference (GSTP) only.
(2) Need to adjust (downward) for the imports where the preferential duty is not applicable.

Around two years ago, the government drastically reduced import duty on electric and hybrid vehicles. This was widely hailed as a step in the right direction because hybrid vehicles use less fuel and are more environmentally friendly. This as lead to the importation of many hybrid cars, and presently over 50,000 vehicles are in use. In 2014 alone, 19,557 hybrid cars and 90 electric cars have been imported, which represents 60% of the total number of cars registered. However, in the recent tax revisions, the tax concessions for hybrid vehicles have been partially removed, in claiming to create level playing field for hybrid and normal cars, thus resulting less preference from the consumers. This action of the government goes against the global trend of promoting echo-environment for hybrid vehicles by way of tax incentives, which is a policy of the government too. In fact, both government policy documents being formulated, the National Action Plan for Haritha (Green) Lanka Programme and Enhancing the Quality of Fossil Fuels for Managing Air Quality in Sri Lanka, the promotion of electric and hybrid vehicles are recommended.

SECTION 03: FUEL ECONOMY OF NEW CARS IN SRI LANKA

3.1 Methodology

Objective of this report is to establish a baseline for the energy efficiency / fuel economy of new passenger cars in the country, which will be useful in

- assisting the government to develop strategies and implement vehicle fuel economy policies, and
- supporting the regional and global tracking of the fuel economy performance towards 50by50 target set by GFEI.

The methodology for the above task has been developed during the Phase I of the GFEI project, which is supplemented by the GFEI Toolkit, as briefed in Section 1.7.4. In particular, a step-by-step guide to the baseline setting is provided within the GFEI toolkit. The basic steps of this process are:

Step 1: Establish the baseline year.

Step 2: Establish the data points that are required to collect for the estimation of a robust baseline.

Step 3: Find and evaluate available new car registration data sources and their quality.

Step 4: Calculate the average fuel economy and other characteristics for newly registered vehicles in the baseline year.

Step 5: Repeat the same exercise using uniform methodology at regular intervals (to derive annual average variations).

3.2 Data Requirement

In the present analysis, the fuel economy of passenger cars that are newly imported to the country in a given year is to be estimated. In Sri Lanka, significant portion of the cars imported are second hand, thus become part of the new registrations and included in the analysis. However, registrations arisen from change in ownership (in-country sales) are not counted. As the fuel economy depends on many attributes of vehicles, there are essential data items to be recorded, which would form the structure and scope of the database. As per the guideline provided in GFEI toolkit, the most critical information required includes:

- Vehicle make and model, and if possible configuration,
- Model production year,
- Year of first registration,
- Fuel type,
- Engine size,
- Domestically produced or imported,
- New or second hand import,
- Rated fuel economy per model and test cycle basis,
- Number of sales by model.

Here the vehicle configuration refers to that labelled by the manufacturer using a sub-model number (or other designation), which could indicate transmission type, trim level, optional accessories, etc.

As discussed in Section 1.5, the fuel economy of a vehicle depends on several technical and non-technical factors, thus designation of a value is not very practical. Yet, in order to quantify fuel consumption and emission characteristics of a vehicle fleet, it is important to establish fuel economy factors (values) through a standardize procedure for a given vehicle. This is usually materialized through performance testing of a vehicle in a specific driving cycle (as presented in Table 1.5). Such data could be obtained either from country of origin or manufacturer or by testing of a select sample of vehicles.

In addition to the key information listed above, it is recommended to collect other information that may be required to perform more advanced analysis, such as:

- Vehicle Information / Identification Number,
- Fuel type (petrol or diesel),
- Injection system type,
- Body type,
- Vehicle foot print,
- Vehicle curb weight,
- Emissions certification level,
- Use of vehicle (private, public, for hire, etc.),
- Vehicle price.

3.3 Information Sources

In Sri Lanka, all new vehicle registrations are carried out by Department of Motor Traffic (DMT), a government agency under the Ministry of Transport (except for vehicles owned by the military). In addition to the owner's information, the data items recorded in a new registration include the following:

- Ownership: Private / Public
- Usage: Personal / Commercial
- Usage: Transport of passengers / Transport of goods / Goods and Passengers / Agriculture / Construction / Other (Specify)
- Registration Status: Locally built / Recondition / Brand New / Bought from Auction / Other (Specify)
- Manufacturer's Description of Vehicle Type: Motor car / Three Wheeler Car / Jeep / Motor / Lorry / Delivery Van / Three Wheeler Van / Crane / Dump Truck / Prime Mover / Motor Cycle / Hearse / Ambulance / Dual Purpose Vehicle / Hand Tractor / Tractor 4 wheel / Lorry Trailer / Land Vehicle / Motor Coach / Container Truck / Other (Specify)
- Make
- Model/Type of Body
- Year of Manufacture

- Country of Origin
- Chassis Number
- Engine Number
- Fuel Type
- Cylinder Capacity (CC)
- Wheel Base
- Tyre Size
- Overall Measurement (Length, Width, Height)
- Seating Capacity
- Driving Side: Right-hand / Left-hand
- Unladen Weight
- Gross Vehicle Weight
- Pay Load.

Though the above information is fed into the computer system, the database is not accessible easily, thus posing difficulty in generating process data in large quantities.

