Ethiopian Journal of Environmental Studies & Management 9(6): 748 – 759, 2016.
ISSN:1998-0507 doi: http://dx.doi.org/10.4314/ejesm.v9i6.7
Submitted: July 20, 2016 Accepted: November 06, 2016

ASSESSMENT OF CO_2 EMISSION LEVEL IN URBAN TRANSPORT OF MEKELLE CITY, ETHIOPIA

TEWELDE GEBRE
Mekelle University - Institute of Environment, Gender and Development Studies, Department of Urban Environmental Management
E-mail: tewe_lde@yahoo.com

Abstract
Transport plays a crucial role in accelerating development and improving quality of life by allowing ease transfer of people, goods and services. It is also one of the important preconditions for achieving developmental goals. This study therefore intends to assess the level of CO_2 emissions in urban transport of Mekelle city. It employs a descriptive research with qualitative and quantitative research approaches and survey research strategy. Data for the study were collected from primary and secondary data sources. Questionnaire, interview, and observation were used to gather primary data, whereas, archives were used to gather secondary data. These data were analyzed through qualitative (narrative analysis) and quantitative (descriptive and statistical analysis) methods. Tables, charts, graphs and plates are used to present the data. This study finds that Atoz and Yaris car models; and Hyundai and Daihatsu motors emit lesser amount of carbon dioxide, while Land cruiser and WllB car models; and Mercedes Benz and Suzuki motors emit more. The average emission level of private automobiles in Mekelle city is found to be 209.93grams of CO_2/km with an average fuel efficiency of 12.115km/liter. This study has also found that, the sampled private automobiles in the city emit an average of 21,768.09kg of carbon dioxide monthly and 264,845.1kg of carbon dioxide annually.

Key Words: *Climate change, Urban transport, CO_2, Vehicular emissions*

Introduction

In today's world, transport plays a vital role in ensuring socio-economic development. However, it is also one of the major sources of greenhouse gas emissions like, carbon dioxide, sulfur dioxide, nitrogen dioxide and particulates, which are the major contributors to the global climate change. The contribution of transport sector to global greenhouse gas emissions is estimated to be more than 7200 billion tons (UNFCCC, 2011). Since little efforts are being exerted to mitigate vehicle emissions, the contribution of transport to greenhouse gas emissions is expected to grow in the coming years (UNFCCC, 2011).

Ethiopia, like other developing countries, has undergone rapid road transport expansion mainly due to the augmentation in economic activities and the consequent income growth (Belew, 2012). Nevertheless, most of the urban transport expansions do not take climate change in to consideration. Unless greenhouse gas mitigation measures are taken for the growing urban transport, the likelihood of social vulnerability to air pollution, urban heat island, and climate change related impacts; like incidence of extreme weather conditions, seasonal fluctuations in rainfall, flooding, drought, and some other related impacts could heap on as evidenced in the recent reports of UNFCCC (2011) and IPCC (2007).

Mekelle is one of the Ethiopian cities characterized by rapid urban transportation growth. The city's transport system is mainly based on road transport. According to the city's road transport office, in 2008, there were more than 4500 vehicles registered in the city. This number has risen to more than 8500 in 2012 (Mekelle City Transport Office, 2014). This rapid increase in urban transport is intensifying the emission of greenhouse gases, which in turn exacerbate the impacts of global warming. If the trend continues, the contribution of urban road transport to total greenhouse gas emission of the city will increase tremendously. Moreover, the boost in automobile dependence and unsustainable transport development in the city could undermine the emission reductions achieved through various mitigation measures. The unsustainable growth of cars in the city when coupled with the little efforts being made to abate greenhouse gas emission level of vehicles could worsen the adverse impacts of climate change globally and in the city. However, proper greenhouse gas mitigation measures could turn away the possible risks of the changing climate. Despite the fact that, cities are now giving emphasis to the changing climate through various adaptation and mitigation measures, they must work to enhance the climate change mitigation measures by providing a solution to the growing number of motorized vehicles. Therefore, this study intends to assess the level of CO_2 emission in urban transport of Mekelle city.

