Addis Ababa Environmental Protection and Green Development Commission

Vehicles Greenhouse Gas Emissions and Ambient Air Quality Measurement in Addis Ababa City

April 2021

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Executive Summary

This study aimed at filling some of the most important data gaps in the transport sector's greenhouse gas (GHG) emissions and air pollution concentration profile of Addis Ababa. The data gaps addressed are annual Vehicle Kilometres Travelled per year (VKT), vehicle fuel economy (kilometres travelled per litre), vehicle pollutant gases and particulate matter (PM) released during tailpipe testing, and ambient air quality measurements. Data was collected through interviewing 406 drivers and tailpipe testing of their 406 vehicles, and through ambient air quality measurements at congested traffic sites. The analysis was carried out by vehicle type, vehicle manufacture year and according to real-time monitoring at sites such as roundabouts, taxi and bus stations. This study showed that PM reduction can be brought about by implementing vehicle standards so as to limit the oldest vehicles from circulating the roads in the city. These standsrds could bring benefits to both health and the economy.

The findings from this study are classified into two parts:

- **Vehicle emissions measurement**: which consists of fuel economy, VKT, vehicle tailpipe emissions measurement and GHG emissions estimation by vehicle type.
- **Ambient air quality measurement**: which consists of the results from the real-time monitoring at congested traffic sites, i.e. roundabouts, and taxi and bus stations.

From the vehicle tailpipe emissions measurements, it was found that $PM_{2.5}$ emissions for diesel vehicles had no perfect relationship with the vehicle age. However, a general trend showed that for newer aged vehicle groups, $PM_{2.5}$ emissions were lower in concentration. Similar patterns were found for gasoline vehicles, where tailpipe emissions were measured for carbon monoxide (CO), carbon dioxide (CO_2), sulphur dioxide (SO_2), hydrocarbons (HC) and nitrogen oxide (NO_x). No perfect relationship was found between the emissions concentration and vehicle age, although a decreasing pattern in pollutant concentration was more evident for newer vehicle age groups.

This study also generated PM concentration data by vehicle type for gasoline and diesel vehicles. For instance from diesel vehicles, midibuses had the lowest concentration of $PM_{2.5}$, i.e 32 μg/m^3, which is outweighed by heavy and light duty trucks, minibuses, cars, pickups and buses. Morover, GHG emissions were also estimated according to data on vehicle fuel economy (km travelled per litre) and VKT per year gathered during interviews with drivers, and by using the IPCC default gasoline and diesel vehicle emission factors. The analysis showed that from gasoline-powered vehicles, Automobile generated the lowest emissions, i.e. 3.59 tCO_2e/year (this value also the lowest when compared to diesel cars), while diesel-powered heavy-duty trucks generated the highest emissions overall, i.e. 45.75 tCO_2 e/year.

The ambient air quality measurements at sites of high traffic congestion were undertaken focusing on PM, CO and SO_2. PM_{10} average concentration at taxi stations was found to be 206.2 μg/m^3

while the $PM_{2.5}$ average concentration at all sample locations (i.e. roundabouts, taxi and bus stations) fell within the range of 26 to 38.5 μg/m^3. The SO_2 average concentration at taxi stations was found to be 1000 μg/m^3.

The findings in this paper reveal the transport sector's contribution to GHG emissions and air quality in Addis Ababa. These will be used as a baseline for the city to develop GHG emissions reduction measures and improve the air its citizens breathe.

Besides, the city can use such data and the methodology employed for this project to compile future inventories, estimating GHG emissions regularly by gathering data on fuel economy and annual VKT.

Finally, this study also includes recommendations to consider to strengthen data collection and analysis and fill the gaps in future GHG and air quality emissions inventories.

Acknowledgments

This study on Greenhouse Gas Emissions and Ambient Air Quality Measurement in the City of Addis Ababa (Ethiopia) was supported by the C40 Empowering Cities with Data (ECWD) – Small Grants Programme (SPG) – and was led by a Technical Working Group formed by ten (10) city institutions (see list of contributors at the end of this report).

A special thank you goes to the Children's Investment Fund Foundation (CIFF) for their generous funding which made this project possible.

The Children's Investment Fund Foundation (CIFF) is an independent, philanthropic organisation. Our staff and Trustees combine the best of business and the best of development, bringing a wealth of experience from both sectors to CIFF's work. We aim to demonstrably improve the lives of children in developing countries by achieving large scale, sustainable impact. We believe that every child deserves to survive, thrive and mature into adulthood in a supportive and safe environment. However, climate change disproportionately affects children living in poverty in developing countries. A key focus for CIFF is climate-smart urbanisation.

C40 Cities connects nearly 100 of the world's largest and most influential cities committed to taking bold climate action to create a healthier and more sustainable future for all. Representing 700+ million citizens and one quarter of the global economy, mayors of C40 cities are committed to delivering on the most ambitious goals of the Paris Agreement at the local level, as well as to cleaning the air we breathe.

C40 Empowering Cities with Data Programme

In order to develop and implement inclusive climate action plans that deliver on the ambitions of the Paris Agreement, city governments require access to reliable data and information to not only design the most impactful policies to tackle climate change, but to also monitor and evaluate the success of such programmes to enable improvements and optimization in policy.

Recognising that city governments face significant constraints and challenges when it comes to climate data, the Empowering Cities with Data (ECWD) Programme has been designed to help C40 and non-C40 cities overcome these in an accessible way.

1. Introduction

Addis Ababa City, in Ethiopia, is working towards creating a safe, green and resilient city for its inhabitants. As part of this effort, the city is mainstreaming climate change and air quality policies into the city's urban planning. These mainstreaming practices will help Ethiopia to reach its national target of reducing GHG emissions to 64% by 2030 compared to the 2010 baseline[1], and to consistently meet the national air quality guidelines[2].

As the city is embarking on addressing GHG emissions and air pollution, data is important to continously monitor and track the effectiveness of the policies in place. Data will also support the design of an efficient emissions reduction plan and an ambient air quality monitoring programme. Currently, both these emissions controlling systems are not well developed in the city, as is the case in most African cities. This is mainly because of the lack of necessary monitoring infrastructure and capacity to collect and analyse data.

This study aimed at filling the data gaps in measuring and tracking transport GHG emissions and air pollution levels. A Technical Working Group (TWG) was formed from ten city institutions. Data was collected from 406 vehicles from a pool of 415,574 vehicles registered and stored in the Addis Ababa Drivers and Licensing and Control Authority database (see Annex IV). The ambient air quality measurements were taken from selected vehicles at congested traffic sites such as roundabouts, and taxi and bus stations. In addition, interviews were conducted with drivers to gather data on their vehicle's daily kilometres travelled, fuel economy and manufacture year.

The transport sector represents a major source of GHG emissions in the city of Addis Ababa. It contributes to numerous urban and regional pollution-related environmental and human health problems caused by the emissions of various air pollutants[3]. Of the major sources of emissions in the city, vehicle emissions is among the highest, according to the city's 2016 GPC GHG emission inventory[4]. The parameters that most heavily affect emissions from vehicles include class and weight, driving cycle, vocation, fuel type, engine exhaust after-treatment, age, and kilometres travelled[5]. This study focuses specifically on vehicle type, manufacture year (age) and fuel type parameters.

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1 **Ethiopia Federal Democracy Republic 2011**
2 **Enviromental Protection Authority 2003**
3 **Manisalidis et al. 2020**
4 **Addis Ababa GHG Emission Inventory for 2016, 2020**
5 **Nigel, et al. 2011**

1.1. Study Area

Addis Ababa is the capital city of Ethiopia. It is the political seat of the African Union (AU) and the United Nations Economic Commissions for Africa (UNECA). The city is in the central highlands of Ethiopia between 8 0 49'. 929'' and 9 0 5'. 583'' north latitude and between 38 0 38' 16.555'' and 380 54' 19.547'' east longitude, on the western margin of the Great East African Rift valley. The City is divided into 11 administrative divisions: (Addis Ketema, Akaki Kality, Arada, Bole, Gullele, Kirkos, Kolfe Keronio, Lideta, Nifas Silk-Lafto,Yeka and Koye fetch), and 129 *Woredas* (the smallest administrative structure of the city).