Another source which records information of vehicles is the SLVET programme, where all the vehicles (except land vehicles and military-owned) are tested annually and data of each vehicle is transferred online to a central database managed by VET Project Office in DMT. There are 44 data items recorded during this process, among which following are related to the vehicle:

- Vehicle Registration No.
- Result of the Test: Pass / Fail
- Emission Test Data
- Vehicle Registration Year
- Make
- Model
- Year of Manufacture
- Engine No.
- Chassis No.
- Number of Cylinders
- Number of Strokes (Two / Four)
- Fuel Type
- Current Mileage
- Vehicle Class.

As this database is developed with the capability of extracting series of test reports, and also include the emission data, development of fuel economy characteristics in the vehicle fleet could be best facilitated SLVET programme. However, as the VET certificate is not required for the first registration of vehicles, information on vehicles registered during most recent year is not available in SLVET database. In the present study, information is collected from both of these sources, for a randomly selected sample of over 16,000 passenger cars tested under SLVET programme during the years 2013, 2014 and 2015.

3.4 Estimation of Baseline Average Fuel Economy of New Passenger Cars

A sample of the information gathered on new passenger car registrations from the two databases indicated above is presented in Table 3.1.

Table 3.1: Information of cars registered during 2012 – 2014 (a sample).

Vehicle Identification Number	Mileage (km)	Year of First Registration	Year of Production	Make	Model	No. of Cylinders	Fuel Type	Capacity (CC)
WPKR8730	22004	2012	2012	MARUTI	800	3	P	796
WPCAC0511	9978	2014	2014	MAZDA	6	4	P	1998
WPKS1986	13350	2012	2012	TOYOTA	COROLLA	4	D	1975
SPKS5408	4558	2012	2012	TATA	1109D	4	P	624
WPKY0126	25902	2014	2014	TOYOTA	YARIS	4	P	998
WPKW4789	12660	2012	2012	PEUGEOT	3008	4	P	1598
WPKS5588	22831	2012	2012	FIAT	LINEA	4	D	1248
WPKW5619	8612	2013	2012	HONDA	100 3A	4	P	1990
SPKW1343	4523	2013	2013	VOLVO	S60	4	D	2179
WPKT0817	30464	2012	2012	HYUNDAI	TUCSON	4	D	1995
WPKU4647	15544	2012	2012	BMW	520 I	4	P	1997
WPKW8505	5067	2013	2012	NISSAN	GE-VPE25	4	P	1490

The information on number of vehicles registered is obtained based on the randomly selected sample of 16,825 cars from the emission tests database during a period of one year (most recent). Figure 3.1 presents the number of diesel and petrol vehicles in the selected sample grouped by the year of 1st registration from 2012 to 2015.

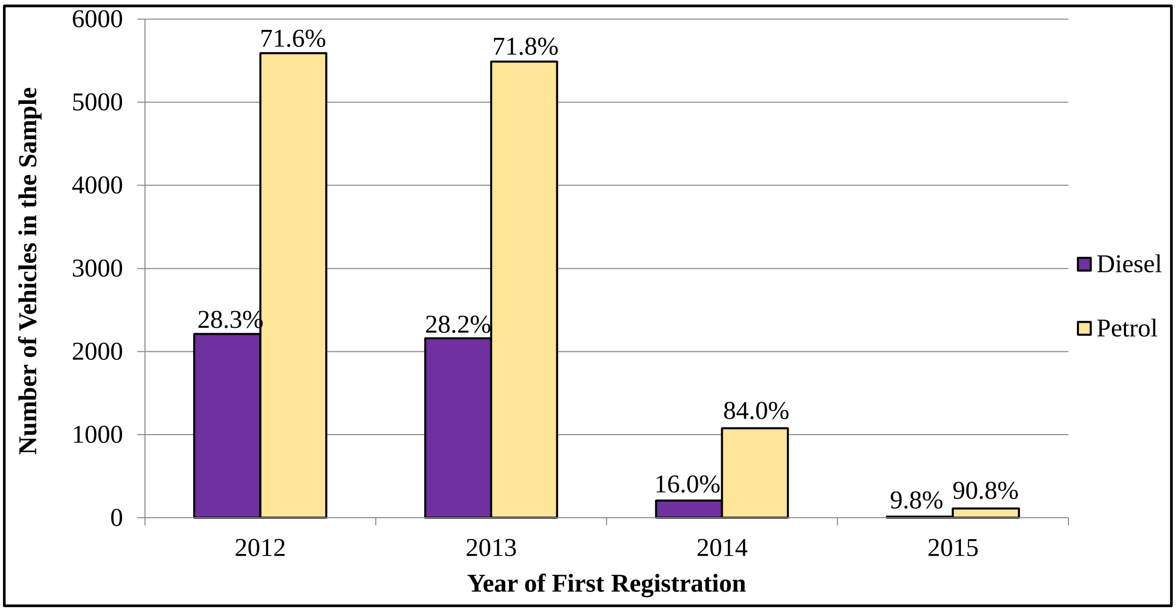


Figure 3.1: Number of diesel and petrol cars in the sample by year of 1st registration

