ROAD TRANSPORT sector and AIR POLLUTION

CASE OF LEBANON

2016

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Road Transport Sector and Air Pollution Case of Lebanon 2016

TABLE OF CONTENTS

This project is part of the "National Campaign for Air Pollution Reduction in Lebanon through Efficient Energy Use in Land Transportation" launched by IPT Energy Center (IPTEC) and supported by the Ministry of Environment (MoE), the Economic and Social Commission for Western Asia (ESCWA), and the United Nations Development Programme (UNDP). This report has been prepared and reviewed by Nabiha El Khoury, Lea Kai Aboujaoudé and Korkin Kadehjian.

LIST OF FIGURES

LIST OF TABLES

ACRONYMS

BRT	Bus Rapid Transit
CAA	Clean Air Act
ELV	End-of-Life Vehicles
ERM	Environmental Resources Management
FEV	Fuel-Efficient Vehicles
GBA	Greater Beirut Area
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GHG	Greenhouse Gases
GoL	Government of Lebanon
GWP	Global Warming Potential
HDV	Heavy-Duty Vehicles
HEV	Hybrid Electric Vehicle
IEA	International Energy Agency
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
IPTEC	Issa Petrol Trade Energy Center
LCC	Lebanese Community Company
LEDO	Lebanese Environment and Development Observatory
LDV	Light-Duty Vehicles
MoE	Ministry of Environment
MoIM	Ministry of Interior and Municipalities
MoPWT	Ministry of Public Works and Transport
NAMA	National Appropriate Mitigation Action
OECD	Organization for Economic Co-operation and Development
PC	Passenger Cars
RPTA	Railway and Public Transport Authority
SUV	Sport Utility Vehicle
TRU	Transport Regulatory Unit
TSP	Total Suspended Particles
UNDP	United Nations Development Programme
URC	UNEP Risoe Center

I. INTRODUCTION

As part of the partnership between the public and the private sector, the United Nations Development Programme (UNDP) climate change projects at the Ministry of Environment has collaborated with IPTEC, the energy center of IPT, to launch a national campaign for "Air pollution reduction in Lebanon through efficient energy use in land transportation".

The campaign aims at conducting research and studies on the subject, promoting solutions with low environmental impact and encouraging the adoption of energy efficient policies and measures in transport in Lebanon. This complements the efforts that have been invested by the Ministry of Environment to plan mitigation measures to reduce greenhouse gas emissions from the transport sector, namely through the Technology Needs Assessment and Third National Communication reports (MoE/URC/GEF, 2012; MoE/UNDP/GEF, 2016). In addition, a Nationally Appropriate Mitigation Action (NAMA) on transport that targets the renewing of the current vehicle fleet and the establishment of a car scrappage program, that the Ministry is currently being prepared under the UNDP Low Emissions Capacity Building project.

This paper examines the origins of, and the damages caused by, air pollution from road transport in Lebanon. It presents the characteristics of the sector in Lebanon and assesses the underlying causes of its major impact on air pollution. The paper also describes measures that are already being undertaken to tackle air pollution from the transport sector and proposes additional measures to improve the current conditions.

The project is supported by the Ministry of Environment (MoE), the Economic and Social Commission for Western Asia (ESCWA), the United Nations Development Programme (UNDP) and IPT Energy Center (IPTEC). This report has been prepared and reviewed by Nabiha El Khoury, Lea Kai Aboujaoudé and Korkin Kadehjian.

II. EMISSIONS OF THE TRANSPORT SECTOR

Transport is fundamental for the social and economic development of countries as well as for sustaining regional and global cooperation and economies. The fact that the transport sector is growing quickly brings advantages, such as quick access to any geographical location, however it is associated with a number of health and pollution problems. The transport sector encompasses land, marine and air mobility subsectors. For the scope of this paper only land transport will be considered.

Transportation involves the combustion of fossil fuels, which produces energy to be transformed into motion. This combustion is the reaction of the hydrogen and carbon present in the fuels with oxygen in the air to produce, idealistically, water vapor (H_2O) and carbon dioxide (CO_2). Neither of these products is damaging to human health. However, CO_2 is the principal gas responsible for the "greenhouse effect", an increase in the average temperature of the planet resulting from the trapping of solar energy, with which the increased presence of this gas in the atmosphere is associated. The more energy consumed for transportation, the more CO_2 emitted. Increases in the average temperature of the planet are believed to lead to unpredictable changes in the global climate, potentially creating, exacerbating or increasing the frequency of natural disasters. The combustion of hydrocarbons produces a number of other by-products more directly damaging to human health.

These other pollutants have three possible origins; the incomplete carbon reactions, the unburned hydrocarbons or other elements present in the fuel or air during combustion (Gorham, 2002).

The main air pollutants are nitrogen oxides (NO_x), carbon monoxide (CO), non-methane volatile organic compounds (NMVOCs) and sulphur dioxide (SO_2). On the other hand, the main greenhouse gases (GHGs) are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). CO_2 emissions are by far the most significant. Also, particulate matter is an important byproduct emitted by the transport sector. These primary pollutants can, in turn, react in the atmosphere to form ozone, secondary particulates, and other damaging pollutants that can change global atmospheric composition.

The cost of environmental degradation in Lebanon was estimated to be close to USD 485 million per year, or 2.9 percent of GDP (World Bank/METAP, 2003). The most significant negative impacts on health are caused by urban air pollution with a mean estimate of USD 145 million per year or 0.87 percent of GDP. The linkage between the transport sector emissions and their adverse impacts on human health is quite complex. Both the type and the proportion of the emitted gases depend on several factors, including the vehicle type, the utilized fuel and the driving conditions of a particular trip (Gorham, 2002). These emissions are dispersed into the ambient air according to atmospheric conditions, which also influence the extent to which they react to form secondary pollutants. The degree to which people may be exposed to these primary or secondary pollutants depends on the type activities they engage in (e.g. jogging, cycling or driving), and where the highest concentrations of

pollutants tend to be in a metropolitan area. The relative dose of the pollutants individuals receive depends on their own physiological conditions during exposure, and responses to doses can vary from person to person (Gorham, 2002).

Global demand for mobility is growing rapidly, with the number of vehicles projected by the International Energy Agency (IEA) to triple by 2050. Transportation accounts about 21% of GHG emissions worldwide. The IEA forecasts that transport sector emissions of carbon dioxide to increase by 92% by 2020 compared to 1990. Methane (CH_4) and nitrous oxide (N_2O) are also of concern for the transport sector, not because it is currently a large source of GHGs, but because certain technologies, namely NO_x control technologies and natural gas fuel systems that may be adopted into widespread use in vehicles to address local pollutant emissions may increase emissions of these GHGs in the future. In fact, most of the nitrogen dioxide in cities is released from motor vehicles. Each car emits 1.6 tonnes of carbon dioxide per year; to offset the emissions from a single vehicle, at least 160 two-year-old trees would need to be planted each year (Wadvalla, 2011). The unabated increase in motorized transport and the concentration of vehicles in urban areas has critically affected the air quality in several cities. The transport sector accounts for 22% of the total greenhouse gas emissions, of which 85% is attributed to in-land transportation. Nevertheless, being highly dependent on fossil fuels, transport is responsible for about 27% of the current energy use worldwide, as it accounts for about 50% of the global oil demand. In fact, energy supply is a critical concern for the transport sector. Vehicle emissions are a function of many factors including (MoE, 2005):

- **Roadway congestion**
- **Vehicle kilometers traveled**
- **Vehicle age and class**
- **Engine tuning and condition**
- **Pollution reduction technology**
- **Fuel type/quality and characteristics**
- **Ambient and engine temperatures**
- **Operating altitudes**
- **Road inadequate maintenance and upkeep**
- **Road low safety and enforcement**
- **Strong reliance on private passenger cars**

III. ROAD TRANSPORT IN LEBANON

A. Overview

Road transport in Lebanon consists of road-motorized vehicles only, since there is no appropriate infrastructure for non-motorized vehicles in Lebanon (e.g. bicycle lanes, safe storage space, and convenient and affordable bike rentals) and the former rail network, currently abandoned. Types of vehicles investigated in this study are motorcycles, passenger cars, vans, buses and trucks, classified into categories: Passenger Cars (PC), Light-Duty Vehicles (LDV), Heavy-Duty Vehicles (HDV) and motorcycles (**Table1**).

The majority of the road-motorized vehicles are personal-owned passenger cars. According to the 2012 vehicle fleet database there is a total of 1.58 million registered vehicles in Lebanon (MoIM, 2013). However, due to the lack of information on the number of vehicles removed from circulation each year and the fact that many vehicles operate illegaly without a license/ illegally, a detailed characterization of the vehicle fleet is not possible (MoE/LEDO, 2001).

Table 1

Vehicle category	Description
Passenger Cars (PC)	Private personal gasoline cars used for mobility including Sport Utility Vehicles (SUV).
Light Duty Vehicles (LDV)	Gasoline vehicles with rated gross weight less than 3,500 kg including light trucks and coaches, designed for transportation of cargo or passengers.
Heavy Duty Vehicles (HDV)	Diesel vehicles with rated gross weight exceeding 3,500 kg including heavy trucks and coaches, designed for transportation of cargo or passengers.
Motorcycles	Includes a mixture of 2-stroke and 4-stroke engines as well as mopeds having an engine less than 50cc.

Table 1 Description of the vehicles categories used in the calculation of road transport emissions

The vehicle fleet distribution in Lebanon is represented in **Figure 1**. The highest share is for passenger cars which constitutes 85% of the total fleet. Vehicles from different manufacturers can produce various vehicle emission ratios. This reflects the engine technology and emission control system used by the manufacturers. The Lebanese vehicle fleet is mostly constituted of European vehicles.

The classification per country of origin of the vehicle fleet is represented in **Figure 2.**

After banning the use of diesel oil for vehicles with gross weight lower than 3,500 kg (law 341 (6/08/2001) and decree No. 341/2002), passenger cars, light-duty vehicles and motorcycles run only on gasoline, while HDVs run on diesel oil.