The city's government is headed by the mayor and the city council. Addis Ababa has a very diverse economy. Trade and commerce are the most popular industries, followed by manufacturing and production, homemaking, and civil administration. Tourism is a growing industry in the area as more shopping centers, restaurants and attractions are built. Almost one-quarter of all people in Ethiopia that live in urban areas live in the capital city. The population in Addis Ababa for 2020 is estimated to be 3,689,000 people[6]. The city is about 527-540 square kilometres in size. The population density is estimated to be near 615,026 people per square kilometre[7].

Figure 1: Topography Map of Addis Ababa[8]

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6 Central Statistical Agency 2013

7 Addis Ababa City Administration Integrated Land Information Centre 2015

8 The map shows the previous 10 sub-cities in the city

1.2. Data Challenge in the Transport Sector

Addis Ababa lacks good quality and complete data which would enable the city to account for and track GHG emissions and air pollution from the transport sector. There is no regular tracking, emissions reduction protocols and policies, or monitoring and evaluation systems in place. Moreover, there is a capacity gap in collecting and analysing data and in preparing mitigation plans based on such data. The recent study from the 2016 GHG emissions inventory for the city showed that emissions in the transport sector increased by 50% from the 2012 GHG emissions inventory, contributing to the highest proportion of total emissions for all sectors[9]. Air pollution in the city is also three to four times higher than the recommended WHO guidelines[10]. The major sources of these pollutants are emissions from the transport and industry sectors, and other activities like waste generation and household energy consumption[11].

1.3. Objectives of the Study

The general objective of this study was to fill the data gaps related to (I) vehicular greenhouse gas emissions and (II) ambient air quality measurement at sites of traffic congestion, such as roundabouts, and taxi and bus stations. This data can be used to create an enabling environment to take GHG emissions mitigation actions in the transport sector and implement and improve air quality management measures.

The specific objectives of the study were to:

- Perform vehicular emissions measurements for Carbon monoxide (CO), carbon dioxide (CO_2), sulphur dioxide (SO_2), hydrocarbon (HC), Nitrogen oxides (NOx), and Particulate Matter (PM) of sample vehicles using a vehicle gas analyser. The vehicle emissions measurements were sorted by manufacture year and type, an important factor to support targeted mitigating actions;
- Estimate the GHG emissions by vehicle type, using annual distance travelled, fuel economy data and the default IPCC 3rd Assessment's emissions factors;
- Conduct ambient air quality measurements at roundabouts, taxi and bus stations where the average number of vehicles circulating is the highest, which helps to understand the share of air pollution from the transport sector;
- Recommend the way forward in monitoring GHG emissions and air pollution related to the transport sector.

9 **Addis Ababa EPGDC 2020**
10 **C40, Benefits of Urban Climate Action 2020**
11 **Mekonnen and Tigist 2018**

1.4. Scope and Limitations

This study was carried out to research the transport sector's GHG and air pollution emissions in the City of Addis Ababa. The data collection was done through the sampling of 406 city vehicles of different manufacture years and types. The sampling was purposive and it was assumed that the vehicle population was homogenous except for age and type. However, in reality, vehicles are heterogeneous in numerous aspects such as engine capacity, maintenance, services and so on. Therefore, it is important to note that these and other factors limit the results obtained to some extent.

1.5. Lessons Learnt and Challenges

Throughout the project, from preparation, to data collection and analysis, many lessons were learnt, and challenges arose. The main lessons learnt and challenges are summarized below:

a) Lesson Learnt

- **Staff capacity**: it was important to train experts in theoretical and practical skills to enable them to measure the tailpipe emissions and take ambient air quality measurements;
- **Equipment Calibration**: calibration of the monitoring equipment was important before carrying out measurements in the field;
- **Tailpipe measurement**: it required a team, and could not be done by one individual, as many tasks needed to be performed concurrently. One expert handled the gas analyser reader, the other inserted the tube into the vehicle exhaustion pipe, the other indicated to the driver when to press the fuel pedal, and the other collected information about the vehicle such as fuel economy, VKT, odometer reading, etc.
- **Ambient air quality measurement**: the measurement was performed by two experts. One expert controlled the sensor for a specified period of time and the other expert recorded the reading. This process required patience in order to get a quality result, as the machine sometimes needed adjustment to give a good reading.
- The Addis Ababa Environment Protection and Green Development Commission (AAEPGDC) was needed to test the technical and financial managing capacity of the project by using the city's institutional structure

b) Challenges

- Training to use the tailpipe gas analysers: it was difficult to find a professional to provide training on how to use the gas analysers. Later, the team tried to understand the process by using the equipment manual and assistance from the local garage who had similar experience in using other types of gas analysers. In addition, the team received virtual training support from professionals abroad who had experience in using similar equipment when studying vehicle emissions in the city years ago. The ambient air quality equipment trainers were relatively easy to find as there were experts from national and AAEPGDC who had experience in using such equipment.

- The COVID-19 pandemic presented challenges to complete the data collection process as per the project timeline. Later, the TWG was able to collect the data following the COVID-19 precautionary advice from the city health office.

2. Methodology and Approach

2.1. The Study Stakeholders

The study had four major actors that participated. These were the Addis Ababa Environment Protection and Green Development Commission (AAEPGDC), C40 Cities Climate Leadership Group (C40), the TWG and other stakeholders. The TWG was established from the Federal Transport Authority, Addis Ababa Transport Bureau, Addis Ababa Driver and License Control Authority (AADLCA), Environment, Forest and Climate Change Commission (EFCCC), Addis Ababa Health Bureau, Kotebe Metropolitan University, Addis Ababa Science and Technology University and National Metrology Agency

2.2. Data Type and Sources

The type of data and data sources used for this study are summarized below.

a) **Primary Data**:
- Vehicle tailpipe emissions measurement using the two FGA4000XDS Gas Analyser for gasoline vehicles and one Opacity meters for diesel vehicles;
- Interviews with drivers to gather data about fuel economy, VKT and vehicle manufacture year;
- Ambient measurement with three Aeroqual Series-500 Gas Sensor portable systems to measure air quality at congested sites;
- Stationed Air Quality Monitoring Data: these include US Embassy, five managed Kunuk monitoring equipment by AAEPGDC and other ambient air quality monitoring equipment, stationed at different sites in the city, were used for the analyses to develop scenarios for vehicle age standards using the manufacture year.

b) Secondary Data:

- Number of vehicles by manufacture year from AADLCA;
- Vehicle stocks by year from AADLCA;
- General health data of the city population from the Addis Ababa Health Bureau: sex and age, total number of deaths, total number of hospital admission for cardiovascular and respiratory diseases (disaggregated);
- Economic Data: VSL (Value of a Statistical Life, representing the value of a premature death), and hospital admission costs for respiratory and cardiovascular diseases (disaggregated)[12].

2.3. Capacity Building

During this study, 16 TWG members received capacity building training on GHG emissions estimation and air quality measurement. The training was delivered by individual local consultants who have prior experience in using vehicle tailpipe emissions and ambient air quality measurement equipment. The tailpipe emissions measurement training was delivered by a local garage owner. The ambient air quality measurement training was delivered by staff from AAEPGDC and EFCCC. The capacity built will help the city when undertaking similar assignments in tracking emissions over time. The training supported the TWG to get hands on experience on how to use the equipment, calibration and theoretical knowledge about GHG and air pollutant emissions. The training was delivered during consecutive meetings with TWG for 2 half-days before the actual data collection begun.

2.4. Sampling Procedure for Data Collection

2.4.1. Vehicle Tailpipe Test

The 406 vehicle tailpipe emissions tests were conducted from the total of 415, 574 vehicles in the 2019 dataset. From the total vehicles sampled, 277 vehicles and 129 vehicles were diesel- and gasoline-powered respectively. The entire data collection process was supported by a standard data collection form (Annex II). The statistical analysis (descriptive statistics) was performed using SPSS software. The vehicle types were categorized into seven types automobiles, buses, pick-ups, mini-buses, midi-buses, light- and heavy-duty trucks and sample were taken from each category (See Table 1).

12 Death and Population: Ethiopia bureau of Statistics Hospital admissions: proxy from the UK. Economic data: proxy from Kenya

Here is the definition of each types of vehicles categories.