Study Area

Mekelle is located in the geographical center of the Regional State of Tigray which is 783km north of Addis Ababa. Astronomically, the city is located between 13° 32′ N of latitude and 39° 28′ E of longitude with elevation of 2000 to 2200 meters above sea level. It is located in the northern highlands of Ethiopia, covering an area of 130 square km. The eastern side, Enda-Eyesus ridges are the highest peaks of the city. Most ($15km^2$) of city's area is covered with urban features and 8km2 is vegetation cover.

Mekelle has a mild climate that can be described as Woina Dega. During the dry season, the days are pleasantly warm and the nights are cool; in the rainy season, both days and nights are cool. There are two rainy seasons namely the *Kiremt* and *Belg*. The main rain season is *Kiremt* whereby sufficient rain and moisture is available. It is estimated that the average annual rainfall of the city ranges from 579-650 mm. The average maximum temperature per year is 24.1°C and the minimum is 11.11°C. There is a time record where the maximum temperature reaches 29.9 °C and the minimum 1.6 °C. This shows that there is

high temperature fluctuation in Mekelle. Temperature is high in March-May and low in October-December. The maximum and minimum sunshine per month in the city are 10.5 hr/ day and 4.1 hr/ day respectively, and the average sunshine is 8.35 hr/ day. The average wind speed of Mekelle per year is 3m/s. The minimum recorded wind speed per month is 5m/s. The maximum recorded wind speed ever is 14m/s, which was recorded in February 8, 2004.

Mekelle, from the time of its establishment as regional capital city of Tigray, its population has been increasing from time to time. The major components of the city inhabitants are small scale merchants, civil servants and daily laborers. Mekelle is one of the highly populated cities of Ethiopia. According to the 1994 population and housing census, population of the city was estimated to reach 96,938. This number increased to 215,546 during the 2007 population and housing survey. The average annual population growth of the city is estimated to be 4.3% with a balanced sex ratio. The population census of 1984 reveals that, an average increase of 70% was recorded over a decade. Most of this growth is mainly due to immigration.

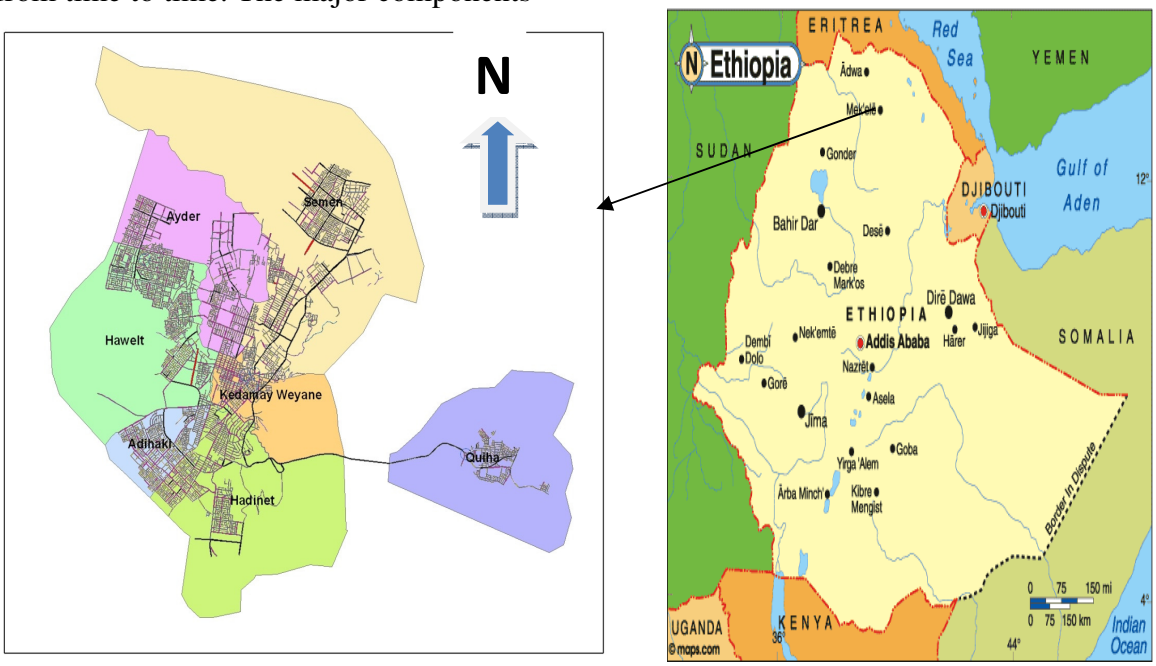

Figure 1: Existing road network of Mekelle city (2010), adapted from Mekelle municipality office

Objectives of the Study

Main Objective of the Study

To evaluate the effectiveness of various climate change mitigation measures, determining the level of CO_2 emission is imperative. Therefore, the main objective of the study is to assess the level of CO_2 emission in urban transport of Mekelle city.