Figure 1

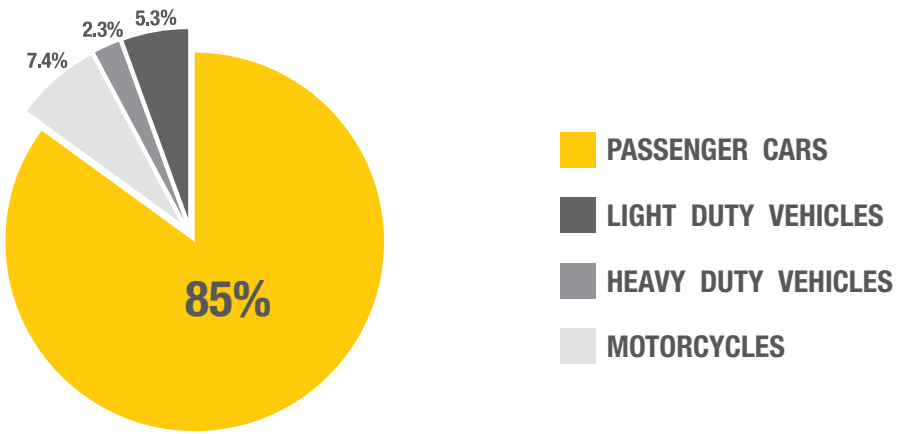


Figure 1 The 2012 vehicle fleet distribution in Lebanon per type of vehicle
Source | MoE/UNDP/GEF, 2015a

Figure 2

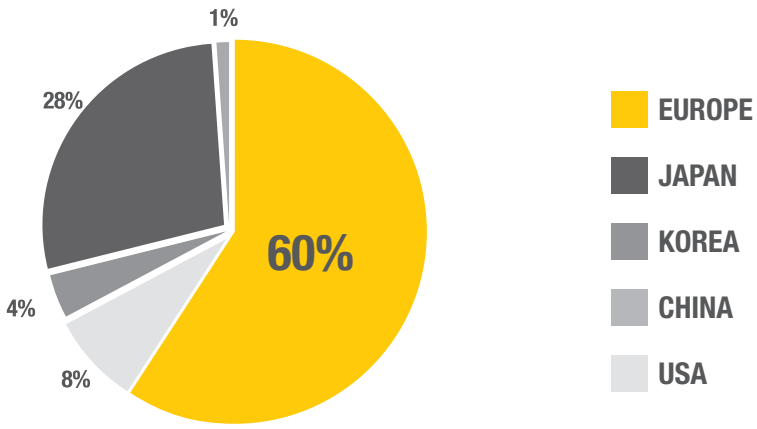


Figure 2 Classification per country of origin of the 2010 Lebanese vehicle fleet
Source | MoE/UNDP/GEF, 2015b

The Greater Beirut Area (GBA), which extends from Nahr-el-Damour south to Nahr-el-Kalb north, encloses more than 40% of the population of Lebanon, and 1.5 million of daily passenger trips estimated in 1994. Traffic conditions in GBA can be described as mostly congested especially at the entrances to Beirut, with a daily traffic volume of 230,000 passenger-car-unit crossing the north coastal highway and 85,000 the southern highway and delays at some intersections ranging from 5 to 30 minutes (MoE/URC/GEF, 2012). The average speeds during the day along the major axes in the GBA range between 15 and 30 km/hr, dropping to 10 km/hr and less in the commercial districts within the city at peak times (MoE, 2005).

Lebanon has around 22,000 km of roads, 30 percent of which are classified and fall under the authority of the Ministry of Public Works and Transport (MoPWT) as international, primary, secondary, and local roadways while the remaining 70 percent are non-classified roads governed by municipalities (MoE/LEDO, 2001).

More than one third of the road network is in poor condition, and the traditional maintenance practices have been twice as costly as those for stable well-maintained networks in other countries. At present, there are no dedicated road fund or road user tariffs to charge road users equitably and to fund maintenance and expansion of the roadway network.

These facts suggest that a proportionately higher percentage of emissions are released into the atmosphere per vehicle-kilometer or vehicle-hour of congestion than in more developed countries. Moreover, it is predicted that the rate of congestion in major urban centers will increase significantly. This increase in congestion as well as in the number and average lengths of vehicle trips will lead to the release of additional emissions into the atmosphere (MoE, 2005).

It has been well established in numerous studies that the Lebanese passenger transport sector is unsustainable from different perspectives. A study conducted by the UNDP climate change projects provides an approach from the cost side of mobility in Lebanon (MoE/UNDP, 2015a). Mobility is by definition the movement of passengers (and goods) from an origin to a destination, and therefore, mobility cost is the cost borne by society at large due to this movement. This cost includes ownership and vehicle operating costs, borne by the driver (also assumed to be the car owner), in addition to the cost of externalities, including but not limited to the costs of pollution, climate change, accidents, congestion and travel time. The cost of externalities is borne by society as a whole. In fact, the study proved the importance of including externality costs in mobility cost as well as their gravity on a social impact level since one third of total mobility cost is attributed to externalities. The study estimated that on average one passenger traveling one kilometer in a vehicle in Lebanon costs around US¢ 48, including externality components of pollution, travel time, congestion, and accident.

It was found that the most critical sustainable mobility indicators were not emissions or safety-related, but mostly pointed towards efficiency with an excessive energy consumption by the passenger transport sector. Globally, energy products are taxed to factor in the negative externalities from energy consumption. For transport fuels, excise taxes are the most common form of taxing. It is found that the average excise rate among 22 OECD (Organization for Economic Cooperation and Development) countries is 60.2 US¢/liter (IMF, 2014), while the gasoline excise rate in Lebanon stands well below this average: at 16.7 US¢/ liter (LBP 5,000 per 20 liters). In reality, the externality cost sums up to 109 US¢/liter (**Table 2**), which is well above the current excise rate.

Table 2

Externality	Corresponding cost (US¢/liter)
Pollution	11.43
Carbon	0.034
Congestion	47.07
Accidents	51.03
Total	109.60

Table 2 Transportation-related externality costs for gasoline and diesel oil in Lebanon
Source | MoE/UNDP, 2015a

B. Institutional and legal framework of the transport sector in Lebanon

Institutional Framework

According to the National Environmental Action Plan (MoE, 2005), there are vague responsibilities and clear-cut functions among involved authorities. An institutional overview reveals that the jurisdiction within various components of the transport sector in Lebanon remains fragmented. Limits of authority are not always clear leading to a low level of accountability and causing inter-ministerial friction.

While there are numerous instances of overlapping functions, there are also serious functional and process gaps, such as:

- Lack of coordination between urban transport modes and components such as the requirements of through traffic (traffic that remains on the highway rather than crossing into a town) versus local traffic, private cars versus public transport, traffic lanes and parking lanes, transport planning and enforcement, etc.
- Major gap in the transport system management function resulting in serious improvement opportunity losses in the urban transport system.
- Road safety addressed only as a physical sub-project, rather than considering it as a comprehensive road safety philosophy.
- Lack of appreciation of the economic impacts of congestion, air pollution, and other adverse effects on the users and the urban economy and the need to adopt knowledge-intensive high-tech management approaches for solving complex (urban) transport problems.

Existing Laws And Regulations

Within the legislative and regulatory framework, Lebanon is legally bound to multilateral environmental agreements (MEAs) for environmental protection and to date effectively complying with practical air quality objectives remains rather weak. Whilst many laws, decrees, ministerial decisions, application decrees related to road transport and air pollution are available since the 1960s, such initiatives require updating, reviewing, approving and/or strengthening for effective implementation and compliance.

Table 3

Policies/Regulations	Description
Decree no. 124/2003	Specifications of motorcycles and engines, and allowed time to drive, applied in all areas of Lebanon.
Decree no. 8243/2003	Mandatory annual vehicle inspection.
Decree no. 11244/2003	Set up Traffic Management Organization (TMO), which has yet to carry out a technical traffic management role rather than just an administrative one.
Decree no. 7858/2002	• Incentives to renew the fleet such as exempting new cars, 5 years old cars, public transport cars, and buses of no more than 24 passengers from import tax, and registration, and inspection fees. • Compensate owners of private cars, public transport cars, and buses which would convert to gasoline engines with amounts ranging from LBP 1,000,000 to 13,000,000 depending on the year of manufacture. • Ban the use of private and public cars of diesel engines starting from 15/6/2002. • Ban the use of private and public transport autobuses of diesel engines starting from 15/7/2002. • Ban the use of public buses of 16 to 24 passengers of diesel engines starting from 31/10/2002. • Designate the port of Beirut and Tripoli for collecting the replaced engines until they are exported outside Lebanon.
Decree no. 8442/2002	Specifications of fuel motor vehicle; Diesel oil and gasoline 92, 95 and 98 octane.

Law 341 (6/08/2001)	The law lays the legal framework for reducing air pollution from the transport sector and encouraging the use of cleaner sources of fuel. Specifically, the law bans the import of minivans operating on diesel engines, as well as old and new diesel engines for private passenger cars and minivans. The law empowered the GoL to retrieve 10,000 public license plates operating on diesel.
Council of Ministers Decision no.9, on 5/4/2000	The decision calls for the reform and reorganization of the Land Public Transport Sector in Lebanon and the reduction of the number of public transport vehicles from 39,761 to 27,061 vehicles.
Decree no.6603(4/4/1995)	It defines standards for operating diesel trucks and buses, as well as the implementation of a monitoring plan and permissible levels of exhaust fumes and exhaust quality (particularly for CO, NO_x , hydrocarbons and TSP).