- Automobile: a seating capacity of 4 to 8 passengers
- Minibus: a seating capacity of 12 to 20 passengers
- Midibus: a seating capacity of 25-50 passengers
- Bus: a seating capacity about 100 passengers
- Pick-up: used for passenger up to three and open back used freight purpose
- Heavy truck: which include Dry cargo =10 ton and > 10 ton and used for liquid cargo
- Light Truck: like Forklift, dual purpose vehicle, vehicle with machinery

Table 1: Vehicle Categories per Manufacture Year

Group /Manufacture Year	**Manufacture Year**	**# Diesel Vehicles**	**# Gasoline Vehicles**	**%**
Group 1	Before 1992	12	45	13%
Group 2	1992-1996	17	9	6%
Group 3	1996-2000	29	11	9%
Group 4	2000-2005	43	35	18%
Group 5	2005-2011	89	20	25%
Group 6	2011-2014	33	4	8%
Group 7	After 2014	55	12	15%
Missing System	Unknown	22	4	6%

Table 2: Total Samples of Vehicles for the Study

Vehicles Type	**Diesel**		**Gasoline**	
	Units	**%**	**Units**	**%**
Automobile	26	9%	117	91%
Bus	75	27%	0	0%
Heavy-duty Truck	29	10%	0	0%
Light-duty Truck	37	13%	0	0%
Midibus	8	3%	0	0%
Mini-bus	42	15%	4	3%
Pick-up	60	22%	8	6%
Total	**277**	100%	**129**	100%

The vehicle manufacture years were categorized into seven groups for sampling and data analysis purposes (Table 2). The number of vehicles tested with the tailpipe emissions test per model for diesel-powered vehicles were Toyota (93), Isuzu (42), Higer (33), Bishoftu (15), Sino (14), Nissan (11), Anbesa (9), Sheger (8), Hilux, Hundai (5) and others. The number of gasoline-powered vehicle models tested were Corolla (38), Vitiz (20), Toyota (17), Lada (9), Suzuki (7), Yaris (95), Land Cruiser (5) and others. Moreover, the drivers of these vehicles were interviewed to gather fuel economy and kilometres travelled data, which was then used to estimate the vehicle GHG emissions using the IPCC default emissions factors for tire 1 and the Global Warming Potential (GWP) from the IPCC 3rd Assessment report for tire 1.

2.4.2. Ambient Air Quality Measurement

Major roundabouts, bus and taxi stations in the city were selected for the ambient air quality measurements (see Figure 2). The roundabouts included Mexico, Hayat Asra Seminet, Abenet, Abuna Petros Hayat, Diaspora, Goterera Nationaliy, Kality, Karl, Mesquel Square, Teklehamanot, Ureal and Winget. The bus stations included Megenagna, Asco, Ayeretena and Lamberet. The taxi stations included 4 Kilo, 6 Kilo Total, Arada, and Ayeretena. The average air pollution concentration measurements from these locations were collected and then analysed.

The pollutant gases were measured as per the Ethiopian and WHO air quality guidelines. Below are the standards used to measure the pollutant gases.

- Particulate matter ($PM_{2.5}$ and PM_{10}) - daily average;
- Carbon monoxide - 15 minutes averaging time;
- Sulphur dioxide - 15 minutes averaging time;

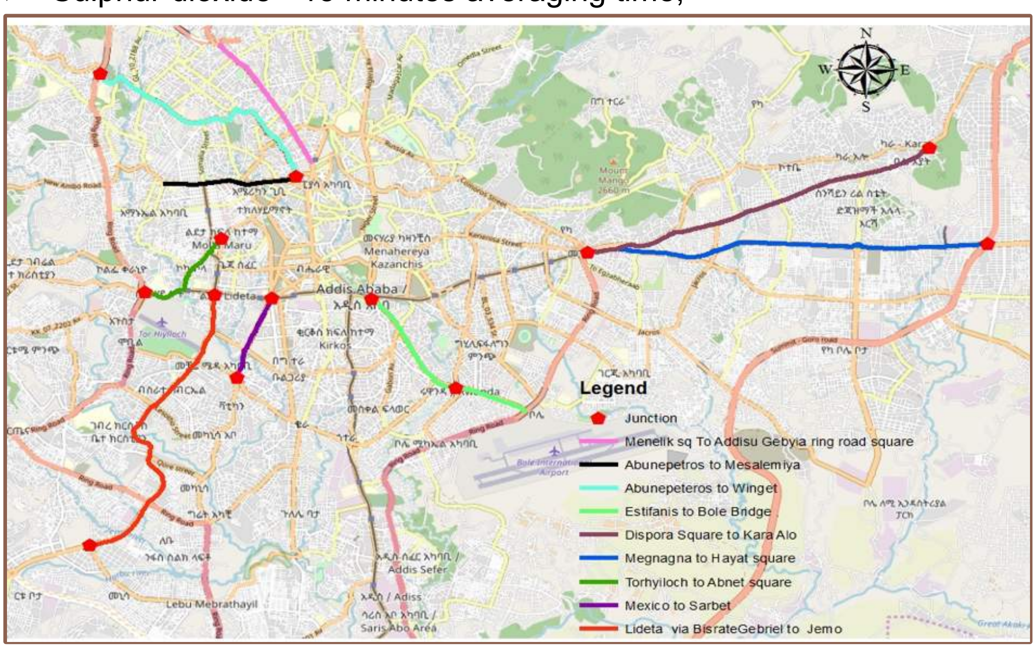

Figure 2: Selected Sites for Ambient Air Quality Measurement

2.5. Data Collection and Analysis

The data collection was undertaken by the TWG members together with additional staff from national and city offices following the group receiving theoretical and technical training as described in section 2.3. All equipment and meters were properly pre-calibrated before usage for quality assurance. The concentrations of CO, CO_2, SO_2, NOx, and HC were measured directly from the tailpipe test with the FGA4000XDS Gas Analyser made by Infrared Industries, Inc, USA. Particulate (PM_{10} and $PM_{2.5}$) emissions measurements in terms of smoke intensity were performed for diesel vehicles by using the opacity meter. The ambient air quality assessment was performed by using the portable Aeroqual Series-500 Gas Sensor and the Hold Peak 5800d Multi Detector for the determination of individual pollutants.

The data analysis was performed through encoding the vehicles emission test, interview and ambient air quality data into the excel and SPSS tool and generate numerical values into graphs and tables.

Figure 3: Vehicles Tailpipe Measurement at Roadside

Figure 4: Ambient Air Quality Measurement at Roundabouts and Bus and Taxi Stations

3. Results and Discussion

The results of this study can be divided into two broad sections. First, the vehicle tailpipe emissions test and resulting GHG emissions estimation. Second, the ambient air quality measurement results. The findings from the first and second sections are presented in 3.1 and 3.2 respectively.

3.1. Vehicles Emissions Measurement

3.1.1. Fuel Economy

The fuel economy is the vehicle's kilometres travelled per litre of fuel. The findings showed that fuel economy for automobile vehicles was 11.7 km and 8.5 km per litre that are powered by gasoline and diesel vehicles respectively. Gasoline- and diesel- powered minibuses travelled for 9.3 km and 8 km per litre respectively. For pick-ups, vehicles of both categories travelled an average of 9.1 km per litre. The average kilometres per litre for other diesel vehicles are as follows: 4 km/l for buses, 2.7 km/l for heavy-duty trucks, 6.5 km/l for light-duty trucks and 4.2 km/l for midibuses.

Table 3: Fuel Economy by Vehicle Type

Fuel Type	Type	Average km/litre
Diesel	Automobile	8.5
	Bus	4
	Heavy Duty Truck	2.7
	Light Duty Truck	6.5
	Midibus	4.2
	Minibus	8
	Pick up	9.1
Gasoline	Automobile	11.7
	Minibus	9.3
	Pick up	9.1

3.1.2. Vehicles Kilometres Travelled (VKT)

The annual vehicle kilometres travelled (VKT) per category was determined based on the drivers' knowledge of kilometres travelled per day and fuel spending per week (for cross checking purposes, the prevailing price at the time of data collection was 21.53 Birr/litre for gasoline and 18.75 Birr/litre for diesel). The total distance travelled by the vehicles during their lifetime was observed from the odometer reading. The average total distance travelled for light- and heavy-duty trucks was far larger than that of automobiles, buses and pick-ups. Light- and heavy-duty trucks covered 22% (592,559 km) and 21% (559,976 km) from the total odometer readings respectively. Pick-ups and minibuses showed the second largest odometer reading as 19% and 12% (gasoline and diesel together) respectively.