Specific Objectives of the Study

Specifically, this study intends to:

- Measure carbon dioxide emission level of selected motor vehicles in the city.

- Compare and contrast the CO_2 emission level of various models of automobiles.
- Describe the relationship between vintage and CO_2 emission level of automobiles.

Research Methodology

Non-probability sampling is the sampling technique adopted for this study. Based on purposes of the study and characteristics of the motor vehicles, purposive sampling has been used to select the population from which sample for the study was taken. This helps to gather pertinent data that are crucial for the achievement of objectives of the study. Furthermore, haphazard sampling has been employed for the selection of respondents for administering the questioner. This is mainly due to the mobile nature of the respondents.

The study focuses on the urban road transport of Mekelle city. According to the region's transport bureau, currently there are about 10,000 motor vehicles registered in the city. This includes, 2,926 of taxis (code 1), 1,146 of private automobiles (code 2), 4,731 of commercial vehicles (code 3), 1,169 of government vehicles (code 4), and 64 of NGO cars (code 5). Due to budget and time constraint, the researcher was limited to one category of the urban transport that was selected purposively. Since purposive sampling is used, the sample for the study was selected based on the motor vehicles contribution for the identified problems and mainly based on availability of substitutions for the transport type. Accordingly, private automobiles (code 2) were selected for taking sample for this research.

There are 1,146 private automobiles operating in Mekelle city (Mekelle City Transport Office, 2014). Based on Godden (2004), if population is less than 50,000, the following sample size determination formula is appropriate when dealing with descriptive statistics. Therefore, the formula was adopted to determine respondents for the study.

$$\textbf{Sample size} = \frac{Z^2 * P\,(1-P)}{C^2}$$ Where:

Z= confidence level
P = percentage of population picking a choice
C = confidence interval

$$\textbf{New sample size} = \frac{sample\ size}{1+(sample\ size-1)/population}$$

Assuming 95% of confidence level, the sample size for this study is calculated as:

Sample size = $\frac{1.96^2 * 0.5\,(1-0.5)}{0.7^2} = 196$

The final sample size will be = $\frac{196}{1+(196-1)/1146} = 167.49$

Therefore, 167 was the final sample size for the study.

Energy and activity based approaches were used to calculate carbon dioxide emission of the automobiles. Energy based approach is used because, data regarding energy use of the vehicles were obtained and standard emission factor is

used to convert values to carbon dioxide emissions. Activity based approach on the other hand, is used to manually calculate the emission level. Combination of the two approaches helps to minimize the shortcoming of the approaches and to be benefited from their synergy. The following formula is sourced from carbon calculator model in order to compute carbon dioxide emission level of motor vehicles.

$$\left(\frac{Miles\ Driven}{Fuel\ Efficiency}\times 19.36\left(\frac{lbsCO_2}{gallon}\right)\right)\div 2204.6 = CO_2\,Emissions\,(tonnes)$$

Source: Institute of Environmental Management and Analysis corporate (2013).

To make the calculation compatible with the data gathered, miles were substituted by kilometers. The emission factor, i.e. 19.36 lbs CO_2/gallon, is divided for 2204.6 so as to convert the pounds of CO_2 emissions to metric tons. 19.36 lbs CO_2/gallon is equivalent with 19.36 lbs CO_2/3.78541 liters or 5.115 lbs CO_2/liter. This is also equivalent with 2.32012kg CO_2/liter. Vehicle's emission factor is computed based on the averaged details of: vehicle numbers; annual mileage travelled; fuel specifications; road distribution by type of road; average vehicle speed; and temperature and humidity (Hao et al., 2013). The vehicle's emission factor for any diesel and gasoline car in Ethiopia is 2.67kg CO_2/liter and 2.42kg CO_2/liter respectively (CRGE, 2011).