The number of cars Percentage of petrol and diesel vehicles is also shown, where the overall percentages are 73% petrol cars and 27% diesel cars. The total number of cars under each year is came to 7784 cars from 2012, 7634 cars from 2013, 1284 cars from 2014 and 123 cars from 2015. Lower number of cars in year 2014 and 2015, compared with those in 2012 and 2013 is attributed to the fact that all the vehicles are exempted from the emission testing requirement for duration of one year from the date of first registration and significant component of vehicles registered in 2014 is yet to undergo the emission testing. Although there is no requirement to test the vehicles registered in 2015 during this year, few vehicles have gone through the testing and thus captured in the present analysis. Therefore, the percentage of petrol and diesel cars derived from the sample selected may not be very representative for 2014 and 2015, and need to update with the next two years data. So validation of the selection of sample is done for the cars registered in 2012 and 2013, as briefed below.

During 2014, total cars tested for emissions were 318,271 petrol and 50,417 diesel, indicating total number of active ICE car fleet as 368,688. Note that the hybrid cars are exempted from emission testing in Sri Lanka, thus not in the above value. Presently, total number of hybrid and electric cars exceeds 50,000. The annual new registration of cars by fuel during 2008 to 2014 is presented in Figure 3.2 [49], [50]. During 2012 to 2014, total number of petrol and diesel cars registered was 48,179 and 13,793, respectively. Among ICE cars, these numbers represent 77.7% petrol cars and 22.3% diesel cars, and corresponding yearly contributions are 80.0% petrol cars and 20.0% diesel cars in 2012, 74.6% petrol cars and 25.4% diesel cars in 2013 and 77.4% petrol cars and 22.6% diesel cars in 2014, respectively . Thus, the sample selected for the estimation of average fuel economy of cars (as shown in Figure 3.1) follows the general pattern of new registration of petrol and diesel cars in the population.

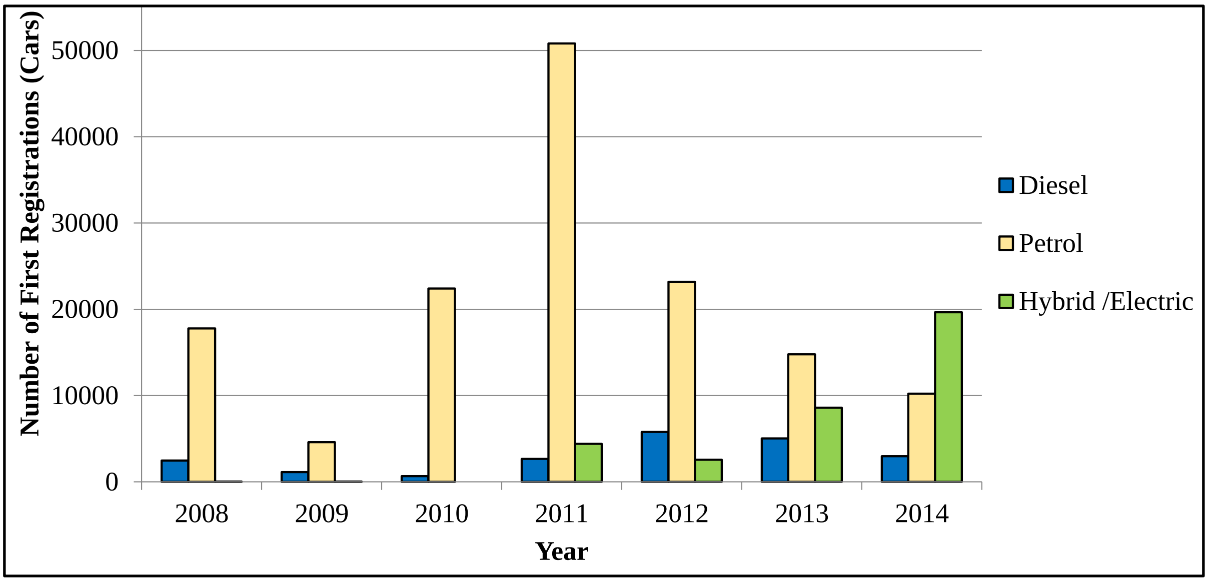


Figure 3.2: Number of annual 1st registration of cars by fuel type from 2008 to 2014

Another important feature shown in Figure 3.2 is the growth of hybrid cars in the recent years. During 2014, total number of hybrid cars registered was over 56% of the total number of cars. This trend was mainly due to the tax concessions provided to the hybrid cars a few years back. As there is a reversal of these concessions in the recent tax revisions, there is a decrease in the sales of hybrid cars during last few months.

Note that, in Sri Lanka, the passenger cars are registered under single category “Cars”, thus further sub-categorization is difficult (though the records in the first registration cover a range of specifications). Further, the category of “Dual purpose vehicles” is also used as a family vehicle and/or passenger transport only. Most of the vehicles in this category too are LDVs. Yet, there are no formal records on the dual purpose vehicles used as a passenger transport only. Thus, the present analysis of fuel economy of vehicles is limited to cars only. Further, the average fuel economy is estimated for ICE vehicles, though the hybrid (and electric) vehicles represent a significant portion of the new registrations. The impact of hybrid and electric vehicles on the average fuel economy could be estimated separately, for policy supports. Estimation of fuel economy of ICE vehicles would help in developing appropriate policies for improving fuel economy of the vehicles imported to Sri Lanka progressively, thereby achieving national goals and also contributing to the global target of 50by50.