Table 4: Average Kilometres Travelled per Day

Fuel Type	Type	Average Odometer reading (Km)	Odometer (%)	Fuel Spending /Week (Birr)	Average VKT/Day
Diesel	Automobile	216,201	8%	1051	80
	Bus	149,849	6%	6344	171
	Heavy-duty Truck	559,976	21%	6722	153
	Light-duty Truck	592,559	22%	3211	141
	Midibus	153,524	6%	2300	74
	Minibus	297,781	11%	2456	129
	Pick up	171,596	6%	997	75
Gasoline	Automobile	166,397	6%	756	52
	Minibus	27,524	1%	2250	87
	Pick up	337,183	13%	802	42

3.1.3. Tailpipe Emissions Test

The tailpipe emissions measurements were undertaken for both diesel and gasoline vehicles. Diesel vehicles were measured for $PM_{2.5}$ emissions, while gasoline vehicles were tested for SO_2, CO, NO_x, HC and CO_2 gases. Diesel vehicles included all vehicle types whereas gasoline vehicles only included automobiles, minibuses and pick-ups, as there are no gasoline-powered buses and trucks.

a) Pollutant Concentrations for Diesel Vehicles

The $PM_{2.5}$ results from the tailpipe measurement were analysed by grouping vehicles by manufacture year. The findings showed that the oldest vehicles (group 1 and 2) were the highest emitters of $PM_{2.5}$, while the newest (group 7) were the lowest. On the contrary, group 1 consisted of older vehicles when compared to group 2, but group 1 was found to be a slightly lower emitter (72 $\mu g/m^3$) than group 2 (74 $\mu g/m^3$). These results show that there is no perfect relationship between the manufacture year and $PM_{2.5}$ emissions. However, it can be concluded from the general trend, that the newer vehicles found in group 7 and 6 produce relatively lower $PM_{2.5}$ emissions. Moreover, $PM_{2.5}$ emissions from midi-buses and buses are the lowest, at 32 $\mu g/m^3$, and the highest at 69 $\mu g/m^3$, respectively (Figure 5).

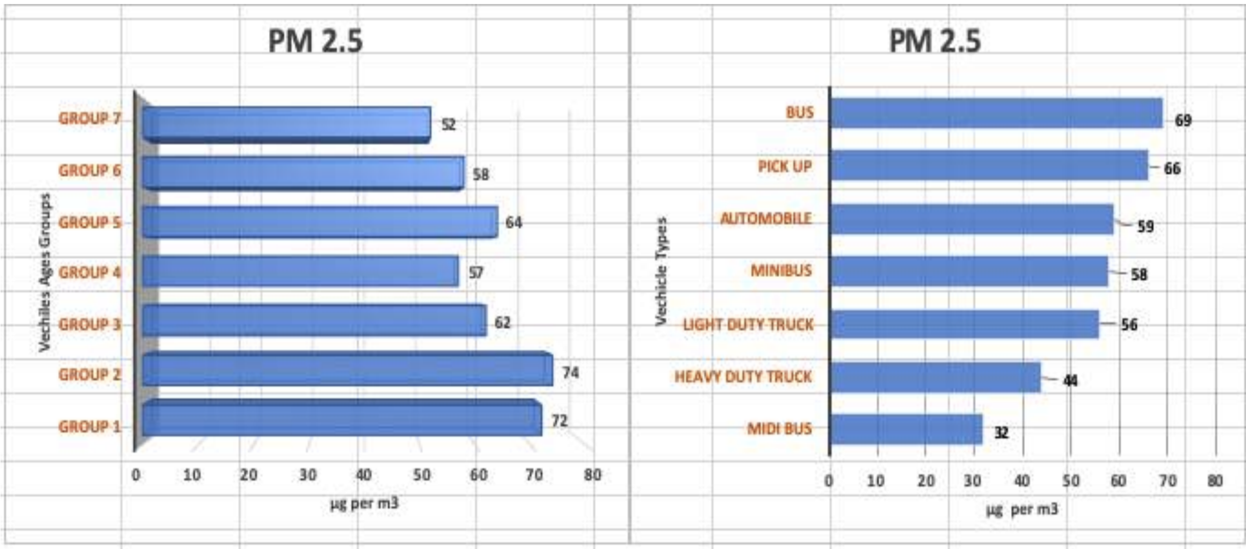

Figure 5: $PM_{2.5}$ Concentration Per Manufacturing Year and Vehicles Types

b) Pollutant Concentrations for Gasoline Vehicles

Vehicle tailpipe emissions were analysed according to the vehicle manufacture year and vehicle type. The following analysis was made based on the findings from each gas measurement.

- **Sulphur dioxide (SO_2)**: The sulphur dioxide emissions for all age groups were almost the same except for group 6. This might be related to higher sulphur content of gasoline fuel (501-3500 ppm) in the Ethiopian fuel market[13].
- **Carbon monoxide (CO)**: The trends were seen to be different, but the newer or more recently manufactured cars in group 6 and 7 had the lowest carbon monoxide emissions measurement from the tailpipe test.
- **Carbon dioxide (CO_2)**: The concentration of CO_2 was parabolic in nature when moving from group 1 to 7. It can be said that group 6 and 7 had lower carbon dioxide emissions measurements than the other age groups.
- **Hydrocarbon (HC) and Nitrogen oxide (NOx)**: The results showed that the more recently manufactured vehicles emitted less NO_x than the older vehicles.

Therefore, from the above findings, vehicles in group 6 and 7 produce lower pollutant gas emissions than the other groups, indicating that there is a relationship, although not perfect, between the manufacturing year and the amount of emissions (Figure 6).

13 **Anas 2018**

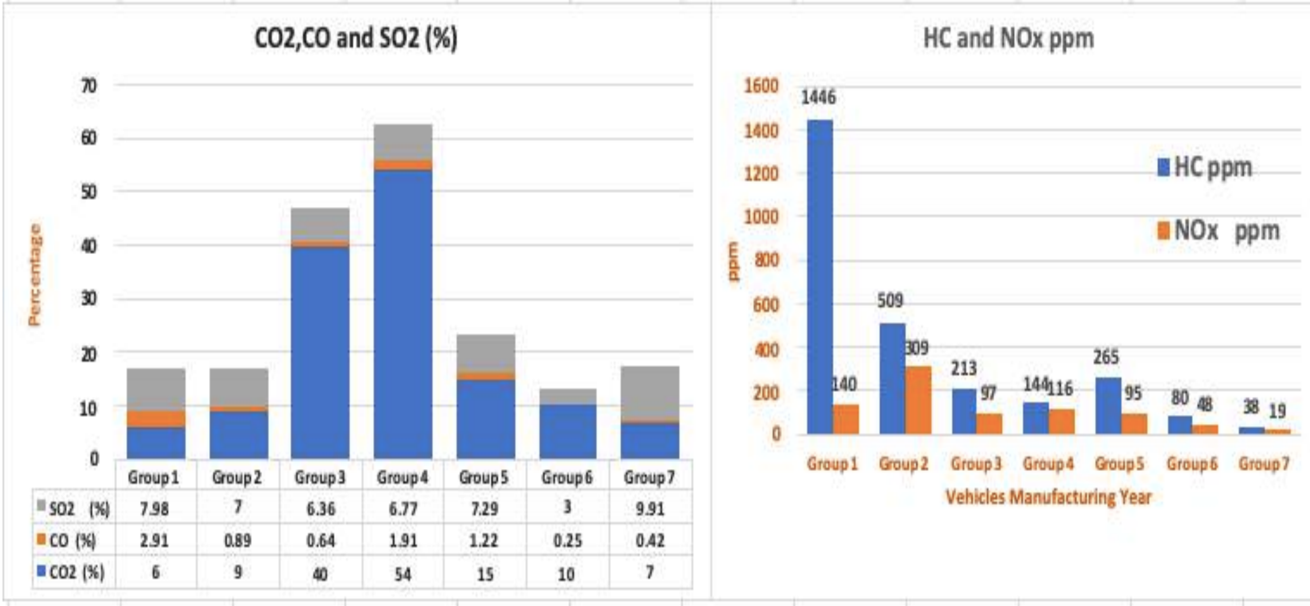

Figure 6: Pollutant Gas per Vehicles Manufacture Year

Automobiles were the highest CO_2, HC and NOx emitters when compared to other vehicles, while minibuses are the lowest emitters for all gases when compared to all the other vehicle types (Figure 7).