In due course, the above formula was modified and the following formula was finally used to compute carbon dioxide emissions of automobiles and results are described in terms of grams of carbon dioxide per kilometer, since international standard of carbon dioxide emissions of cars is expressed in grams of carbon dioxide per kilometer.

$$\left(\frac{Kilometers\ Driven}{Fuel\ Efficiency}\times 2670\left(\frac{grams\ of\ CO_2}{liters}\right)\right) = CO_2\ Emissions\,(grams)\ for\ Diesel\ Cars$$

$$\left(\frac{Kilometers\ Driven}{Fuel\ Efficiency}\times 2420\left(\frac{grams\ of\ CO_2}{liters}\right)\right) = CO_2\ Emissions\,(grams)\ for\ Gasoline\ Cars$$

Results and Discussions

Carbon Dioxide Emission Level of Private Automobiles in Mekelle City

Mileage of cars is the initial requirement to compute vehicle emissions. According to table 1, most 82 (49.1%) of the private automobiles travel for 21-25kms per day averagely, followed by others travelled for 16-20kms (31.13%). The least distance traveled by the selected private automobiles is 10-15kms, which accounts for 13 (7.78%). Generally, the average distance travelled by the private automobiles per day is 20.74km.

To obtain the mileages driven, an estimation given by automobile owners on their average distance travelled per day is used as summarized in the table below.

Table 1: Average distance travelled per day by private automobiles

Mileage travelled in km/day	Frequency	Percent
10-15	13	7.78
16-20	52	31.13
21-25	82	49.1
26-30	20	11.98
Total	167	100.0

Fuel efficiency is the other most important requirement while computing emission level of cars. The fuel efficiency of these cars is sourced from US Environmental Protection Agency; office of Transportation and Air Quality. For locally assembled cars, fuel efficiency data were obtained from their respective sale houses. Vintage and model of the cars is used as an input to acquire the fuel efficiency of these cars. The result was given in gallons (US) per 100 miles, and the value was converted to kilometers driven per liter.

Accordingly, the carbon dioxide emission level of the selected private automobiles (code 2) of Mekelle city is summarized in the table below.

Table 2: Carbon dioxide emission level of private automobiles

Car model	Vintage	frequency	Average mileage in km/day	Fuel type	Fuel efficiency in km/liter	Emission factor (g/km)	Total CO2 emissions in gram	CO2 emissions (gram/km)
Toyota Motors								
Corolla	1994	7	20.35714	Gasoline	11.188	2420	4403.316	216.3032
Corolla	1997	5	21.5	Gasoline	12.504	2420	4160.991	193.5345
Corolla	1998	5	19.5	Gasoline	12.883	2420	3662.924	187.8423
Corolla	2000	2	22.5	Gasoline	12.883	2420	4226.451	187.8423
Corolla	2002	8	20.625	Gasoline	13.285	2420	3756.846	182.1501
Corolla	2003	3	20.83333	Gasoline	13.285	2420	3794.793	182.1501
Corolla	2004	6	21.66667	Gasoline	13.285	2420	3946.585	182.1501
Corolla	2006	6	20.83333	Gasoline	13.285	2420	3794.793	182.1501
Corolla DX	1988	1	22.5	Gasoline	9.4476	2420	5763.343	256.1486
Corolla DX	1994	1	22.5	Gasoline	11.188	2420	4866.823	216.3032
Corolla DX	1996	3	20.83333	Gasoline	12.504	2420	4031.968	193.5345
Corolla DX	1998	3	22.5	Gasoline	12.883	2420	4226.451	187.8423
Corolla DX	2000	3	17.5	Gasoline	12.883	2420	3287.24	187.8423
Corolla DX	2002	1	22.5	Gasoline	13.285	2420	4098.377	182.1501
Corolla DX	2003	2	20	Gasoline	13.285	2420	3643.002	182.1501
Corolla DX	2005	1	22.5	Gasoline	13.285	2420	4098.377	182.1501
Corolla GL	1997	1	27.5	Gasoline	12.504	2420	5322.198	193.5345
Corolla GL	2001	2	20	Gasoline	13.285	2420	3643.002	182.1501
Corolla GL	2003	2	20	Gasoline	13.285	2420	3643.002	182.1501
Corolla GL	2004	3	22.5	Gasoline	13.285	2420	4098.377	182.1501
Corolla GL	2005	2	20	Gasoline	13.285	2420	3643.002	182.1501
Corolla GL	2006	2	20	Gasoline	13.285	2420	3643.002	182.1501
Corolla GL	2007	1	17.5	Gasoline	13.285	2420	3187.627	182.1501
Executive	2006	6	21.66667	Gasoline	13.496	2420	3884.92	179.304