Figure 3.3 presents the distribution of cars by make in the selected sample. There were over 45 car makes registered during 2012 to 2014. Toyota leads the market with a share of 25.4%, followed by Maruti – 15.6%, Micro – 15.3%, Mitsubishi – 11.3%, and Perodua – 8.6%.

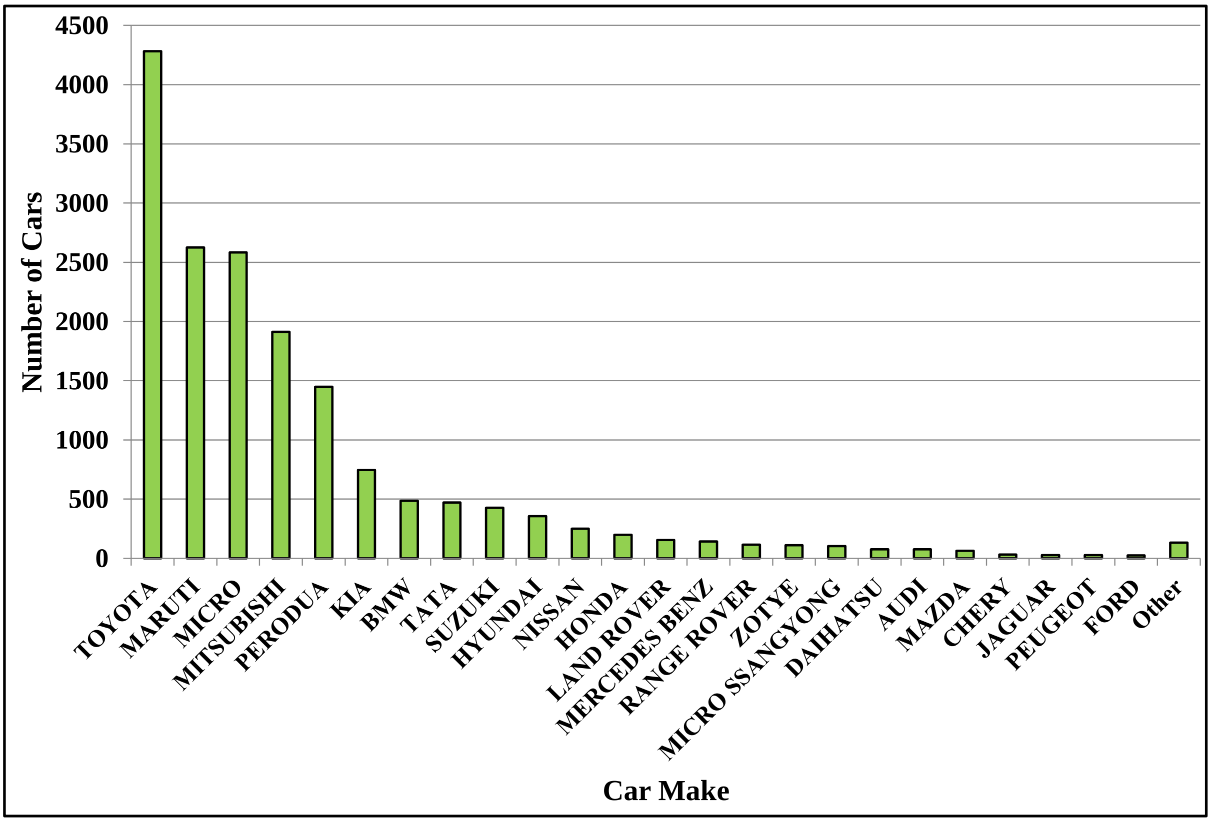


Figure 3.3: Number of cars in the sample by make

In general cars with smaller capacity engines are more energy efficient than those with larger ones, engine capacity distribution would be an indicator of the average fuel economy of the car fleet. Figure 3.4 presents the distribution of number of cars under different engine capacity ranges in the entire sample selected (for the first registration years of 2012 to 2015). The data clearly indicates the dominance of small cars in the fleet, where 66% of the cars are less than 1500 cc. The average engine capacity of the total sample is 1593 cc.