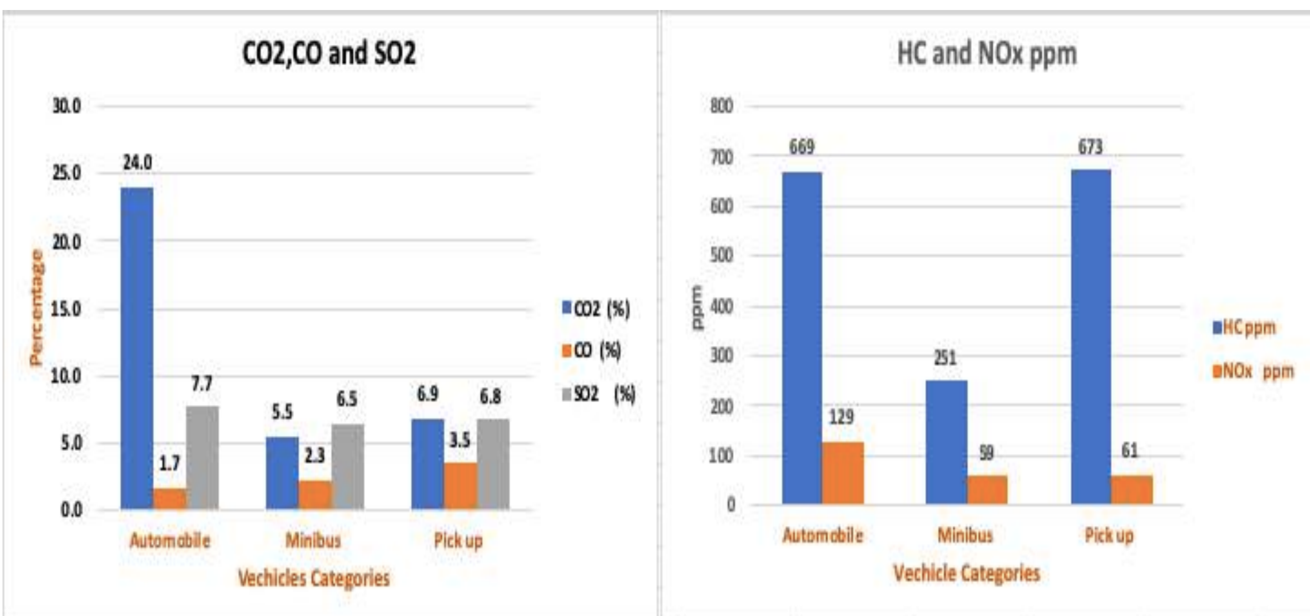

Figure 7: Pollutant Gas per Vehicle Type

3.1.4. GHG Emissions Estimation

GHG emissions were estimated using the data collected on fuel economy (Table 3) and annual VKT (Table 5) by different types of vehicles. VKT/year data in Table 5 was derived from VKT/day (Table 4) by assuming the average vehicle operation per year in Ethiopia is 275 days[14]. Moreover, the IPCC default emissions factors and global warming potential were used. The emissions factors used for gasoline vehicles were 2.3652 kg CO_2/liter, 3.564 g CH_4/liter and 0.3564 g N_2O/liter, whereas the emission factors for diesel vehicles were 2.682328 kg CO_2/liter, 0.34067 g CH_4/liter and 0.43032 g N_2O/liter. The GWP used for the calculation of CH_4 and N_2O were 21 and 310, respectively. GHG emissions from vehicles were calculated using the general formula of fuel consumption and emissions factor (fuel consumption data x emission factor). This study did not include the apportioning of GHG emissions into the Scope 1 and Scope 3, as this would require vehicles to be counted at the city vehicle inlet and outlet. This extension could be taken as an assignment for future studies. The number of vehicles in the city grew by 79.4% from 231,681 in 2013 to 415,574 in 2019[15]. The total emissions estimated from these vehicles increased from 2 to 3.6 million tCO2e per year from 2013 to 2019. The driving force for this increase was the growth in vehicle population. VKT/year and number of people using mass transit could reduce this estimation. These factors could be more accurately analysed when data is continuously collected through annual vehicle inspections, for example, and compared with vehicle growth, annual VKT, etc.

Table 5: Annual Vehicle Kilometers Travel and tCO2e/Year/Type of Vehicles

Fuel Type	Categories	VKT/Year (km)	Total GHG Emissions (tCO2e/year)
Diesel	Automobile	22,000	7.6
	Bus	47,025	34.51
	Heavy-duty Truck	42,075	45.75
	Light-duty Truck	38,775	17.51
	Midibus	20,350	14.22
	Minibus	35,475	13.02
	Pick up	20,625	6.65
Gasoline	Automobile	14,300	3.59
	Minibus	23,925	7.55
	Pick up	11,550	3.73

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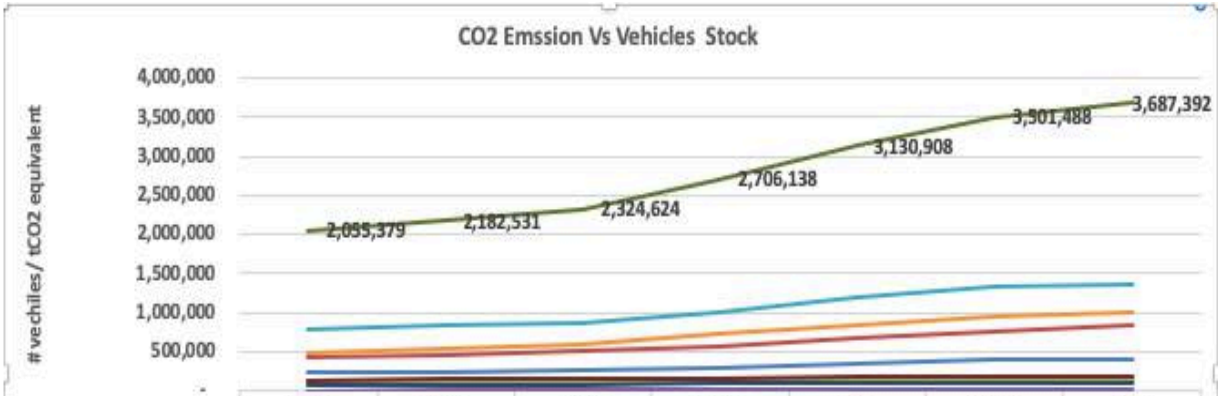


	2013	2014	2015	2016	2017	2018	2019
# Vehicles	231,681	246,636	263,985	304,943	350,979	392,437	415,574
Automobile (t CO2e)	442,876	471,519	507,133	579,869	675,246	770,195	836,264
Midibus	98,914	102,313	110,276	121,425	133,455	145,300	155,297
Bus	10,992	11,376	12,258	13,495	14,831	16,140	17,249
Heavy Duty Trauck	796,434	831,500	859,059	1,012,549	1,196,499	1,327,138	1,371,505
Light Duty Truck	493,334	540,602	598,235	723,215	840,388	957,575	1,011,753
Minibus	77,723	81,225	84,818	90,529	95,217	99,963	103,078
Pick-up	135,105	143,997	152,845	165,056	175,272	185,177	192,246
Total Emssion	2,055,379	2,182,531	2,324,624	2,706,138	3,130,908	3,501,488	3,687,392

Figure 8: Total Emission from vehicles

3.2. Ambient Air Quality Measurement

The findings from the ambient air quality measurement exercise were compared with the Ethiopian and WHO guidelines for pollutant gases (as shown in Table 6). This section highlights the ambient measurements undertaken at roundabouts, taxi and bus stations. Moreover, the results were also compared and analysed against other air quality monitoring readings such as the US Embassy- and AAEPGDC-managed air quality equipment. This data was further analysed to show the different scenarios of vehicle manufacturing year standards for reducing the pollutant gases and the impact on health and the economy.

Table 6: Air quality guidelines: Ethiopia and WHO[16]

Pollutants	Ethiopian guideline value	WHO guideline value
Sulphur dioxide (10 minutes)	500	500
Carbon monoxide (15 minutes)	100,000	-
PM 10 (daily)	150	50
PM 2.5 (daily)	65	25

16 **Urban air quality in Ethiopia: guidance framework for clean air action,2016**

3.2.1. Air Pollutants at Roundabouts, Bus and Taxi Stations

The measurements showed that the average $PM_{2.5}$ and PM_{10} concentrations were higher than the WHO guidelines. For instance, the average concentration of $PM_{2.5}$ was observed within the average of 26-38.5 µg/m, which is higher than the daily WHO guideline of 25 µg/m^3 (Figure 9).