Executive	2008	8	20	Gasoline	13.496	2420	3586.08	179.304
Yaris	2006	4	21.25	Gasoline	13.714	2420	3749.73	176.4579
Yaris	2008	7	20.35714	Gasoline	13.714	2420	3592.179	176.4579
Vitz	2004	3	22.5	Gasoline	13.496	2420	4034.34	179.304
Vitz	2008	3	20.83333	Gasoline	13.714	2420	3676.206	176.4579
land cruiser	1990	1	17.5	Diesel	5.1222	2670	9122.029	521.2588
land cruiser	1998	2	22.5	Diesel	5.9879	2670	10032.66	445.8961
land cruiser	2004	1	12.5	Diesel	6.8571	2670	4867.175	389.374
Rav4 4WD	2008	2	22.5	Gasoline	10.122	2420	5379.12	239.072
Suzuki Motors								
Vitara	1999	3	20.83333	Gasoline	8.8571	2420	5692.19	273.2251
Vitara	2000	5	21.5	Gasoline	8.8571	2420	5874.34	273.2251
Vitara	2002	7	20.35714	Gasoline	8.8571	2420	5562.083	273.2251
Vitara	2003	7	20.35714	Gasoline	8.8571	2420	5562.083	273.2251
Vitara	2005	2	20	Gasoline	9.2422	2420	5236.815	261.8408
Geely Motors								
Addis	2011	3	20.83333	Gasoline	13.496	2420	3735.5	179.304
Holland Motors								
Shebelle	2012	1	20.83333	Gasoline	13.670	2420	3688.065	177.0271
Abbay	2013	3	20.83333	Gasoline	13.496	2420	3735.5	179.304
Tekeze	2012	2	22.5	Gasoline	13.496	2420	4034.34	179.304
Lifan Motors								
520	2012	6	20	Gasoline	12.883	2420	3756.846	187.8423
X-50	2013	2	20	Gasoline	13.582	2420	3563.311	178.1656
Diahatsu Motors								
Terious	2008	6	21.66667	Gasoline	13.714	2420	3823.254	176.4579
Hyundai Motors								
Atoz	2006	4	18.75	Gasoline	13.939	2420	3255.221	173.6118
Mercedes Benz Motors								
W11B	1986	1	17.5	Diesel	5.9879	2670	7803.181	445.8961
W11B	2002	2	22.5	Diesel	7.5918	2670	7913.085	351.6927
Mitsubishi Motors								
Colt	1998	1	17.5	Gasoline	8.8571	2420	4781.44	273.2251
Colt	2002	1	22.5	Gasoline	8.8571	2420	6147.565	273.2251
Colt	2005	1	22.5	Gasoline	9.2422	2420	5891.417	261.8408
Renault Motors								
Dostur	2010	2	20	Gasoline	11.809	2420	4098.377	204.9188
Mahindra Motors								
2.5 turbo	2006	1	22.5	Diesel	11.337	2670	5298.941	235.5085
Total		167					725603.1	

As observed in the table above, 107 (64.07%) of the private automobiles are Toyota motors. Out of these Toyota Motors, 42 (39.25%) are Corolla cars followed by Corolla DX, 15 (14%), Executive, 14 (13.01%), Corolla GL, 13 (12.15%), Yaris, 11 (10.3%), Vitz, 6 (5.6%), Land Cruiser, 4 (3.75%), and Rav4 4WD, 2 (1.85%).