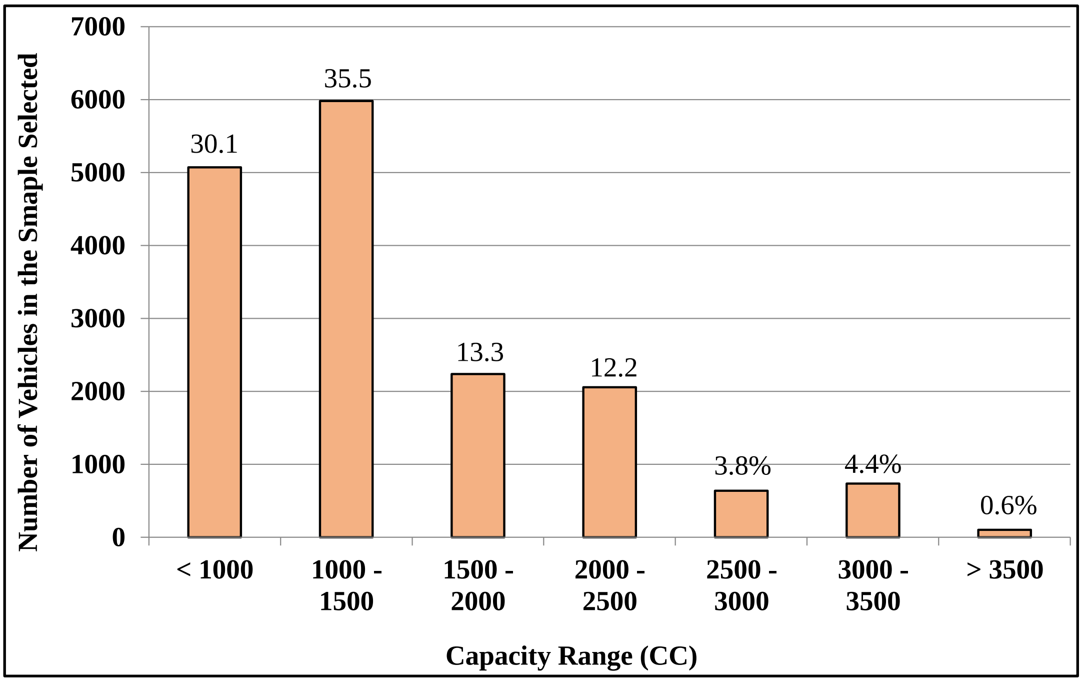


Figure 3.4: Distribution of number of cars under different engine capacity ranges

It is more relevant to follow the average engine capacity yearly as an indicator of the trend in fuel economy. Therefore, the above data is arranged under different year of first registration and the results are presented in Figure 3.5.

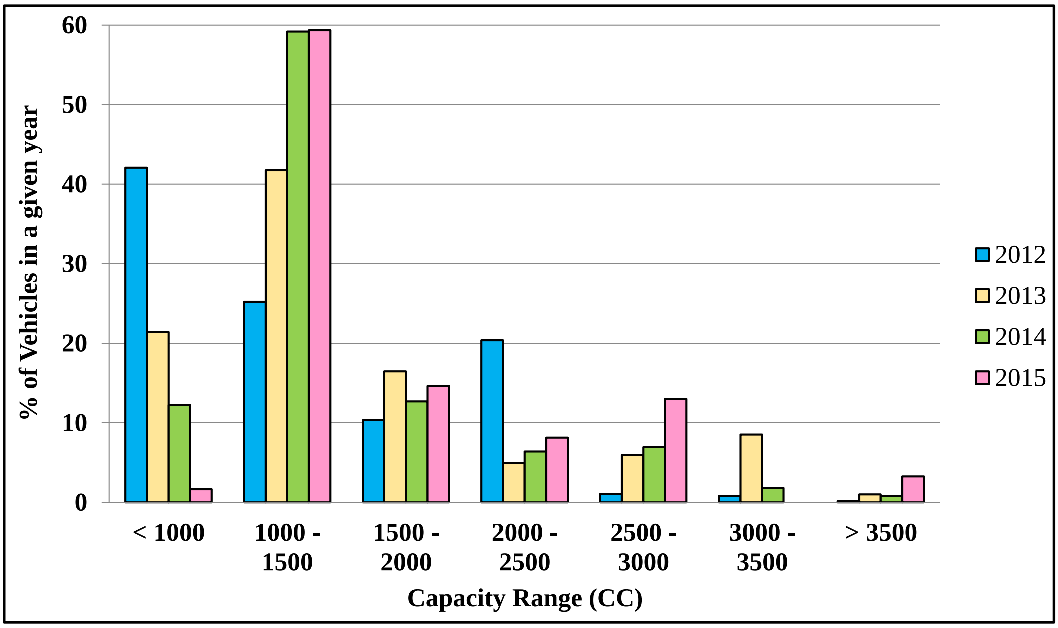


Figure 3.5: Yearly distribution of number of cars under different capacity ranges

The trend in shifting from small engine capacity cars to higher ones is apparent from these data. The annual average engine capacities of the first registrations are 1443.1 cc, 1730.0 cc, 1661.8 cc and 1880.5 for the years 2012, 2013, 2014 and 2015, respectively (see Figure 3.6). Again, the values for 2014 and 2015 have to be considered with care, as the sample may not represent the total population.