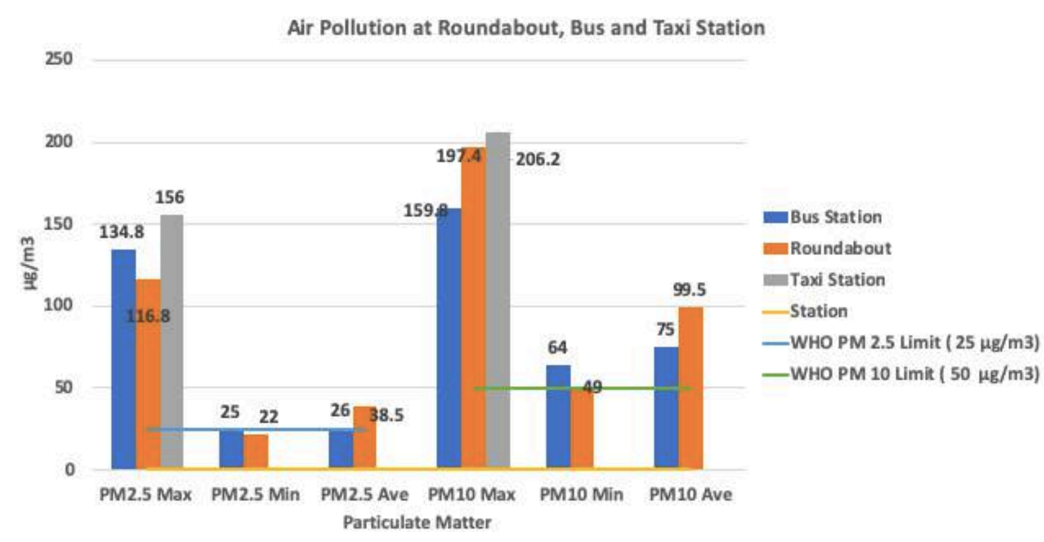
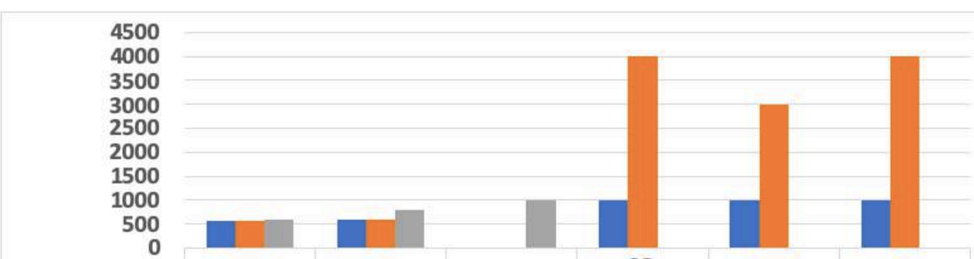


Figure 9: $PM_{2.5}$ and PM_{10} Air Pollution at Congestion Traffic Sites

The average concentration of sulphur dioxide (SO_2) at selected taxi stations was found to be 1000 µg/m^3 which is above the permissible limits of the WHO and Ethiopian guidelines of 500 µg/m^3. The CO concentration is below the Ethiopian guideline which is 100,000 µg/m^3 (15 minutes). The highest concentration of VOC was recorded at taxi stations, i.e. 800 µg/m^3 (figure 10).



	CO2 Ave (mg/m3)	VOC Ave (µg/m3)	SO2 Ave (µg/m3)	CO MaxAve (µg/m3)	CO Min (µg/m3)	CO Ave (µg/m3)
Bus Station	562.8	600	0	1000	1000	1000
Roundabout	567.9	583	0	4000	3000	4000
Taxi Station	584.8	800	1000	0	0	0

Figure 10: Pollutant Gases at Congested Traffic Sites

3.2.2. Health and Economic Benefits of Cutting Air Pollution from the Transport Sector

A recent Global Burden of Disease study showed that air pollution is the second greatest risk factor for death and disability in Ethiopia. In 2017, it is estimated that 21% of non-accidental deaths were due to exposure to poor air quality, representing 2,700 deaths in the city. Without action to control air pollution, by 2025 this figure is estimated to rise to 6,200 and account for 32% of deaths[17]. Therefore, it is necessary to act on air pollution mitigation. The four vehicle standard scenarios have been developed to analyse the health and economic benefits of cutting down air pollution from the transport sector. All four scenarios assume that the underlying number of vehicles remains constant, and then a different vehicle replacement rate is applied to each scenario (i.e. oldest vehicles replaced by newer vehicles). The associated overall $PM_{2.5}$ reduction is then calculated and used to model the health and economic benefits (Table 7).

Table 7: Scenarios and Benefit Analysis

Scenario	Reduction in $PM_{2.5}$ non-background concentration	Benefits				
		Premature Deaths avoided per year	Day of life expectancy gained for each Citizen	Life Years Gained across the population per year	Cardiovascular and Respiratory hospital admissions averted per year	Health Cost Saved (USD) per year
1	9% (1.93µg/m^3)	100	23	3,745	235	27,000
2	11% (2.40µg/m^3)	130	30	4,660	292	34,000
3	15% (3.3µg/m^3)	180	40	6,520	410	47,000
4	19% (4.2µg/m^3)	225	50	8,110	510	60,000

- **Scenario 1:** 20% of older vehicles (before 1992) which is about 104,000 polluting vehicles are banned and replaced by more recent vehicles (from 2000-2005);
- **Scenario 2:** 34% of older vehicles (before 2000) which is about 179,000 polluting vehicles are banned and replaced by more recent vehicles (from 2000-2005);
- **Scenario 3:** 20% of the vehicles aged before 1992 are banned and are replaced by new vehicle (from 2014 onwards)
- **Scenario 4:** 25% of the vehicles aged before 1992 are banned and are replaced by new vehicles (from 2014 onwards).

The actions in the four scenarios will have different impacts on air pollution, health and the economy. Table 7 shows that the air quality improvements linked to the four scenarios lead to a reduction in the health burden of cardiovascular- and respiratory- related diseases and deaths. Hospital admissions are used as an indicator for morbidity, while the change in premature deaths, life expectancy and life years gained are used to quantify mortality impacts. The economic impact represents the monetary value of averting a hospital admission on public healthcare costs. More details and assumptions can be found in *Benefits of Urban Climate Action, C40 Cities Technical Assistance Report 2020, Addis Ababa*.

17 **C40, Benefits of Urban Climate Action 2020**

4. Conclusion & Recommendations

4.1. Conclusion

This study has successfully filled some of the GHG- and air quality- related data gaps in the Addis Ababa transport sector, i.e. fuel economy, annual kilometers travelled, GHG and pollutant emissions per type, and ambient air quality measurements at roundabouts, taxi and bus stations. This study also showcased the health and economic benefits of implementing vehicle standards for the Ethiopian market.

Most importantly, it informed the development of the draft 10-year (2020-2029) 'Environment and Air Pollution Monitoring and Control Strategy in Addis Ababa City Transport Sector', which highlights some of the pollution control challenges and gaps in Addis Ababa. This strategy aims to assist the city in developing and accelerating action to prevent further deterioration of the air quality. It also aims to raise awareness of pollution control issues in the city and to propose solutions to the problems of local and trans-boundary air pollution, including the threat of climate change. It sets out some guiding principles and recommendations to resolve the challenges and overcome the barriers, including policies and methods to control vehicular emissions, regulating and enforcing these policies, improving infrastructure to be more climate resilient, promoting environmentally friendly vehicles and sustainable transport modes, building capacity and coordinating with stakeholders and partners to ensure integrated policies and plans.

4.2. Recommendations and Next teps

GHG emissions and air quality measurement are not one-time actions. These need to be measured continuously and should be accompanied by emissions mitigation efforts. Strengthening the data flow system is a crucial step for tracking emissions overtime. This can be done through a well-organized institutionalized system. Therefore, the city needs to strengthen the data required by collaborating with different institutions and installing more real-time air quality monitors throughout the city.

These are the main recommendation based on this study's findings:

- Improve data availability through an institutionalized system: essential data such as fuel economy, vehicles kilometers travelled, etc. should be gathered continuously to understand the different types of vehicle travel behavior, which will inform evidence-based mitigation actions, such as vehicles carbon or pollution taxes, and the promotion of mass transit, walking and cycling, etc.
- Increase real-time air quality monitoring: this will allow for a more representative picture of pollutant concentrations across the city.
- Limit pollution from vehicles by developing vehicle standards, by combining vehicles emission test, limiting old vehicles by making use of the vehicle manufacture year as a vehicle age proxy, and performing vehicle tailpipe emission tests on an annual basis to understand the impacts of the policy.
- Achieve emissions reductions by implementing evidence-based climate actions and developing a detailed air quality management plan for the city.