Suziki motors are the second largest in number next to Toyota motors by having 25 (14.37%) of shares. Vitara is the only Suziki motors model. The other cars include Lifan motors, 8 (4.8%); Holland and Diahatsu motors (3.6% each); Geely, Mercedes Benz, and Mitsubishi motors (1.8% each); Renault motors (1.2%); and Mahindra motors (0.6%).

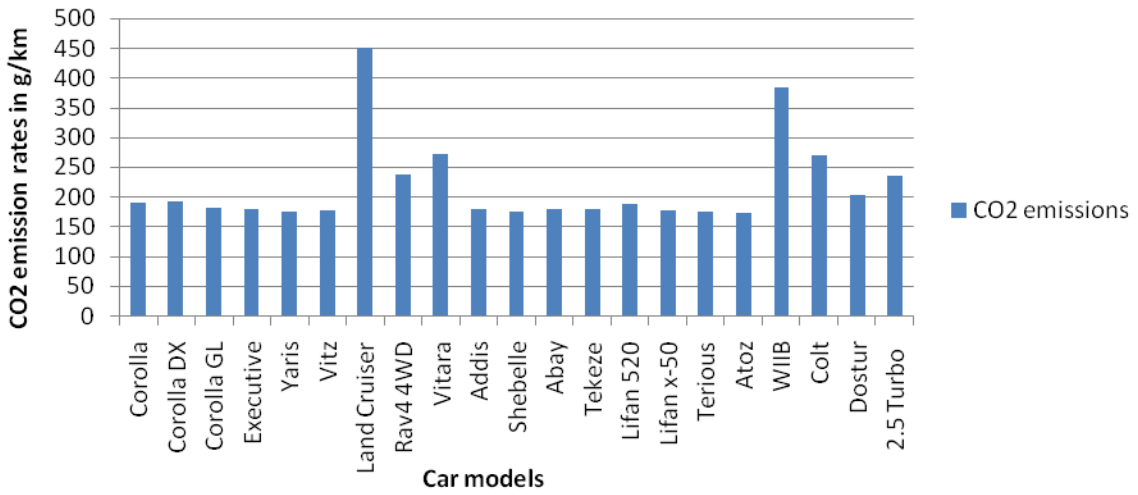

Figure 2: an average carbon dioxide emission levels by car models

The above chart shows that, land cruiser cars emit highest amount of carbon dioxide (450.6grams of CO_2/km) followed by WllB (383.09grams of CO_2/km), Vitara (272.27grams of CO_2/km), Colt (269.43grams of CO_2/km), and Rav4 4WD (239.072 gram of CO_2/km). On the other hand, Atoz cars emit lowest level of carbon dioxide (173.61grams of CO_2/km) followed by Yaris and Terious (176.45grams of CO_2/km each), Shebelle (177.02grams of CO_2/km), Vitz (177.88grams of CO_2/km), and Lifan X-50 cars (178.16grams of CO_2/km). Executive, Abay, Tekeze, and Addis cars have identical emission levels, i.e. 179.304grams of CO_2/km.

Eleven different manufacturers fabricate these models of car. Figure 2 shows that, Mercedes Benz Motors emit highest amount of carbon dioxide (383.09grams of CO_2/km) followed by Suzuki Motors (272.27 grams of CO_2/km), Mitsubishi Motors (269.43grams of CO_2/km), and Mahindra Motors (235.50grams of CO_2/km). In contrary, Hyundai Motors emit the lowest amount of carbon dioxide (173.61grams of CO_2/km) followed by Daihatsu Motors (176.45grams of CO_2/km), Holland Motors (178.92grams of CO_2/km), and Geely Motors that emit 179.3grams of CO_2/km.