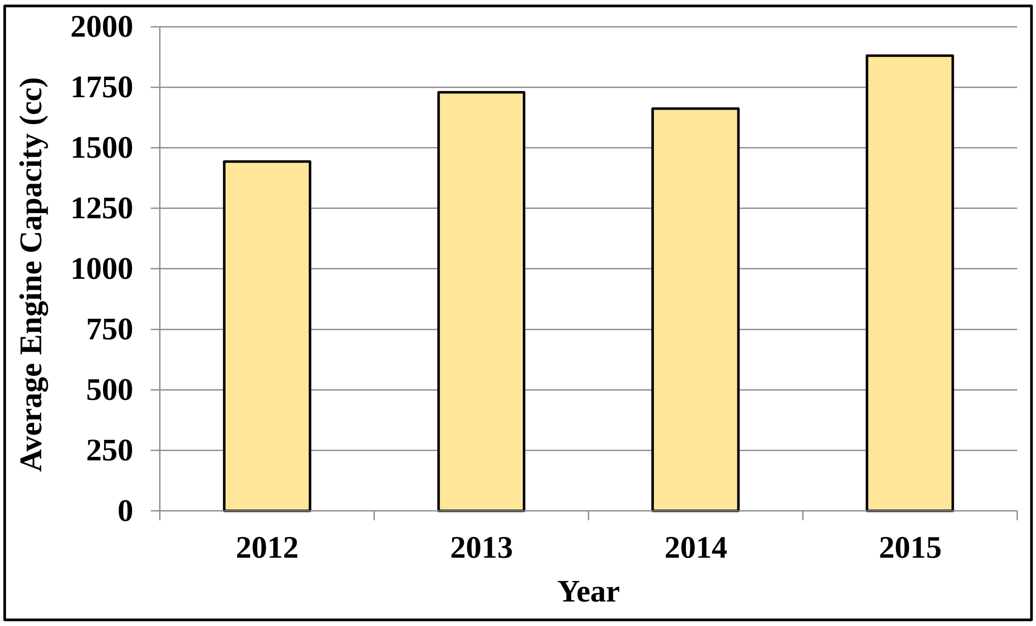


Figure 3.6: The annual average engine capacities of the cars

Another important feature identified is that the majority of the cars imported are brand new (particularly smaller cars), with a contribution of about 90% and the balance 10% is second-hand cars.

Finally, the average fuel economy and CO_2 emissions in a given year of first registration could be estimated by fuel economy and emission values of each vehicle type. The date required for these estimations are obtained from the data extracted from international literature/databases and vehicle manufacturers (references [51] to [59]). It is important to highlight here that the fuel economy and emission values are reported based on various test driving cycles (and different units) and therefore need to converted to a single test driving cycle (and same unit), for which conversion factors have been developed. In particular, International Council on Clean Transport (ICCT) has developed factors to convert values from CAFE and JC08 test cycles to corresponding values of NEDC, based on the Modal Energy and Emissions Model (MEEM), a well-established model allowing for the simulation of fuel economy or CO_2 emissions across a wide variety of test cycles. The simple average conversion factors (referred to as test cycle multiplier) derived through simulation results for series of gasoline LDV fuel economy ratings under various test cycles are presented in Table 3.2 [13].

Table 3.2: Test cycle conversion factors for fuel economy of LDVs

Conversion Factor	Test Cycles		
	NEDC-JC08	CAFE-JC08	CAFÉ- NEDC
Test cycle multiplier (simple average)	1.15	1.29	1.12

Adjusted fuel economy value for a single test cycle (NEDC for this study) is then given by:

[Adjusted fuel economy value] = [Original fuel economy value] × [Unit conversion] × [Test cycle multiplier].

A summary of unit conversion is presented in Table 3.3 [13].

Table 3.3: Unit conversions in fuel economy and GHG emissions

Metric	Standard A	Standard B	Conversion
Fuel economy	km/l	mpg	B = A × 2.35
	l/100 km	mpg	B = 235.2/A
	CO_2 g/km	mpg	B = 5469/A(1)
GHG emissions	km/l	CO_2 g/km	B = 2325/A
	l/100 km	CO_2 g/km	B = A × 23.2
	mpg	CO_2 g/km	B = 5469/A(1)

Notes: (1) For diesel vehicles, this relation is replaced by B = 6424/A to reflect the higher carbon content of diesel fuel.

The complete set of information covering technical, fuel economy and CO_2 emissions (normalized to NEDC) of all the vehicles in the selected sample is compiled in a Microsoft Excel document, and a sample table is presented in Annex 1.

Finally, the annual average fuel economy and CO_2 emissions for the years 2012, 2013, 2014 and 2015 are estimate via simple weighted average of all cars registered in a given year by the following equations, and the results are presented in Table 3.4, Figure 3.7 and Figure 3.8.

$$\text{Average annual fuel economy} = \frac{\text{Total vehicles of first registration during the year}}{\sum_{i=1}^{n} \frac{\text{Number of vehicles in Model } i}{\text{Fuel economy of vehicles in Model } i}},$$

$$\text{Average annual emissions} = \frac{\sum_{i=1}^{n} \text{Number of vehicles in Model } i \times \text{Emission of Model } i}{\text{Total number of vehicles registered in the year}}.$$

Table 3.4: Annual average fuel economy and CO_2 emissions in cars

Year	No of Vehicles in the Sample	Annual Average Fuel Economy (l/100 km)	Annual Average CO_2 Emissions (g/km)
Petrol Cars			
2012	5610	6.04	145
2013	5473	6.27	148
2014	1078	6.30	149
2015	111	6.54	158
Diesel Cars			
2012	2175	8.42	204.9
2013	2158	7.37	180.9
2014	206	7.61	188.9
2015	12	7.77	228.6
All Cars			
2012	7785	6.56	161.8
2013	7631	6.55	157.6
2014	1284	6.48	155.6
2015	123	6.70	164.1