Table 3 Rules, policies and regulation covering the mitigation of GHG emissions from road transport
Source | MoE/URC/GEF, 2012

IV. EMISSIONS FROM ROAD TRANSPORT IN LEBANON

A. Air Pollutants Emissions: CO, NMVOCs, SO_2, NO_x

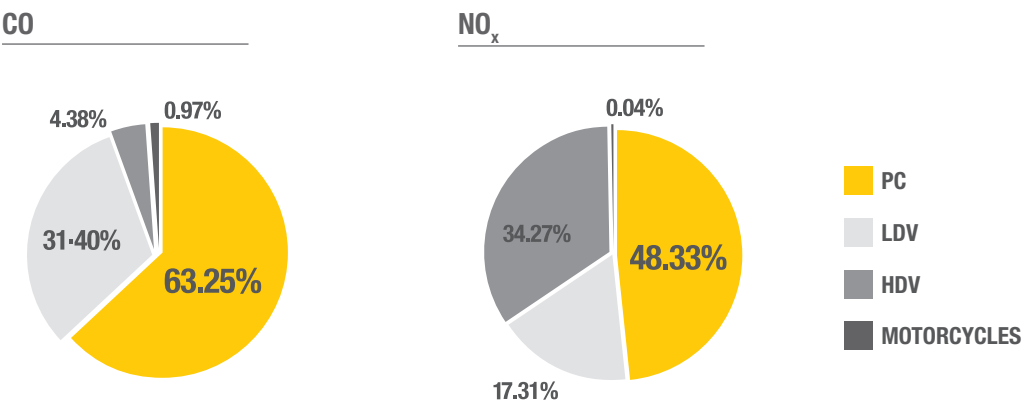
The transport sector is responsible for the emissions of nitrogen oxides (NO_x), carbon monoxide (CO), Non-Methane Volatile Organic Compounds (NMVOCs) and sulphur dioxide (SO_2) among other gases. In 2011, the emissions from road transport in Lebanon were 51.79 Gg NO_x, 358.37 Gg CO, 72.34 Gg NMVOCs and 5.34 Gg SO_2 (Table 4). Transport contributes more than half of the national NO_x emissions (62%) and the majority of total national CO emissions (99%). Emissions per vehicle category are dominated by passenger cars as presented in Figure 3. HDV contribution to SO_2 emissions is considerable despite their relatively low number as HDV uses diesel fuel with higher sulphur content than gasoline used for PC.

Table 4

	NO_x	CO	NMVOCs	SO_2
Emissions Gg	51.79	358.37	72.34	5.34
Share of national emissions	62%	99%	63%	4.8%

Table 4 Transport sector air pollutants emissions for 2011

Figure 3



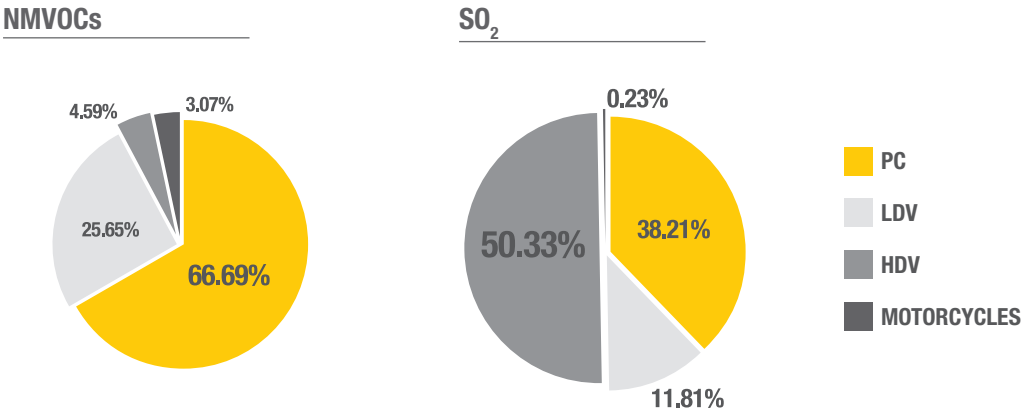


Figure 3 Contribution of the different vehicle categories to the indirect GHG pollutants for 2010
Source | MoE/UNDP/GEF, 2015a

In addition, an important air pollutant emitted by the transport sector is particulate matter which refers generally to all particles suspended in air. Sources of particulate matter emissions are numerous such as vehicle tire, brake, clutch and surface wear, which are mainly responsible for the emissions of PM10 (Waked and Afif, 2012). PM2.5 emissions are of greater concern since they are small enough to penetrate into the lungs. Elements like Cu, Zn and Pb predominate in PM2.5. Anthropogenic sources of these elements are worn brakes and tires in high traffic density area especially in populated and large cities (Saliba et al., 2007).

Particulate matter, small solid or liquid particles or aerosols suspended in air, is the most daunting because the direct impacts on human health as far as they are understood today appear to be significant, and because reducing these emissions is tricky. Unfortunately, while the adverse effects on human health are well established, the precise chemical, biological, and physical mechanisms responsible for these effects are poorly understood. Larger particles (larger than 10 µg in diameter) precipitate rapidly from the atmosphere, and are then less likely to be inhaled. In case they are, they get filtered efficiently by the nasal system and upper respiratory tract. Consequently, these particles, such as resuspended road dust, are not considered substantial health risks. However, many particles associated with fossil fuel combustion, and tire and brake wear, such as PM2.5, are small enough that they can penetrate deep into the lungs, and take longer to precipitate out of the atmosphere. These respirable particles are produced as a result of fossil fuel combustion-not only in the combustion chamber itself, but also potentially minutes, hours, or even days later as gaseous pollutants react in the atmosphere in myriad complex ways. Aerosols produced from combustion that are of concern include carbonaceous particles, sulphates, nitrate-based particles, and ash.

B. Greenhouse Gas Emissions: CO_2, CH_4, N_2O

The transport sector is the second consumer of fossil fuel in Lebanon after energy production. Greenhouse Gas (GHG) emissions from transport account for 23.6% of the total national GHG emissions and include emissions of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Indeed, in 2011, transport in Lebanon was responsible for around 5,813.43 Gg CO_2eq. The emissions per gas were 5,645.42 Gg for CO_2, 25.41 Gg CO_2eq. of CH_4 and 142 Gg CO_2eq. of N_2O (Table 5).

Table 5

	CO_2 Emissions	CH_4 (CO_2eq.)	N_2O (CO_2eq.)	Total GHGs Emissions (CO_2eq.)
Emissions Gg	5,645.42	25.41	142.60	5,813.43
Share of national emissions	27%	0.88%	15%	23.6%

CO_2eq.: The amount of CO_2 that, if released into the atmosphere, will have the same global warming effect as the mixture of gases actually released.

A Global Warning Potential (GWP) of 1 was used for CO_2, 21 for CH_4 and 310 for N_2O. Source | MoE/UNDP/GEF, 2015a

Table 5 Transport sector GHG emissions in 2011

Contribution of The Different Vehicle Categories

The contribution of the different vehicle categories to GHG emissions shows that Private Cars (PC) have the highest share of the 2011 emissions, with 58.38% of the total road transport emissions (CO_2eq.), while Light-Duty Vehicles (LDV), Heavy-Duty Vehicles (HDV), and motorcycles account for 17.46%, 23.81%, and 0.35% respectively. PC is the main emitting subcategory of all GHG. LDV is the second most important contributor to CH_4 and HDV to CO_2 and N_2O, as illustrated in Figure 4 (MoE/UNDP/GEF, 2015a).

Figure 4

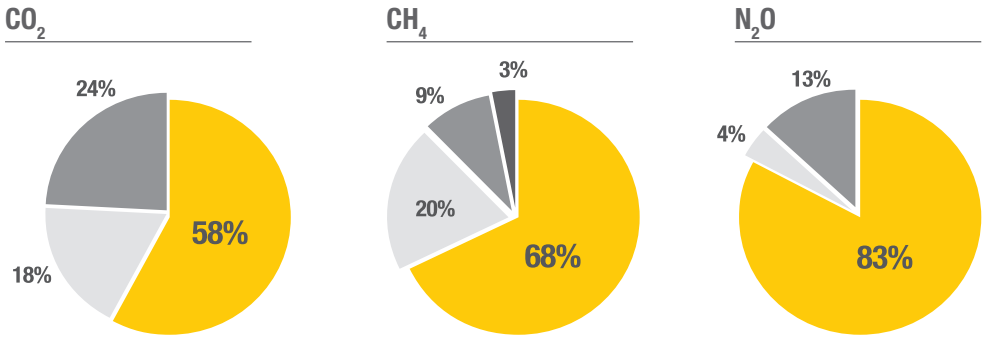


Figure 4 Contribution of the different vehicle categories to the direct GHG pollutants for 2011
Source | MoE/UNDP/GEF, 2015a

C. Trends In Lebanon's Emissions For The Transport Sector: 1994-2011

During the last 10 years, and due to an increase in population, urbanization and consumption patterns, an increase by at least a factor of 2 was observed for air pollutants from transport Figure 5 presents the evolution of NO_x, CO, NMVOCs and SO_2 from 2005 to 2011.