Annex I: Methodology – "How-to" Guidance

- **Step 1: Form Technical Working Group**

The Technical Working Group was formed from 10 institutions across the city. The group completed theoretical and hands-on training. The content of the training included analysing the transport sector GHG emissions and air quality levels, and the use of gas analysers and ambient measurement equipment, etc.

These are the major topics covered in the training:

- Basic Science of Air Pollution and GHG emissions - Cause and Effect;
- How to Operate, Use and Care for Exhaust gas analysers, Opacity Smoke Meters and Ambient Air Monitors;
- Principles and methodologies of roadside inspection, traffic control, placing traffic cones, the setup of a roadside inspection lane and random selection;
- How to undertake a two-speed idle tailpipe emissions test, data recording, and interact with motorists;
- Methods of data analysis and report writing;
- Safety and General Instruction.

- **Step 2: Determine Sample Size and Location for Tailpipe Emissions Test and Ambient Air Quality Measurement**

  - A statistically significant sample size was determined;
  - The data collection tool was prepared and data collection was undertaken based on such tool;
  - Primary data for 406 vehicles was collected within 30 days;

Selection of Sample Test Location: Eight roadside sites were selected for inspecting the in-use vehicles. Eight test locations were selected from 10 sub-cities. The intent was to obtain representative samples because some sub-cities are larger and contain relatively more vehicles.

Criteria for site selection included the following:

- Roads with at least two parallel lanes so that traffic would not be blocked;

- Sites where vehicles would be fully warmed up (i.e. vehicles have been driven for at least five to ten minutes);
- Sites that would result in a broad mix of vehicle types, model years, usage, etc.

➢ **Step 3: Preparation and Calibration of the Equipment**

Tailpipe Emissions Test: Two types of equipment were used to collect tailpipe exhaust emissions at each of the selected locations. These were gas analysers and digital opacity smoke meters. In addition, materials were purchased for data collectors such as overalls, hats, safety glasses, safety shoes, etc. which were used for safety protection while collecting the data. The calibration of the equipment was done based on the company manual and support from experts with experience in working with similar equipment.

- ❖ There were four portable Gas analysers, Model FGA4000XDS, manufactured by Infrared Industries, was used to measure ambient HC and NOx in parts per million and CO, CO_2 and O_2 in percentages. They are equipped with printers to print the emissions readings at the end of the tests. Six 12-Volts, 72 ampere-hour batteries to power the gas analysers were used.
- ❖ One digital opacity meter with accessories was used for the diesel vehicle emissions measurement.

Ambient Air Quality Measurement: it was undertaken at different congested sites in the city. The equipment used was six handheld ambient PM monitors, Model Nitrogen dioxide 0-1ppm, carbon monoxide 0-25ppm GSE, Sulphure Dioxide 0-10ppm and $PM_{2.5}$ PM_{10} 0-1.000mg/m^3. These sensors were manufactured by Aeroqual Limited and were used to measure ambient PM. This instrument has an ambient particulate measuring range of 0.001 to 400 mg/m^3.

➢ **Step 4: Data Collection**

a) Data Collection Format

The data collection format for both the tailpipe and ambient air quality measurements were prepared, and included both qualitative and quantitative data. The qualitative data consisted of interviews from the vehicle drivers about the different parameters concerning their vehicles such as fuel economy (km/l), VKT and fuel expenditure per year, etc. The quantitative data consisted of the measurements undertaken with the equipment.

b) Data Sources

The ambient air quality measurements were also undertaken at the selected sites along with the vehicle GHG emissions survey. Both primary and secondary data was collected. Primary data was collected through a prepared data collection template which was suited to address GHG emissions and air quality data gaps in the transport sector. The primary data sources are tail pipe roadside emission testing of HC, SO_2,CO_2, CO, O_2, NOx, ambient PM and ambient air quality measurement, whereas secondary data was gathered from institutions. The data collection process was carried out from February to June 2020. Data collection began at 9:00 AM and ended at 5:00 PM in a normal working day, and it was limited to these hours due to difficulties in transporting inspectors and equipment from the AAEGDC store to the test sites and back.

c) Data Collection Process

i) General Steps to Complete the Tailpipe Emissions Test

Inspectors set up their measuring instruments at the sites. The instruments remained stationary for 30 seconds. Then roadside inspectors and traffic controllers waved vehicles into the inspection lanes, where they were given a visual and tailpipe inspection.
The vehicles were randomly chosen from different categories and were tested using diesel and gasoline gas analysers. A mixture of various manufacture years and models were tested. These included automobiles, field vehicles, mini-buses, midi-buses, buses, light duty and heavy-duty vehicles. The manufacture years' ranged from 1985 to 2019.

The roadside inspectors performed the following procedures while collecting the data for the study:

a) TWG were divided into three inspection teams. The first team, including the traffic police, (who waved down the vehicles and greeted the motorists at the test lane), filled the data collection form, performed the visual inspection and noted the findings on the test reporting tool. The second team operated the analyser and the third team conducted the tailpipe exhaust emissions measurement.
b) Informed owners about the study;
c) Directed vehicles to the roadside test locations including the placement of the traffic cones to act as guides for directing the selected vehicles;
d) Placed the analyser on a table and connected it to the charger;
e) Turned on the analyser, allowing it to warm up;
f) Performed safety inspections and gathered primary data;
g) Conducted the tailpipe exhaust emissions measurement in accordance with specifications.
h) Recorded or printed out and stored data.
i) Informed drivers of the test results and released vehicles to merge into the flowing traffic.
j) Each morning the analysers' calibration was checked and re-calibrated if necessary.
k) Each inspection team took its analszer, charger and traffic cones to the assigned site.

ii) On-site Data collection

The Tailpipe Emissions Data Collection Process

In this study, eight roadside sites were selected for inspecting the vehicles. The collected data included a visual inspection and interviews to collect data such as type of vehicle, fuel type (gasoline or diesel), model name, manufacture year, kilometres travelled in total (odometer reading), kilometres travelled per day, fuel economy and registration year, as well as the tailpipe measurement which included ambient levels of HC, CO_2, CO, O_2 and NOx and ambient $PM_{2.5}$ mg/m^3.

- To obtain a random sample of vehicles to inspect, a common fuel type was chosen. When one of the vehicles with that fuel type passed, the vehicle directly behind it was selected. The traffic police would flag the selected vehicle and direct it into the testing area. Often, one was waiting while another was being inspected. The inspector explained to the driver the purpose and got his/her verbal consent to perform the inspection.
- **Visual Inspection**: included information such as type of vehicle, fuel type (gasoline or diesel), model name, manufacture year, kilometres travelled in total (odometer reading), kilometers travelled per day, fuel economy and registration year.
- **Tailpipe Inspection** - spark ignition engines: a clamp-on tachometer was attached to a spark plug wire to measure the engine speed in revolutions per minute (RPM).
- The analyser's sampling probe was inserted into the vehicle's tailpipe to draw an exhaust gas sample for the analyser to evaluate.
- The driver operated the under test (VUT) while the second team operated the analyser.
- The driver accelerated the VUT's engine to 2500 RPM, assisted, if necessary, by the second team member, who can also read the engine's RPM on the analyser.
- When 2500 RPM was reached and a steady level obtained (±100 RPM), the analyser button was pressed to start the test. The analyser averages and records RPM and emissions data for the 25th through to the 30th second, then stores and prints the partial results.
- This printing acted as a signal for the driver to drop the engine speed to idle. At idle speed, the second phase of the test began and ran for another 30 seconds. Again, the last five seconds of data were averaged and recorded, and the analyser printed two types of results.
- The second team member stapled a copy of the final printout to a brochure, which was discussed with the vehicle's driver. The member explained the emissions results and showed the driver a table in the brochure displaying what levels of pollutants vehicles in proper repair should emit.
- The second member stapled the copy of the final printout to the test report and stored the form.
- Diesels: a few samples were tested for informational purposes only.

- Inspections were performed from 9:00 AM to 5:00 PM. Data collection was limited to these hours because of the problems encountered in transporting inspectors and equipment from the store to the test sites and back.
- At the end of the day, the equipment was brought back to AAEPGDC and the hardcopy of analyser data was collected and secured.
- These steps were followed throughout the study period.