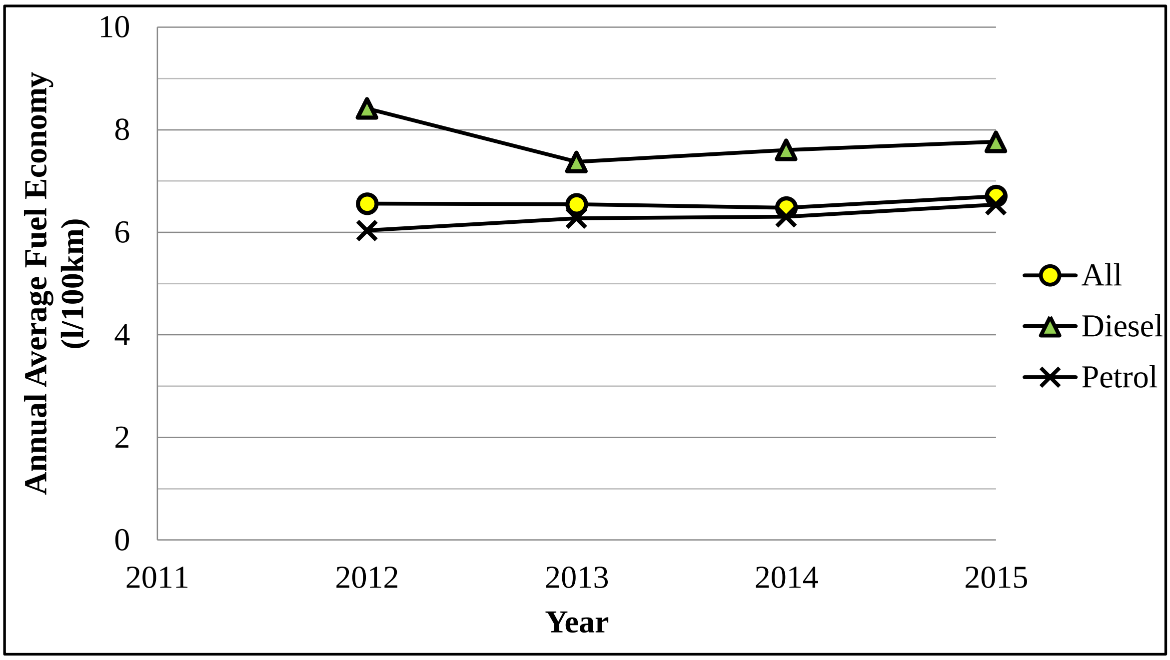


Figure 3.7: The annual average fuel economy of cars

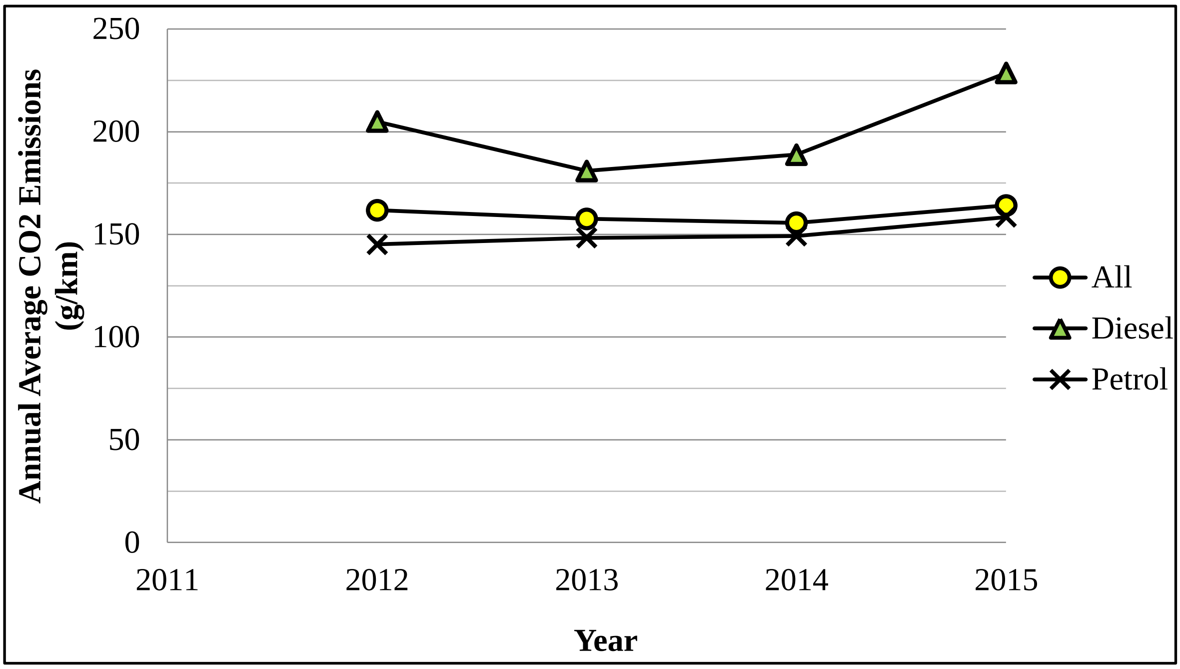


Figure 3.8: The annual average CO_2 emissions in cars

The results show slight improvements in both fuel economy and CO_2 emissions from cars from 2012 to 2014 (about 6.6 l/100 km and 160 g/km of CO_2). The number of the vehicles selected for the present analysis for 2015 is low, and therefore the results for 2015 has to be updated to derive environment and energy performance characteristics for 2015. The above estimations are only for ICE cars and the impact of hybrid and electric cars have not been considered. Some rough estimation could be derived by considering the market share of hybrid vehicles (see Figure 3.2), with an average fuel economy rating of hybrid vehicles (say 4.5 l/100 km). Then the percentage improvement of the fuel economy for 2012, 2013 and 2014 is estimated as 3%, 10% and 18%, respectively. The fuel economy values with inclusion of hybrid vehicles become 6.4, 5.9 and 5.3 l/100-km), respectively.