Figure 5

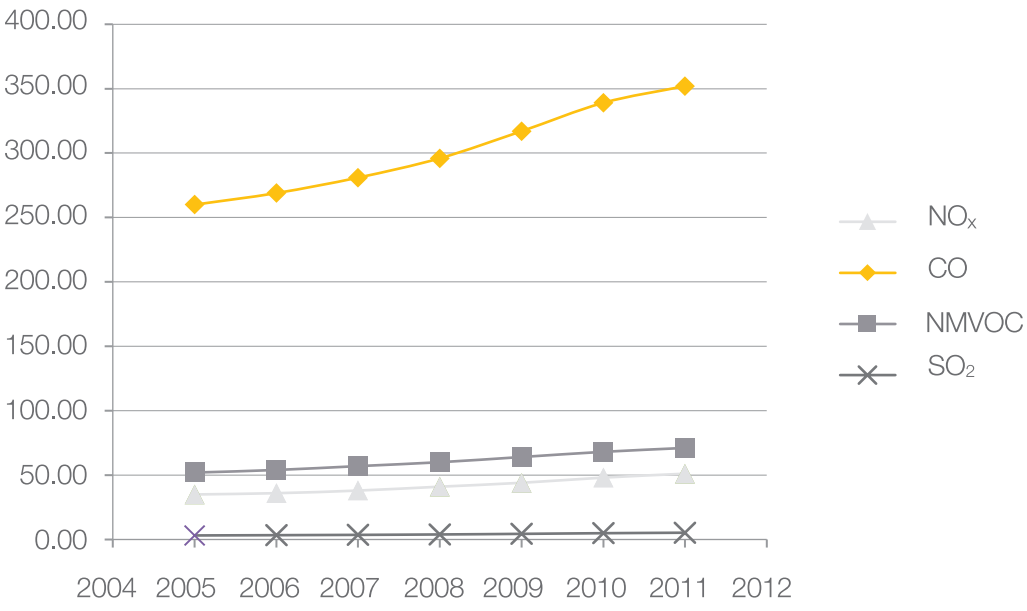


Figure 5 Evolution of NO_x, CO, NMVOCs and SO_2 from 2005 to 2011
Source | MoE/UNDP/GEF, 2015a

Also, the transport sector evolved drastically between 1994 and 2011 in terms of GHG emissions. Considering 1994 as base, GHG emissions from the road transport sector increased since by a factor of 3.7 reaching 5.8 million tonnes CO_2eq. in 2011 (**Figure 6**). A key driver to this significant increase is the fleet volume, which doubled in around two decades (MoE/UNDP/GEF, 2015b)

Figure 6

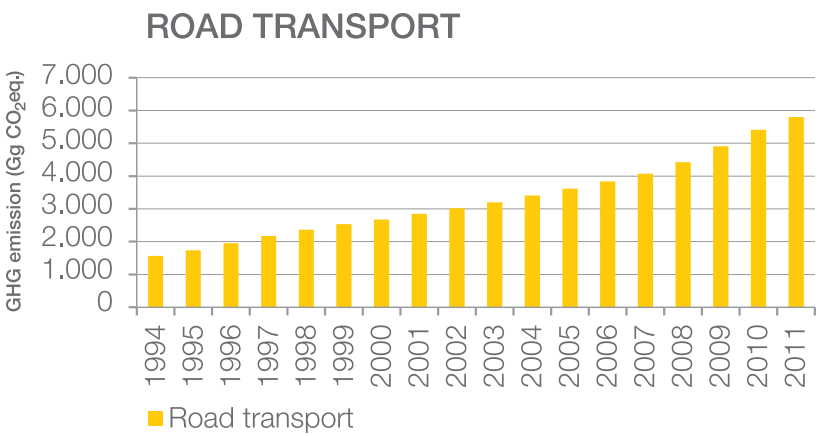


Figure 6 GHG emissions from 1994 to 2011for road transport in Gg of CO_2eq.
Source | MoE/UNDP/GEF, 2015b

The emissions variations of the three main GHGs normalized to the 1994 level are presented in Figure 7. The results show that carbon dioxide has the highest greenhouse impact in Lebanon's transport sector as it shares 97.8% of the total GHG emissions in 2005 (MoE/UNDP/GEF, 2015b). CO_2 emissions from the transport sector increased by a factor of 1.46 compared to the 1994 level i.e. from 3,957.12 to 5,645.14 Gg while methane emissions have increased by a factor of 1.08 i.e. from 1.12 Gg to 1.21 Gg. This is mainly due to the remarkable growth in the vehicle fleet number. Similarly, nitrous oxide has also increased in 2011 by a significant factor of 15.33 compared to the 1994 level, i.e. from 0.03 Gg to 0.46 Gg. This is due to the fact that vehicles equipped with technologies for emission control are suspected to emit higher amounts of nitrous oxide. Consequently, a yearly increase of 20% for CO_2, 14% for CH_4 and 60% for N_2O are observed (MoE/UNDP/GEF, 2015b). These results are summarized in **Table 6**.

Figure 7

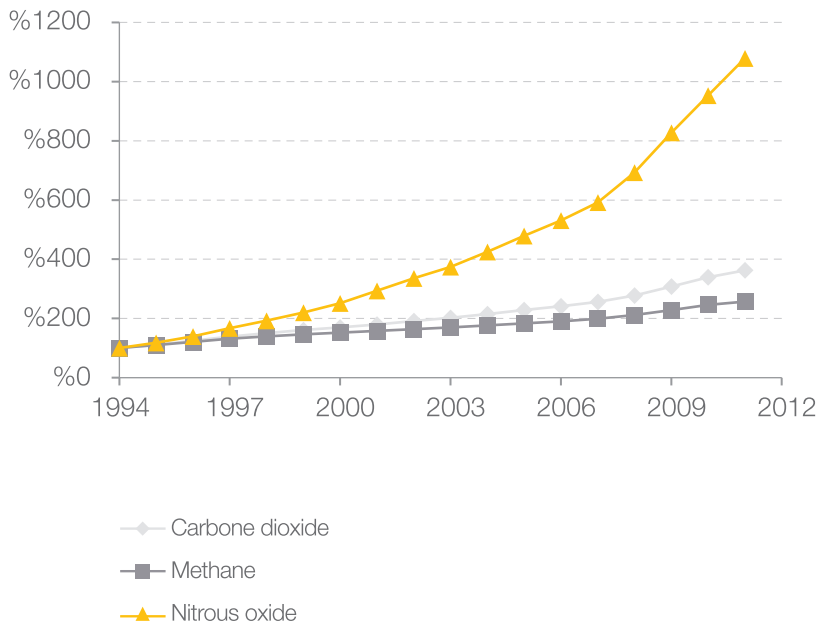


Figure 7 Variation in % of the emissions for the road transport sector of CO_2, CH_4, and N_2O relative to the 1994 level
Source | MoE/UNDP/GEF, 2015b

Table 6

	1994	2011	Percentage Change	Yearly percentage Change
CO_2	3,957.12	5,645.14	146%	20%
CH_4	1,12	1,21	108%	14%
N_2O	0,03	0,46	1533%	60%

Table 6 Variation of the different greenhouse gases from 1994 to 2011

D. Comparison With Neighboring Countries

Lebanon's energy consumption and CO_2 emissions are benchmarked against neighboring countries in the Middle East and North Africa (MENA) region and within the Gulf Cooperation Council (GCC) area, as well as other developed Mediterranean countries, such as Greece and Cyprus (MoE/UNDP, 2015a).

Energy consumption comparison is found in **Figure 8**. In terms of the percentage of energy consumed by the road transport sector, Lebanon ranks second highest with 27.2%, after Cyprus with 31.3%.

The country consumes close to double the world average, which reflects the excessive energy requirements of the Lebanese transport sector. In fact, the passenger transport sector in particular has a high energy demand per capita, higher than the world average (Electris et al., 2009).

This argument is further reinforced when gasoline consumption per capita is investigated: an average Lebanese consumes about 2.7 times more than the world average and 2.3 times more than a citizen of the Arab world.

Furthermore, it is found that Lebanon is on par with the Arab world average and most countries in comparison (except Tunisia and Armenia) in terms of fossil fuel consumption percentage of total energy consumption. However, it still exceeds the world average.

Therefore, the argument that the Lebanese transport sector is dependent on finite fossil fuels is further reinforced, and thus should be a main objective to tackle when formulating policies.

Figure 8

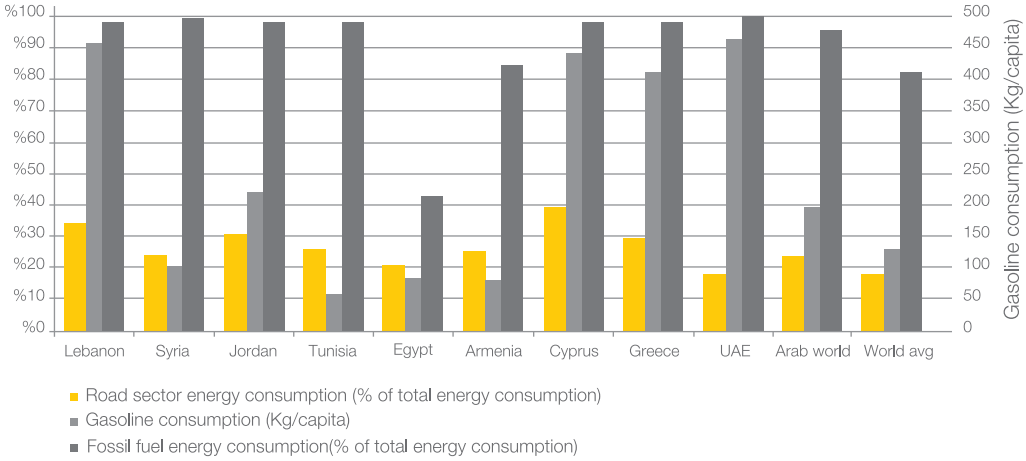


Figure 8 Energy consumption indicators
Source | World Bank, 2014a

CO_2 emission indicators of Lebanon in comparison with other countries is found in Figure 9. Among the countries in comparison, Lebanon ranks second highest in terms of road transport CO_2 emissions, with 27.1% of total CO_2 emissions, close to the Arab world average, but 1.4 times higher than the world average. However, when CO_2 emissions per capita and per GDP/capita are compared, Lebanon ranks among the lowest countries: the figures for CO_2 emissions per capita are 7 times lower than the Arab world average and 4 times lower than the world average. Furthermore, Lebanon ranks amongst the lowest emitters in terms of CO_2 per GDP/capita figures. This shows that Lebanon is an important contributor to CO_2 emissions on a capita basis and therefore, its GHG emissions needs to be reduced.