This handheld ambient PM monitor measured and collected the daily levels of ambient NO_2, CO, SO_2 and PM concentrations at selected sample sites each day**.**

Ambient Air Quality Measurement Data Collection Process

- At the beginning, the ambient air measuring instruments were connected to a power source to be charged for three hours and their calibration checked in accordance with the manufacturer's specification.
- Ambient air inspectors carried measuring instruments and measured the daily levels of ambient NO_2, CO, SO_2 and PM concentrations at selected sample sites each day. Meanwhile, ambient inspectors carried a replacement unit in case of equipment and accessory breakdown.
- At each site, the instruments were handled at approximately six to eight feet above the ground.
- The instruments were turned on and the data was collected.
- At the end of each day, the instruments were shut down and taken back to AAEPGDC and the data was copied and secured.
- The instruments were connected to a power source to be charged for the next day's testing.
- These steps were repeated until the end of the data collection.

GHG Emission Estimation

- Data for fuel economy and VKT was collected from interviews with drivers.
- Default emission factors for gasoline and diesel were used from the IPCC 3rd Assessment.
- GWP for CH_4 = 21 and for N_2O = 310.
- Annual vehicle operation day per year = 275 days.
- Fuel consumption estimated through annual VKT and fuel economy.
- GHG emissions estimated using the formula: fuel consumption X emission factor.

Annex II: Tailpipe Emissions Data Collection Sheet

S/N	Type of Vehicles	Fule Type	Vechile Model	Manufacture year	Kilometer Travelled/Year	Kilometer Travel/Day	Fuel Economy (K/L)	Registration Year in the city	PM2.5	HC ppm	CO_2 (%)	NOx ppm	CO (%)	O_2 (%)	Fuel Spending /Week (Birr)
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002															
003															
004															
005															
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Annex III: Ambient Air Quality Measurement

S/N	Area	Sites	Time	Ending time	PM 2.5/ PM 10	CO2/NO2/VOC/SO2/CO	Humidity	Temprature
Examples	Bus Station	Megenagna Bus Station	10:10	10:50	29/90	eg CO2 = 587	43	26.2
	Roundabout	Asco Bus Station	3:00	3:30	175/210	eg CO2 ==537	52.6	26.2
	Taxi Station	Ayeretena Bus Station	2:00	2:50	163/169	eg CO2 =579	41	26.1
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Annex IV: Addis Ababa Vehicles Stock and Type of Fuel Used

Vechiles Categories		# of Vehicles Per Year 2013	2014	2015	2016	2017	2018	2019
	Ambulace	53	69	92	108	130	137	167
Automobile	Automobile	82530	87855	94473	108020	125783	143481	155771
Bus	Bus(> 11 Seats)	7729	7995	8617	9488	10428	11353	12134
	Trailer	10828	11443	11875	14358	16808	18656	19142
Heavy Duty Trauck	Dry Cargo(>10 Quintals)	45180	47031	48537	56848	67334	74673	77307
	Dry Cargo(<=10 Quintals)	12052	13354	15160	19198	23128	27349	29356
	Liquid Cargo	2726	2851	2999	3447	3772	4738	4938
	Vehicle with Machinery	87	99	123	182	317	546	645
	Forklift	33	41	48	84	126	172	199
	Three wheel public load	188	197	207	3	7	12	12
	Dual Purpose Vehicle	17961	19668	21603	25253	28568	30869	32223
Light Duty Truck	Gotach	1646	1807	1930	2692	3181	3654	3777
Minibus	Bus(< 12 Seats)	14493	15146	15816	16881	17755	18640	19221
Pick-up	Field Vehicle	25193	26851	28501	30778	32683	34530	35848
Motor Bicycle	Motor Bicycle	6538	7393	8696	11252	13980	16192	17108
	Tractor	128	164	217	370	473	548	620
	Dozer	1	1	6	6	8	9	9
	Combiner	5	9	9	11	13	15	17
	Three wheel dry load	1	1	1	211	212	213	215
Off-Road Vechiles	Grader	3	3	3	3	3	5	5
Others	Other	4306	4658	5072	5750	6270	6645	6860
	Total	231681	246636	263985	304943	350979	392437	415574

Year	Gasoline	Diesel	Nofuel	Electric charchable	Proportion gasoline and diesel vechiles in City (%) Gasoline	Diesel		
2013	117426	101455	1059	3	53	46		
2014	124835	108343	1299	4	53	46		
2015	133848	116136	1538	5	53	46		
2016	151437	136900	4000	27	52	47		
2017	173143	158677	6420	32	51	47		
2018	194782	176591	8237	33	51	47		
2019	209090	184880	8712	34	52	46		
				Average	52	46		

Bibliography

Addis Ababa City Administration Integrated Land Information Centre. "Addis Ababa City Atlas." 2015.

Addis Ababa EPGDC. *Addis Ababa GHG Emission Inventory for 2016*. 2020.

Adiloğlu, Sevinç, I, Chaochao Yu, Rui Chen, Juan Jinxing Li, Juan Jinxing Li, Martin Drahansky, et al. *In Intech*. 2012. The Air Quality Influences of Vehicular Traffic The Air Quality Influences of Vehicular Traffic Emissions Emissions. <https://doi.org/10.1016/j.colsurfa.2011.12.014>.

Anas, Abdoun. *Fuel Quality and Emission Standard Developments in Africa*. 2018. 7 April 2021. <https://wedocs.unep.org/bitstream/handle/20.500.11822/25233/FuelQualityEmissionStandardDevelopments.pdf?sequence=3&isAllowed=y>.

Anumita, Roychowdhury and Chandola Priyanka. *URBAN AIR QUALITY MANAGEMENT IN ETHIOPIA: A GUIDANCE FRAMEWORK* . Centre for Science and Environment, 2016.

C40, Benefits of Urban Climate Action. *C40 Cities Technical Assistance Report* . Addis Ababa, 2020.

Central Statistical Agency. *Population Projections for Ethiopia 2007 to 2037*. Addis Ababa, 2013.

Enviromental Protection Authority. *Guidline Ambient Enviroment Standards for Ethiopia*. Addis Ababa, 2003.

Ethiopia Federal Democracy Republic. *Climate Resilience Green Economy Strategy* . 2011.

Manisalidis, Ioannis, Elisavet Stavropoulou, Agathangelos Stavropoulos, and Eugenia Bezirtzoglou. *A Review." Frontiers in Public Health 8 (February): 1–13*. 2020. Environmental and Health Impacts of Air Pollution. <https://doi.org/10.3389/fpubh.2020.00014>.

Mekonnen, Maschal Tarekegn and Yohannes Gulilat Tigist. *Trends of Ambient Air WŽůůƵƚŝŽn and the Corresponding Respiratory Diseases in Addis Ababa*. Addis Ababa: C linical Pharmacology & Toxicology Journal , 2018.

Nigel, N. Clark, et al. *Factors Affecting Heavy-Duty Diesel Vehicle Emissions*. Journal of the Air & Waste Management Association, 2011.

List of Contributors

Members of the Technical Working Group (TWG)

- Mandefro Wegayehu, Federal Transport Authority
- Meseret Abdissa, Environment, Forest and Climate Change Commission
- Wami Kumbi, Addis Ababa Transport Bureau
- Aklilu Adefris, Addis Ababa Transport Bureau
- Yehalem Tesera, Addis Ababa Drivers and Licensing and Control Authority
- Elias Fiseha, National Meteorology Agency
- Belay Tesfaye, Addis Ababa Health Bureau
- Shemsu Jihad, Kotebe Metropolitan University
- Dr. Shimelis Kebede , Addis Ababa Institute of Technology
- Daniel Bogale, AAEPGDC
- Fantu Kifle, AAEPGDC
- Lemessa Gudeta, AAEPGDC
- Lakech Haile , AAEPGDC
- Sani Haji, AAEPGDC
- Mulatu Wasenu, AAEPGDC
- Said Abdella , AAEPGDC

Technical Assistance

- Tibebu Assefa, C40 Cities Climate Leadership Group
- Giovanni Tedesco, C40 Cities Climate Leadership Group
- Helen Ho, C40 Cities Climate Leadership Group
- Honorine van den Broek d'Obrenan, C40 Cities Climate Leadership Group

CONTACT

Addis Ababa Environmental Protection and Green Development Commission

Telephone: +251-116-675-946
: +251-118-547-278