SECTION 04: CONCLUSIONS

Transport sector in Sri Lanka is dominated by road vehicles for both passenger and freight transportation. Presently the active fleet in the country exceeds four million, among which vehicles used for private transport contributes to over 83%, majority of those are two wheelers (51%) and three-wheelers (22%) and the balance is cars (8%). The use of private vehicles is in the rise, and there is a continuous decrease in the contribution from mass (or public) transport systems in Sri Lanka. The estimation shows that the present modal share of private vehicles in passenger transport is about 26%, thus indicates its important role in the transportation sector. The main technology of vehicles is ICE, where the main fuels are diesel and petrol. In the country, about 70% of the petroleum is consumed by the transport sector, where the main fuel is diesel. As the petroleum fuels are totally imported, there is a heavy economic burden to the country and management of fuel economy/energy efficiency becomes very important aspect in the energy sector.

There are about 420,000 cars in the active fleet, where over 75% are petrol and the balance is equally shared with diesel and hybrid vehicles. The number of hybrid vehicles has been in rapid increase since 2013, and will have a major impact on the average fuel economy of cars in the country.

The estimations of the present study show that the annual average fuel economy and CO_2 emissions of ICE cars (first registration) in Sri Lanka are about 6.6 l/100 km and 160 g/km of CO_2, respectively. The average fuel economy is less than the global average of 7.1 l/100 km, primarily due to the use of small capacity vehicles. The average engine capacity of the cars is about 1590 cc, 30% of the cars are less than 1000 cc and 36% are 1000 cc – 1500 cc. The data shows a progressive increase in the average engine capacity during last few years (from 1440 in 2012 to 1880 in 2015). Accordingly, it could be expected to have an increase in fuel economy value (i.e. decrease in energy efficiency) and CO_2 emissions in the coming years, though there is a progressive improvement in the fuel economy of new vehicles manufactured. Therefore, it is important for the government to develop appropriate policies to manage the fuel economy in cars to mitigate the adverse effects on the economy and the environment.

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ANNEX 1: VEHICLE INFORMATION DATA SHEET – A SAMPLE

VIN	Mileage (km)	Year of First Reg.	Year of Manufacture	Make	Model	No. of Cylinders	Fuel Type	Capacity (cc)	Fuel Economy (l/100 km)	CO_2 (g/km)	Power (kW)
CPKR9801	11501	2012	2012	KIA	Sorrento	4	D	2199	8.1	189	145
WPKS2276	11311	2012	2012	MICRO	MX711	4	P	1498	6.5	153	69
WPKR8730	22004	2012	2012	MARUTI	800	3	P	796	6.2	145	37
WPKS1547	3024	2012	2012	MICRO	PANDA	4	P	1342	7.2	168	63
WPKV0683	27082	2013	2012	TOYOTA	VITZ	4	P	1298	6.0	140	64
WPKS1547	3027	2012	2012	MICRO	PANDA	4	P	1342	7.2	168	63
WPKV0309	2612	2012	2012	TOYOTA	DBA NZT260	4	P	1496	6.0	141	80
CPKT1040	4250	2012	2012	MARUTI	ALTO	3	P	796	6.4	150	35
WPKS3644	4583	2012	2012	MICRO	PANDA LC 1.3	4	P	1342	7.2	168	63
SPKS1438	3024	2012	2012	MICRO	PANDA	3	P	998	5.5	129	44
WPKV1108	440	2013	2012	TOYOTA	DBA NZT260	4	P	1496	6.0	141	80
WPKS1081	13124	2012	2012	MARUTI	ALTO-K10	3	P	998	5.9	138	50
NWKV0793	1090	2013	2012	TOYOTA	DBA-KGC10	3	P	996	5.3	124	51
NWKR9678	8265	2012	2012	MARUTI	A STAR	3	P	998	5.3	124	49
WPKV1053	487	2013	2012	TOYOTA	DBA NZT260	4	P	1496	6.0	141	80
WPKV1116	275	2013	2012	MITSUBISHI	OUTLANDER	4	P	1998	6.7	158	110
WPKY0005	7407	2013	2012	BMW	520D	4	D	1995	5.9	139	135
WPKV1096	19140	2013	2012	TOYOTA	COROLLA	4	P	1598	5.9	137	91
EPKS1499	4002	2012	2012	NISSAN	SUNNY	4	P	1498	8.0	186	73
WPKS5173	16996	2012	2012	MITSUBISHI	LANCER	4	P	1590	6.0	141	86
SPKR9577	9470	2012	2012	MICRO	TREND	4	P	1075	6.5	152	52