Figure 9

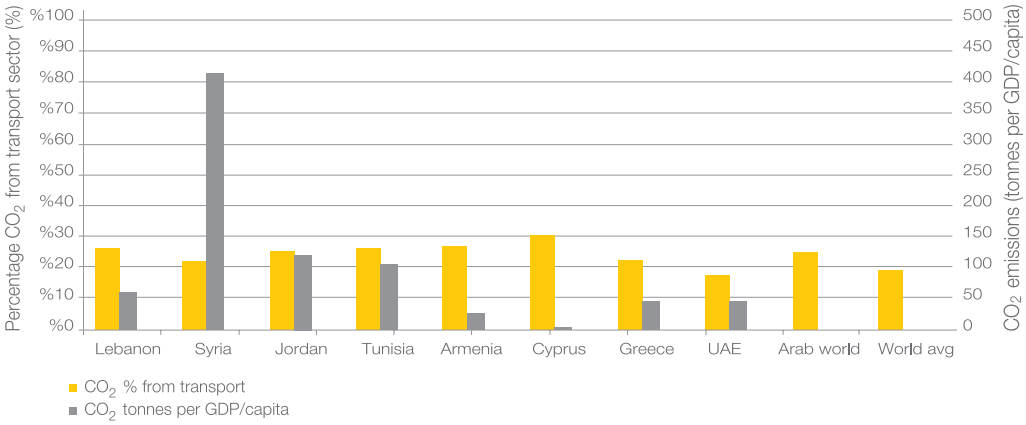


Figure 9 CO_2 emission indicators
Source | World Bank, 2014b

E. Health and Economic Impacts

The fossil fuel combustion associated with transportation results in emissions of pollutants that cause damage to human health, agriculture and sensitive ecosystems, and contribute to global climate change. Transportation can also contribute to the degradation of urban environments, with loss of quality of life and economic productivity from the delays and frustration caused by congestion and stress from traffic noise. They also contribute to the physical and social isolation of certain vulnerable segments of society, such as the poor, children and the elderly.

No study that statistically links urban air pollution and health, based on local health and ambient air monitoring data, has been carried out in Lebanon. However, applying findings from international studies to the local air pollution situation in Lebanon can produce an estimate. Air pollution caused by the transport sector is majorly responsible for human health degradation, and is therefore considered as the main cost of pollution (Delucchi and McCubbin, 2010). In the human body, CO can cause oxygen deprivation (hypoxia) displacing oxygen in bonding with hemoglobin (Gorham, 2002). This can cause cardiovascular and coronary problems, increase risk of stroke, and impair learning ability, dexterity and sleep.

VOCs represent an air quality concern because they are toxic. Some VOCs have shown to have harmful effects on the immune system, the neural network, and hemoglobin. Others are mutagenic and carcinogenic, they can bind to soot particles and be delivered deep into lung tissue (Gorham, 2002). It has also been proven that they cause sensory irritation in humans particularly to the eyes (Calabrese and Kenyon 1991). NO_x has been shown to have toxic effects on human health, including altered lung function, respiratory illness, and lung tissue damage **(Shah and others 1997)**. NO_x has also been shown to exacerbate asthmatic symptoms. Both VOCs and NO_x are important precursor to ozone formation.

Because ozone is an unstable molecule, it requires energy to form and remain intact, and can break down easily into normal oxygen molecules (O_2). For this reason, ozone is dangerous to human health; it interferes with respiratory function, leads to reduced lung capacity and increases the intensity of lung infections (Gorham, 2002).

SO_2 is associated with various bronchial conditions, which can be acute even at relatively low levels of exposure for children or asthmatics.

Particulate matter has been associated epidemiologically with cardiopulmonary disease, cardiovascular disease, respiratory disease, lung cancer, and other cancers (Krewski and others, 2000). It has been suggested to exacerbate conditions such as bronchitis and asthma (Finlayson- Pitts and Pitts, 1999). They are generally too small for the body's natural mechanism to filter, and can lodge in different parts of the respiratory system. However, the precise nature of the mechanism for these diseases

is unclear. It is suspected that both particle size and particle composition play a role in these diseases. Particulate matter also contributes to the formation of ozone which leads to visibility degradation and can scatter and/or absorb solar radiation (IPCC, 2001).

Transportation is also a major source of global pollutants, that is, those responsible for the greenhouse effect. Greenhouse gases cause global warming by acting as a blanket that retains solar heat in the atmosphere. Greater concentration of GHGs in the atmosphere increases the heat retention, which leads to higher global temperatures in other words to global warming.

This process is suspected to cause adverse environmental consequences including coastal zones flooding and desertification. Both flooding and desertification are likely to affect Lebanon significantly since it is located at the border of desert regions and more than 60% of its economic activity lies in a narrow coastal plain along the Mediterranean sea (ERM, 1995).

Emissions such as carbon dioxide and other greenhouse gases are primarily responsible for global warming, local smog and regional acid rain creating additional damage to health, as well as to the esthetic quality of the environment. CO_2 is the most important of the greenhouse gases, accounting for half of the annual increase in average global temperatures. It is also the predominant greenhouse gas emitted by motor vehicles. The transport sector is not a large source of anthropogenic methane, a highly stable, usually non-reactive hydrocarbon. Gasoline, diesel and jet fuel contain minimal amounts of methane. Of concern, however, is the growing use of natural gas in the transport sector worldwide, which consists mostly of methane. Nitrous oxide is the most potent of the greenhouse gases emitted by the transport sector. It is estimated that nitrous oxide is 310 times as potent as carbon dioxide.

Pollution from transportation also causes damage to crops, farmland, forests, lakes, rivers, streams, coastal waters and wetlands. This damage is mainly due to the effects of acidification, eutrophication and migratory ozone among others. Acidification is a reduction in the pH balance of precipitation, affecting surface freshwater bodies, forests and crops. In freshwater bodies, such as lakes and streams, acidification reduces the viability of the water environment to support life. It can lead to the extinction of a number of species of fish and other freshwater fauna. Acid deposits from rainfall have also been implicated in forest degradation, both by directly injuring certain species of trees, such as high-elevation spruces, and through long-term changes in soil chemistry (Gorham, 2002).

There may be similar effects on agriculture, potentially reducing crop yields. Acidification is caused by complex atmospheric reactions from nitrogen and sulphur compounds, in particular nitrogen dioxide, sulphur dioxide, nitric acid (HNO_3) and sulphuric acid. Nitrate runoff from soil depositions can cause biological “hyper productivity” in fresh and salt-water bodies known as eutrophication.

This hyper productivity can stimulate the development of algae, to the detriment of other flora and fauna through complex changes in the ecosystem balance (Gorham, 2002). Eutrophication has traditionally been associated with sewage and fertilizers as the primary source of nitrates. However recent attention has begun to identify NO_x formed during fossil fuel combustion as another potential culprit. Eutrophication affects predominantly freshwater aquatic and coastal marine systems.

In addition to affecting air quality and natural environmental degradation, transportation can also play a key role in the degradation of urban environments. The delays and frustration caused by urban traffic congestion can reduce human productivity and quality of life, thus possibly reducing the potential gross domestic or gross regional product. The noise produced by various types of motor vehicles, as well as the excessive use of horns - a fact of life in cities in many developing countries - raises the level of ambient noise, increases stress and reduces the quality of life. Transportation can also contribute to the physical and social isolation of certain vulnerable segments of society, such as the poor, children and the elderly.

F. Analysis Of Results

As previously stated, direct and indirect GHG emissions are an inevitable combustion byproduct, which is at the basis of transportation. However, these emissions are magnified in Lebanon by the following factors:

- **Behavior habits**
- **Old fleet**
- **High passenger transport energy intensity**
- **Absence of a proper public transport system**

Behavior Habits

The current land transportation system mainly relies on vehicles, particularly private passenger vehicles. The annual travelled distance in Lebanon is estimated at 12,000 km/year for passenger cars, 25,000 km/year for light-duty vehicles, 50,000 km/year for heavy-duty vehicles and 5,000 km/year for motorcycles (MoE/UNDP/GEF, 2015b). Based on collected data from on-road measurements in the GBA with a Global Positioning System (GPS)-guided survey of typical driver habits, the driving patterns can be characterized by the relatively low driving range with a high rate of congestion and frequent stops at short time intervals which highly impact emissions from cars (MoE/URC/GEF, 2012):

- **50% of total trips have a total distance lower than 5 km and 75% lower than 12 km, with an average trip distance of 9.6 km.**
- **25% of stops are below 2 seconds and 75% below 10 seconds.**
- **Stop time corresponds to more than 15% of travel time.**

Moreover, observed results show an inefficient operation of internal combustion engines, and a high rate of fuel consumption and pollutant emissions due to the continuous stop-and-go driving patterns and the significant acceleration rates at very low speed.

In addition, vehicular emissions are correlated with the car speed. In a study by H. Sbayti et al. it was found that HC, CO and NMVOCs emission factors generally decrease with increasing speeds up to 50 mph, rapidly at first then more slowly. However, the NO_x emission factors, which are less sensitive to speed changes, follow a parabolic path and tend to decrease to 30 mph and then increase. Given the congestion problem in Lebanon, passengers frequently have to drive on a minimal speed which leads to higher emissions.

Also, the high rate of car ownership is estimated to be 3.7 individuals per car (MoE/UNDP, 2015a) with low vehicle occupancy, counting 1.2 passengers per car (MoE/URC/GEF, 2012). The latter fleet characteristics, high vehicle ownership and low occupancy rate, create heavy congestions during peak hours, especially on entries and exits of Beirut. This high car ownership, at the given GDP level, suggests that a very considerable part of the household income has to be spent on transport.

A study conducted by Waked et al. in 2012 on the variation of the number of vehicles in urban areas during the year, showed an increase in the number of vehicles in winter

(December and January) and a decrease in summer (August and September). It also showed that the traffic flow increases from Monday till Wednesday and then decreases from Wednesday till Friday. A significant decrease is observed on Saturdays and Sundays, which is related to the fact that the majority of businesses and schools are closed. Therefore, emissions will increase during the peak times since the car will be operating under its speed efficient level with continuous intervals of acceleration and deceleration. This is of serious concern since Lebanon faced a constant congestion problem especially in the Greater Beirut Area.