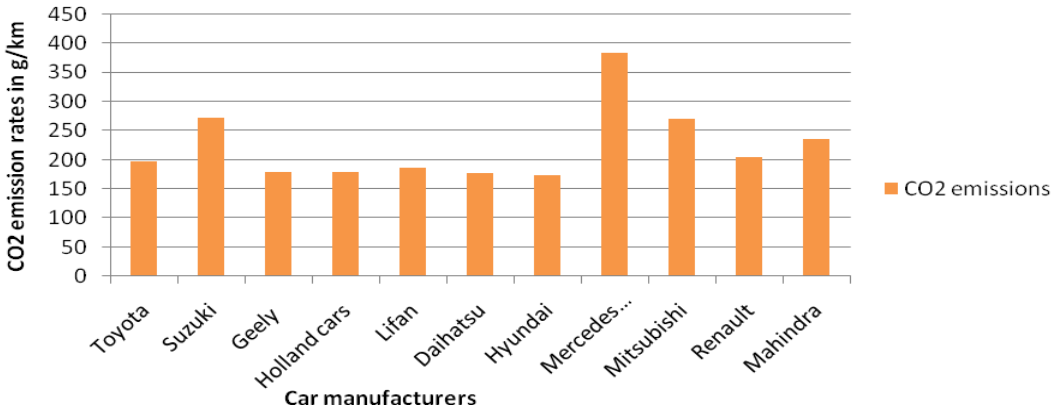

Figure 3: Average carbon dioxide emission levels by car producers

Generally, the average emission level of private automobiles in Mekelle city is 209.93grams of CO_2/km. This is much higher than the automobile emission standards of Europe, which is 203grams of CO_2/km for 2007 and 181.4grams of CO_2/km for 2010 (European Commission, 2013) and that of United States, which is 131.73grams of CO_2/km for 2017 (United States Environmental Protection Agency, 2012).

Fuel efficiency of cars is the most decisive factor of vehicle's emission level, which in turn is determined by vintage, engine type, and model of the car. According to Ethiopian Road Transport Authority (2012), there is no fuel efficiency standard that limits the import of less fuel efficient vehicles by the country. The average fuel efficiency of the cars listed in table 2 is 12.115km/liter. Based on the African Public Transport Association Study for Addis Ababa, the Sub-Technical Committee of CRGE initiative estimated the fuel efficiency of private automobiles in Addis Ababa is 8.33km/liter (CRGE, 2011). This indicates that, the fuel efficiency of private automobiles in Mekelle city is better than that of Addis Ababa. This is partly due to the variation in vintage of these cars. Various sources like Tsehaynesh (2014) and Sue (2010) show that, most of the vehicles in Addis Ababa are more than 15 years old. Whereas, most (51.5%) of the sampled cars of Mekelle city are below 10 years old. Nevertheless, the fuel efficiency of Mekelle city is much poorer when compared with the average fuel efficiency of motor vehicles in United States, which is 19.04km/liter (United States Environmental Protection Agency, 2012).

Carbon dioxide emission level of cars is also highly influenced by vintage of cars. Most 60 (35.92%) of the private automobiles described above are 4-8 years old followed by cars that are 9-13 years old, 54 (32.33%) and 14-18 years old, 33 (19.77%). On the other hand, the cars whose age is 2-3 years, 19-23 years, and 24-28 years have a percentage share of 5.34%, 4.8%, and 1.8% respectively. As shown in figure 4, the cars whose age is 24-28 emit 407.76grams of CO_2/km on average. This reduces to 216.3grams of CO_2/km when the age of these cars decreases to 19-23. However, the emission level increases to 228.32grams

of CO_2/km and 221.83grams of CO_2/km when the age of the vehicles reduces by five and ten years respectively. This is partially due to the subsistence of different car models with different emission rates. For instance, the vintage of Land Cruiser in the year 1996-2000 and Mercedes Benz in the year of 2001-2005 has raised the average emission rate of the cars in their respective years. The average emission rate of the cars whose age is 4-8 years is 183.0014grams of CO_2/km. This is lower by 21.22% than that of 9-13 years of cars. This further reduces to 179.05grams of CO_2/km for those cars that are 2-3 years of service.