Old Fleet

For a number of complex reasons, older vehicles are more closely associated with higher emissions of both global and local pollutants than newer vehicles. First, performance deteriorates as a function of age. They are also less often equipped with advanced engine technologies such as catalytic converters. Also, catalyst function can deteriorate because of a build-up of trace contaminants, poor maintenance or misfuelling, all of which are a function of age. Vehicles themselves lose energy efficiency through ageing, and the depreciation of vehicles increases the likelihood of neglect and poor maintenance. Second, older vehicles are more likely to use obsolete technology, with poor carburetion, inefficient engine design consuming more fuel and outdated use of heavy materials. These factors improve with younger models. The age distribution of vehicles in Lebanon is illustrated in Figure 10 reflecting the old nature of the Lebanese fleet, with 71% older than 10 years. A study conducted in Tripoli, showed that three-quarter of the older models (before 1970) failed the exhaust emission tests (MoE/LEDO, 2001).

Figure 10

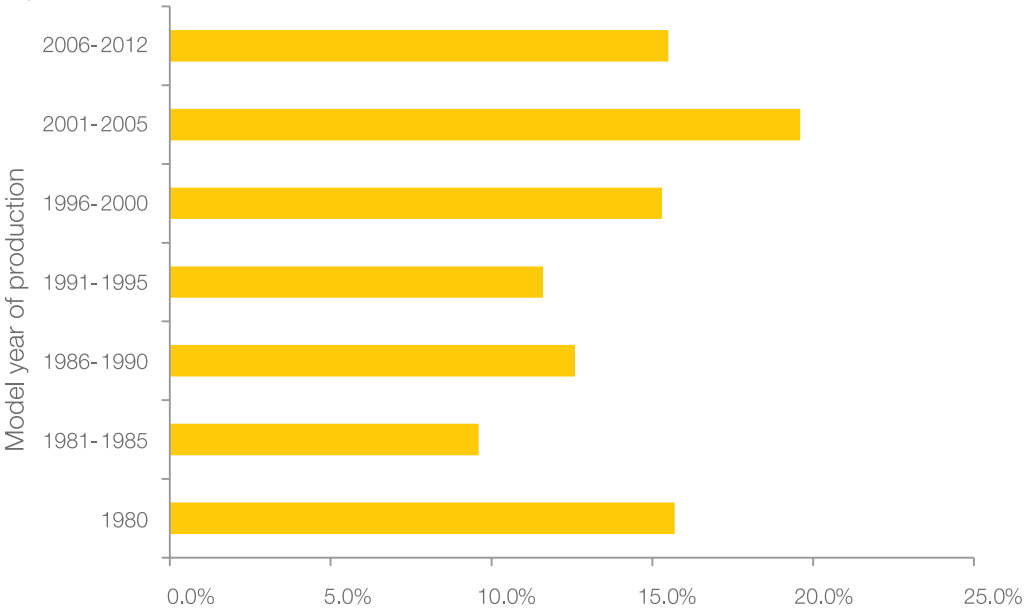


Figure 10 Vehicle percentage distribution per model year of production
Source | MoIM, 2013

According to the NEAP (MoE, 2005), such a high fleet age is attributed to:

- **The non-restricted import of vehicles prior to 1995, the date where the Lebanese authorities imposed new regulations banning the import of vehicles above 8 years old.**
- **The availability of old and cheap vehicles in the Lebanese market.**
- **The cost of vehicle registration and of annual license that decreases with vehicle age.**

Also, the vehicle inspection procedure was interrupted for over 15 years until 2004, which contributed to poor conditions of the vehicle fleet (MoE, 2005). And, like in many other countries, there appears to be many new, four-wheel-drive multi-purpose vehicles, which consume more fuel and are less favorable from the safety point of view compared to normal passenger cars.

Additionally, the current taxation system encourages people to buy or keep older, cheaper cars since it is based on vehicle model year. It imposes higher taxes on newer and more expensive models which are generally more efficient and contribute to fewer emissions. Moreover, pollution control devices such as catalytic converters are taxed similarly to other spare parts. Such tax structure should be modified to encourage the purchase of fuel efficient, less polluting cars. On the other hand, pollution control devices should benefit of special low taxes (El-Fadel et al., 1999).

High Passenger Transport Energy Intensity

The transport sector is the second consumer of energy in Lebanon, totally dependent on fossil fuels. It is responsible for over 60% of the total oil consumption where 99.2% is gasoline. In fact, 14% on diesel oil imports and 99% of gasoline imports go to the transport sector. Figure 11 presents the trend of gasoline and gas/diesel oil imports for the road transport sector from 1994 to 2011.

Figure 11

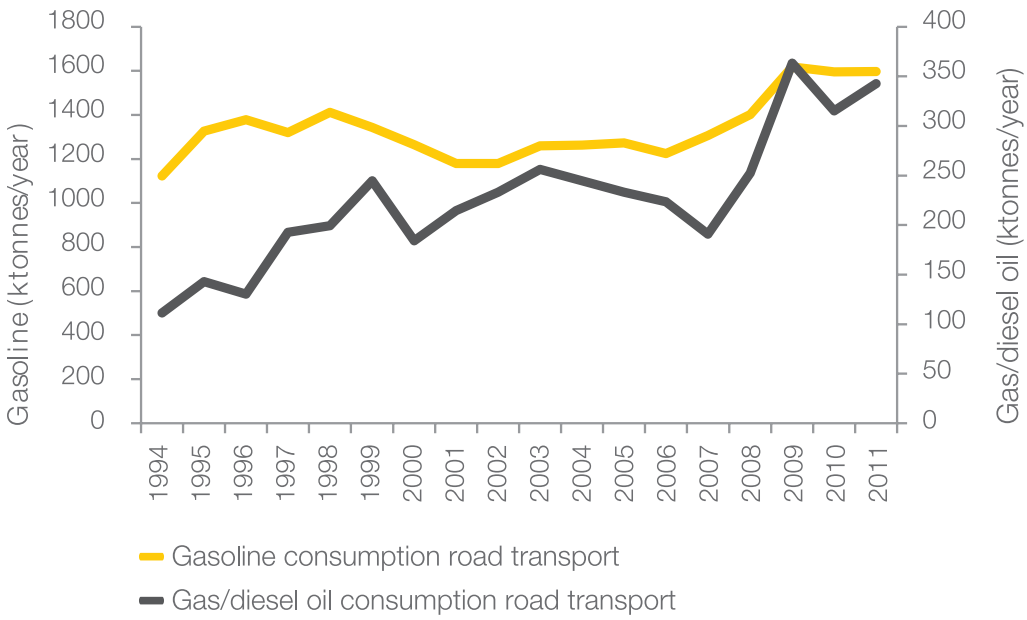


Figure 11 Gasoline and gas/diesel oil imports for road transport from 1994 to 2011 in Lebanon
Source | MoE/UNDP/GEF, 2015b

Moreover, the engine distribution of the passenger cars fleet shows that the fleet is mostly inefficient, since 60% of the cars have engine displacements exceeding 2.0 liters, while only 8% have engines less than 1.4 liters as presented in Figure 12 (MoE/URC/GEF, 2012). The greater the engine displacement is the greater are the fuel consumptions by the vehicle and the less efficient it is. In fact, CO_2 emissions are largely dominated by midsize and large vehicles. This is due to the absence of environmental considerations during vehicle purchase, resulting in 88% share of midsize and large vehicles of the total passenger vehicle fleet.

Figure 12

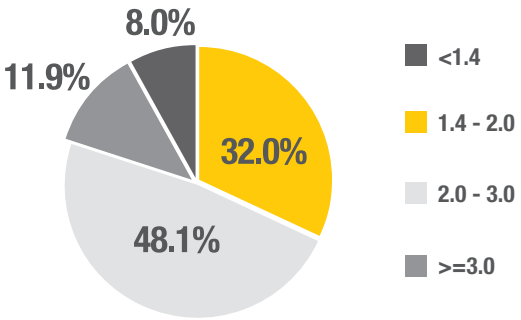


Figure 12 Engine displacement distribution of the Lebanese car fleet in 2007
Source | MoE/UNDP/GEF, 2015b

All these existing conditions have led the road passengers' transport sector to have a high passenger transport energy intensity, estimated at 3.08 MJ/passenger-kilometer, in addition to having a high energy demand of 15.06 GJ/capita, exceeding the world average of 13 GJ/capita (MoE/URC/GEF, 2012).

Absence of a Proper Transport System

Mass transport consists of public and private buses, minivans and exclusive and shared-ride taxis, all operating on an ad-hoc basis without any coordination. Contrary to the high number of mass transport vehicles, occupancy rate of mass transport systems is very poor in Lebanon, with about 1.2 passengers per vehicle for taxis, 6 for vans and 12 for buses as indicated in Table 7 (MoE/URC/GEF, 2012). This low occupancy rate would suggest at first glance that there is excess public transport capacity today. However, the mass transport market share in the Greater Beirut Area is estimated at 31%, split between modes as illustrated in **Figure 13**.

This clearly reflects the level of underdevelopment of mass transportation in Lebanon. This limited share of the market continues today due to the impracticality, lack of safety and restricted reach of public transportation compared to the attractiveness of owning a private automobile, an alternative that is still promoted over mass transportation in Lebanon through bank loan facilities and affordable new and used car imports (MoE/UNDP/GEF, 2015a).

Table 7

	Vehicle occupancy (passengers excluding driver)
RPTA buses	15.1
LCC buses	11.2
Exclusive ride taxis	1.18
Shared ride taxis	1.18
Red plate vans	5.93

Table 7 Vehicle occupancy in the GBA
Source | MoE/URC/GEF, 2012

Figure 13

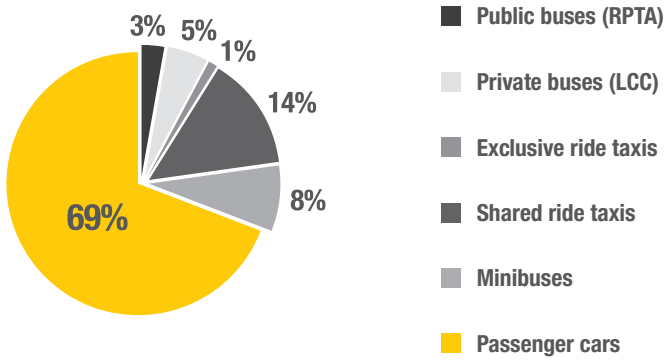


Figure 13 Market share of transport systems in GBA in 2002
Source | MoE/UNDP/GEF, 2015a

This reality is due in large part to the chaotic, inefficient and unreliable management of the transportation sector; it neither runs on a specific schedule nor on dedicated lanes while also most of the taxis are old and dating back to the 1980s. This is preventing the modernization and growth of the system and allowing the market to be controlled by private operators. For example, the system is oversupplied with 50,000 taxi licenses (known as "red plates"), where an estimated 17,000 of these are illegally procured and operated, with a similar situation of poor forecasting and control of the number of shared taxis and minibuses relative to actual market demand.

This oversupply can be noticed from continuous cruising of taxis on their search for passengers, which unnecessarily increases mileage driven. These vehicles are increasing traffic congestion, transport delays, and air pollution. The absence of a sufficient policy, regulatory, and competitive framework diminishes public transport's ability to serve the public to the maximum degree of quality, efficiency, and reliability. The low-quality public transportation system does not provide a reasonable alternative to the automobile, restricting use to only few riders who have no choice.

The special public transport sector is also characterized by lack of organization and structure. School transport is provided by all kinds of vehicles, which in some cases lack the minimum safety requirements. Often enough organized school transport is not available at all, forcing parents to pick up children at school. Heavy congestion can be observed around schools. Part of the overcapacity of minibuses could be used to organize school transport for children. Touristic transport is poorly understood and, as a result, weakly organized. Wheelchair-accessible transport is not currently given any significant attention in the country.

The main barriers that inhibit the development of a proper public transport system have been determined as follows (MoE, 2005; MoE/URC/GEF, 2012):

- The current poor market infrastructure for mass transit bus systems. No efficient, reliable, clean, fast and cost-effective mass transport system .
- Absence of a regulatory framework and lack of government planning, regulation and enforcement.
- Regulations relating to vehicle safety, condition and operation are not enforced.
- Absence of transport policy at the national level, providing a coherent transport demand management strategy. This lack of national policy is mainly due to having a government clash of interests and therefore limited willingness to invest.
- Lack of institutional capacity for planning and operation management.
- Underdeveloped supply due to limited capacity of relevant institutions and insufficient number of specialized experts, particularly at the MoPWT.
- High implementation costs of a mass transit bus systems operating on dedicated lanes.
- Low ridership and low revenues among operators. These are due to the fact that the overall supply is quite in excess of demand causing downward competitive price pressures. This in turn has led to the neglect of vehicle maintenance and insurance, thus yielding serious potential safety problems for the riders, drivers and general public.
- Improper allocation of the existing supply over the market. Some areas are over-served while others are under-served.
- Stopping of vehicles along the road is unregulated, where vehicles stop anywhere and anytime to board/alight passengers. This increases the potential for accidents and trip time.
- Socio-cultural stigma associated with bus riding.
- Cultural attachment to car ownership.

  Well-established alternatives to mass transit due to the lack of regulatory framework, from which the government is reaping benefits through tax revenues levied on fuel import and on car purchase and road usage.
- Availability of credit facilities for the purchase of new private passenger cars and the easy access to pre-owned imported cars.

V. Recommendations to improve the environmental performance of road transport in Lebanon

A. Planned Actions

Fully eradicating the problems of the Lebanese transport sector is neither affordable, nor economically feasible. However, much can be done to reduce and to lessen the burden of their negative impacts on the environment and mainly on air quality. Hence, effectively managing this sector requires both a holistic and integrated strategy that goes beyond the visible incidence of these problems and extends to setting a national transport policy, managing all transport services as a whole. While there are many possible measures that can be deployed, there is no single perfect solution.

Many ongoing projects aim at improving the air quality by reducing the impact of the road transport on air pollution. These projects include:

- **Master plan of the Ministry of Public Works and Transport**
- **The Air Quality Monitoring Network**
- **The Clean Air Act**

Master Plan of The Ministry of Public Works And Transport

In 2014, the Ministry of Public Works and Transport (MoPWT) presented to the Council of Ministers the master plan to revitalize the land public transport for passengers. It encloses a set of actions to be implemented on the short and medium terms, shifting the passenger transport demand to mass transit systems. The main actions that have a direct impact on reducing our emissions are:

On the short term:

- **Implementation of phase 1 of the rail transportation plan, namely the lane connecting port of Tripoli to the Syrian border.**
- **Revitalization and restructuring of the operation of public buses inside cities.**
- **Continuing the development project of traffic management in GBA.**
- **Improvement of the pedestrian infrastructure.**

On the long term:

- **Deployment of a Bus Rapid Transit (BRT) on Beirut north and south gates, commuting Jounieh to Jiyeh.**
- **Development of a mass transit system covering territories all over Lebanon and commuting cities.**
- **Restructuring the freight transport.**

The Air Quality Monitoring Network

Air monitoring has vastly improved in Lebanon. In parallel to the national, government-driven program for air quality monitoring, several universities and institutions have started to coordinate their air pollution related activities. In fact, in its efforts to improve the understanding of air quality and weather in Lebanon, the Ministry of Environment through a project managed by the United Nations Development Programme (UNDP), developed an Air Quality Monitoring Programme for the measurement of criteria air pollutants, setting the stage for the promotion of a national ambient air quality management plan. In 2013, the first phase of a national network was implemented with the installation of 5 stations in line with the provisions of national legislation, namely the proposed Draft Law for the Protection of Air Quality. The existing network is currently being expanded through the implementation of a second and final phase consisting of 13 additional real-time monitoring stations to be hosted in various locations by different institutions. Such an effort can in turn guide epidemiological studies on understanding the correlation between air pollutants and health impacts with larger datasets. Also in line with the Draft Law for the Protection of Air Quality or Draft Clean Air Act, MoE is currently working on developing a national Ambient Air Quality Management Strategy, mainstreaming cross-sectoral air quality management considerations into different existing and planned strategies. Once established, these efforts will allow the government to assess the air quality in Lebanon, quantify pollutants, identify sources of pollution and depict trends in order to take appropriate mitigation and adaptation measures.

The Clean Air Act

In 2004, and within the EU funded Strengthening the Environmental Legislation Development and Application System in Lebanon (SELDAS) project, the MoE started the preparation of the Draft Law for the Protection of Air Quality, known as the Clean Air Act (CAA). The CAA was finalized in 2005 epitomizing a landmark effort to reduce emissions, improve air quality and associated betterment of human health. Comprising of 34 articles, the CAA sets the stage for MoE to collaborate with all stakeholders to protect air quality and human health in Lebanon. Commensurate with this, relevant ministries received the draft law for revisions and through a ministerial committee approved it in 2012 under decision no. 34/2012 that awaits discussion via the committee concerned under decree no. 8075 dated 05 May 2012. With the guided framework of establishing Air Quality Management Strategy for Lebanon, the National Air Quality Strategy under the CAA currently under development necessitates updating and full adoption as a multi-disciplinary platform in collaboration with all concerned stakeholders (public and private). This is identified as a priority action under developing a national legal framework for air quality management. Once issued the CAA will provide an opportunity to abate air pollution from anthropogenic

emission sources including road transport, a key strategy for protection of air quality and is still lacking in regulation enactment and enforcement.ministerial committee approved it in 2012 under decision no. 34/2012 that awaits discussion via the committee concerned under decree no. 8075 dated 05 May 2012. With the guided framework of establishing Air Quality Management Strategy for Lebanon, the National Air Quality Strategy under the CAA currently under development necessitates updating and full adoption as a multi-disciplinary platform in collaboration with all concerned stakeholders (public and private). This is identified as a priority action under developing a national legal framework for air quality management. Once issued the CAA will provide an opportunity to abate air pollution from anthropogenic emission sources including road transport, a key strategy for protection of air quality and is still lacking in regulation enactment and enforcement.

B. Proposed Actions

Reviewing the existing conditions in the transport sector, several factors need to be considered to mitigate its significant air impacts: (1) reduce the number of passenger cars, (2) reduce the number and length of trips, (3) increase the vehicle occupancy rates, (4) increase mass transit means, (5) improve the vehicle efficiency, (6) increase the use of low carbon fuels, (7) and increase urban average traffic speed. Based on these mitigation factors, it is clear that no single measure will provide the solution and that action is needed simultaneously through different mitigation strategies (MoE/URC/GEF, 2012). The proposed strategies are:

- **Scrappage programme**
- **Deployment of fuel efficient and hybrid electric vehicles**
- **Mass transport system**

Scrappage Programme

In May 2015, the UNDP climate change projects prepared a study on the vehicles fleet renewal through a scrapping scheme in Lebanon, which consists of recycling End-of-Life Vehicles (ELVs) and adopting a renewal of car fleet strategy. The owners of old cars would voluntarily submit their cars for scrappage and replace them by fuel efficient vehicles after receiving a package of incentives. This is one of the main mitigation strategies recommended for Lebanon to reduce traffic congestions and air pollution from the transport sector.

In fact, the scheme was proposed as a National Appropriate Mitigation Action (NAMA) for Lebanon, with the aim of reaching by 2030 60% scrappage coverage of the targeted car population and an approximate of 6,260,000 $tCO_2eq.$ reduction. The requested financing for the NAMA is USD 15 million, afterwards it will be self-sufficient (MoE/UNDP, 2015b).

ELVs are already being scrapped in Lebanon by small and large-scale metal scrapping facilities. However, the existing facilities are unregulated and the current initiatives are limited to metal scrapping. Tires, glass and plastics end up in the municipal waste stream, and the spare parts are sold through a black market at elevated rates.

Vehicle scrapping schemes usually target old vehicles, which are less fuel-efficient and have high carbon emissions in comparison with to newer vehicles. These schemes provide financial incentives for drivers of older vehicles to remove their vehicles off the road before the vehicle's lifespan is completed.

The scrapping and recycling of ELVs has a number of environmental and socio-economic benefits. It provides a proper disposal of toxic and hazardous car components such as oils, battery acid, paint, refrigerants, airbags and other fluids.

The improper disposal of these components can lead to water and soil pollution and cause a threat to livelihood. Reusing components of vehicles prevents wasting land (i.e. junkyards) and serves as an economic incentive. When raw materials such as metals are recycled, ELVs prevents a great portion of vehicles ending up in landfills and a great amount of energy is saved. Renewal of the fleet reduces air pollution when fuel-efficient and vehicles with catalytic converters are introduced. It can be a start to regulate the market of spare parts and prevent the existence of illegal black markets. Scrapping schemes can create various job opportunities and enhance the livelihood of citizens. Scrapping vehicles and selling them as scrap metals is an uncommon practice in Lebanon and old vehicles usually remain in the fleet for a long period of time, which is one of the main causes of air pollution. In fact, some of the facilities have a capacity of 50 cars/day, however, the number of processed vehicles currently does not exceed 5 to 6 cars/week. In 2010, 45% of the private vehicles in circulation were ELVs.

The best course of action for the scrapping program was found to be the usage of the existing limited initiatives with some enhancements. Those consists of accrediting scrapping facilities, establishing an exhaustive legal framework for the scrappage programme, providing an incentive for the drivers or the owners of the vehicles (direct payment for the owner to support him in buying a new car or a subsidized loan that facilitates the purchase of a new car) and enhancing the processing steps (drainage of fluids, removal of the battery and airbags, full dismantle of the vehicle…). Another more costly alternative would be the establishment of new scrapping facilities that has all sorts of recycling methods for the different components especially those unavailable in the current facilities. Is it important to note that the incentive has an essential impact on the input of cars by owners, in case of a voluntary scrapping scheme, which is the usual trend. This scrappage programme can solve the old fleet problem Lebanon is facing and its high impacts on air pollution. In fact, the study showed that the implementation of the programme significantly reduces air pollutants and GHG emissions during operation and during the conversion of the old fleet to a newer and efficient one. Nevertheless, further studies are needed to thoroughly analyze the cost effectiveness of such a scheme to support decision makers and policy makers.

Deployment Of Fuel Efficient And Hybrid Electric Vehicles

Fuel efficient vehicles (FEVs) are commonly known in Lebanon by conventional gasoline powered vehicles with reduced fuel consumption compared to similar gasoline vehicles within same vehicle segment (MoE/UNDP/GEF, 2015b). These vehicles are equipped with advanced technologies like downsized turbocharged engines. As for hybrid electric vehicles (HEVs) they combine an electric motor and battery pack to the internal combustion engine found in conventional vehicles (MoE/UNDP/GEF, 2015b). They can be classified as micro-hybrid, mild-hybrid, full-hybrid, plug-in hybrid and range-extender electric vehicles. As such, both FEVs and HEVs lead to less pollutants and GHG emissions than conventional vehicles. Creating and expanding the market for these vehicles can be an efficient way to reduce emissions from transport in Lebanon.

For this to be successfully implemented, the following action plan is suggested:

- **Create appropriate financial incentives for hybrid and fuel efficient cars purchase.**
- **Set up new coherent tax policies.**
- **Renew the passenger car fleet.**
- **Implement a vehicle retirement program.**
- **Implement legislation governing vehicle emissions.**
- **Create institutions to support technical standards for transportation.**
- **Establish awareness campaign.**
- **Create Mobility Monitoring Indicators (MMI) framework.**

A study undertaken by the climate change projects at the MoE shows that an increase in the share of small passenger vehicles from 11.5% to 35% while maintaining at 55% the share of midsize vehicles and decreasing the share of large vehicles from 33.3% to 10% can reduce emissions by 19% by 2040. The market for these fuel efficient vehicles will develop gradually with new vehicles registrations and will rely on the implementation of policies and awareness campaigns to improve the environmental culture of drivers and direct their purchases to environmental friendly vehicles (MoE/URC/GEF, 2015b).

The introduction of hybrid electric vehicles to the market to reach a rate of 10% by 2040, can lead to further energy and CO_2 emissions decrease due to the technological advancements of hybrid vehicles in terms of fuel consumption. Results showed an additional 11% savings in energy use and CO_2 emissions can be achieved.

In conclusion, the more we replace the existing vehicles with small and midsize vehicles or FEVs and HEVs, the more energy and CO_2 emissions we will be saving. The reduction in emissions increases with the increase of the percentage of these low fuel-consuming vehicles in the fleet. This strategy can be an incentive for Lebanon to transform its old and polluting fleet into an efficient and friendly one.

However, despite the savings the fleet renewal scheme offers, the transport system remains characterized by being highly personal vehicle oriented. This strategy is not sufficient to offset the growth in passenger activity and vehicle stock, both estimated to double by 2040 compared to 2010. As such, this strategy should be complemented by a functional mass transport system.

Mass Transport System

The objective of deploying mass transit buses is to benefit from the fuel savings and emission reductions it leads to. Therefore, it is important to identify the proper strategy to revitalize public transport in Lebanon and to identify the most efficient bus technologies under the current driving conditions.

As a first step towards reforming and ultimately improving public transport in Lebanon, the MoPWT established the Transport Regulatory Unit (TRU) in 1999 with the aim to orchestrate the reform of public transport, develop a plan of action, and supervise its implementation. Currently, the Government's Railway and Public Transport Authority (RPTA) owns and operates 302 buses, as compared to 2,400 buses in the private sector, and receives LBP 20 billion in annual subsidy from the government (MoE/LEDO, 2001). In order to restructure the bus system, MoPWT estimates that 507 buses will be needed in GBA, 85 in Tripoli, and 45 to serve intercity; a total of 637 buses countrywide. The total non-recurring investment in vehicles, infrastructure, terminals, depots, etc. is estimated at USD 400 million. Such revitalization target could be implemented on a 5 year basis.

A shift to mass transport charcterized by an increase in mass transport passenger-kilometers share from 36% in 2010 to 53% by 2040 results in 45% reduction of vehicle-kilometer activity in 2040 compared to the baseline scenario, which obviously reflects a net improvement in traffic congestion. As a result, the energy use and CO_2 emissions are reduced by 10% in 2020 and 24% in 2040 compared to 2010.

In order to have a transport system that citizens will be encouraged to take, the following action plan is recommended (MoE/UNDP/GEF, 2015b;MoE/URC/GEF, 2012):

- Develop the supply channels of bus mass transit system.
- Improve the operation management and the infrastructure.
- Facilitate the government investments in mass transit buses.
- Create an employee package for taxi drivers.
- Exempt mass transit buses (and their spare parts) from custom and excise fees, and from registration fees.
- Give appropriate financial incentives for mass transit buses rather than conventional pre-owned gasoline vehicles.
- Encourage taxi and shared taxi owners to work in the bus mass transit system.
- Improve the quality of service to approximate that which car drivers have been used to.
- Establish dedicated lanes with wide coverage to all boroughs to encourage people to use them during rush hour (because they are faster).
- Establish bus stops, well-designed so that they do not obstruct walkways or traffic.
- Develop and disseminate clear bus schedules and maps.
- Inform regularly the passengers of real-time information, uninterrupted operation, and inevitable services.
- Maintain an adequate level of cleanliness and comfort in buses.
- Provide bus tickets and clip cards (pack of tickets) at competitive rates from various accessible points of sale, such as drugstores, coffee shops and postal offices with concessionary fares to older people, students and disabled persons.
- Stimulate passengers demand to use mass transit buses.
- Set up a regulatory framework for mass transit sector.
- Implement laws and regulations and enforce them. Draft new ones where necessary.
- Enhance bus transit service by employing and developing technical expertise
- Induce/initiate legislative reforms in urban planning laws, expropriation laws, and traffic laws.
- Increase awareness of travelers on ecological and economic benefits of transit bus systems.

VI. Conclusion

In the current patterns of transport activity, based mainly on passenger vehicles, the Lebanese transport sector causes a heavy environmental and economic burden on the government and the population: 4,350 Gg CO_2 emissions in 2011, 1.5 million tonnes of fuel consumed and a chronic traffic congestion at every intersection inside Beirut and on the entry gates of the city.

The future transport national strategy for Lebanon should necessarily be based on the integration of a carefully designed portfolio of policies and incentives, promoting the removal of the old fleet and the revitalization of public transport. Moreover, urban areas should be made friendly to non-motorized transport. Bicycle lanes and improved sidewalks have the potential to make considerable contributions to mitigation efforts. Eliminating price, tax and economic regulatory distortions can also benefit the environment if such distortions favor inefficient use of “dirty” resources or “dirty” industries.

Reducing degradation and protecting the environment should be viewed in the context of economic and sector policies, socioeconomic development and in the broader framework of environmental management. It requires strict enforcement of environmental legislation, public/private partnerships, environmental awareness raising, and local participation.

Sound environmental management therefore requires that the roles of the public and the private sectors be clarified. Environment remedial actions should not necessarily be undertaken by the public sector. The private sector has a very important role as well. It should not only bear the cost of remedying the pollution and degradation it causes but also provide a significant contribution to the delivery of environmental services.

NGOs also have a role; they should work hand-in-hand with the community in awareness campaigns, in order to first raise awareness on the unsustainable state in which Lebanon is. Furthermore, the campaigns would help in promoting the different solutions recommended for Lebanon.

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