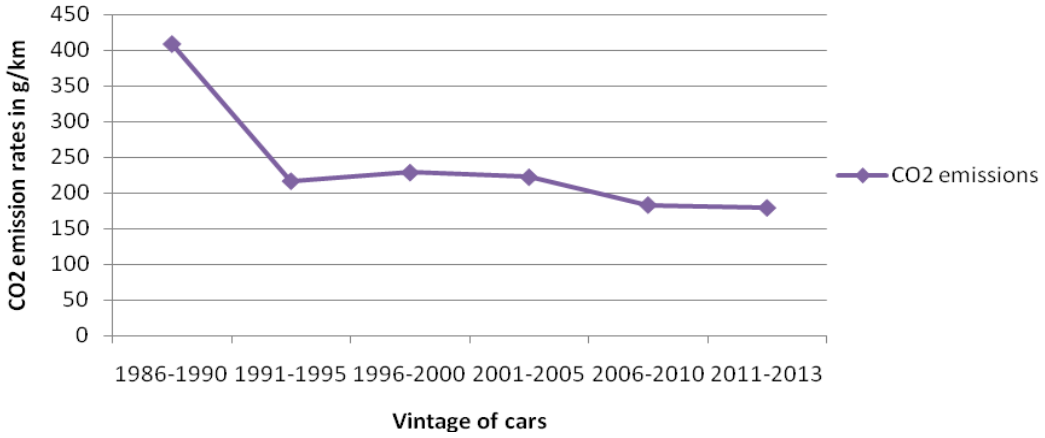

Figure 4: Carbon dioxide emission levels by vintage of cars

Regarding the fuel type, nearly all, 159 (95.2%) of the automobiles are petrol vehicles, while the rest 8 (4.8%) of the cars are diesel vehicles. This corresponds with the ratio of diesel cars in Europe during 1990s, which accounted about 10%. Since the production of ethanol is increasing from time to time, and as it can only be muddle up with gasoline fuel, the dominance of petrol cars in Mekelle city could be seen as an opportunity in reducing car emissions. However, the number of diesel cars is increasing tremendously due to the improvements made to their engine power in the last two decades. This raised the share of diesel cars in Europe to 33.2% in 2009 (Michel and Eckward, 2013).

Generally, based on the fourth assessment report of IPCC (2001), diesel vehicles are more fuel efficient than petrol cars. Nevertheless, the calorific (heat) value of diesel fuel, which contains 14% of carbon per liter, is much higher than gasoline fuel. This increases the carbon dioxide emission level of diesel cars as compared to petrol cars. Furthermore, B and M Development Consultants (2006) showed that, the greenhouse gas emissions of petroleum products in Ethiopia for the year 2004 was largely contributed by diesel fuel followed by gasoline and jet fuel.

Although there is unbalanced ratio among the two engine typed vehicles in Mekelle city, their average carbon dioxide emission level indicates that, petrol cars emit 200.45grams of CO_2/km on average, whereas, the average emission level of diesel cars in this case is 398.4grams of CO_2/km. This great deviation is partly due to the entire, but

one, diesel cars are more than ten years old; of which more than half of them are above 16 years old and two of the diesel cars are 24 and 28 years old. If the same years of gasoline and diesel cars are compared, their discrepancy reduces. For instance, 2002 diesel cars emit 351.69grams of CO_2/km on average, while the average emission rate of all 2002 gasoline cars is 225.0089grams of CO_2/km. In this case, gasoline cars emit much lower level of carbon dioxide than diesel cars. Furthermore, the emission factor, which is higher for diesel cars, affects comparison of the emission level among the two engine types.

Generally, a sum of 725.603kg of carbon dioxide is emitted in Mekelle city daily from the selected 167 private automobiles. This means that, these private automobiles emit an average of 21,768.09kg of carbon dioxide monthly and 264,845.1kg of carbon dioxide annually.

Conclusions

Urban road transport is one of the basic requirements for economic development. Analogously, it is also one of the main drivers of global climate change via its emissions. Fuel efficiency of cars, which depend on vintage, engine type, and model of the car is the most determinant factor for the emission level of cars. The average fuel efficiency of the private automobiles in Mekelle city is 12.115km/liter. Most of the private automobiles in the city are Toyota Motors, of which corolla cars has the highest share. The average daily mileage of these automobiles is 20.74km. In their trip, they averagely emit 209.93grams of CO2/km. Atoz, Yaris and Terious emit lesser amount of carbon dioxide. In contrary, Land cruiser and WllB emit higher amount of carbon dioxide. Mercedes Benz and Suzuki Motors emit higher amount of carbon dioxide among the car manufacturers, whereas, Hyundai and Daihatsu Motors averagely emit lesser amount carbon dioxide. The average CO_2 emission level of these cars increases as their service age increase. In addition, diesel cars are found to be higher carbon dioxide emitters than petrol cars.

References

B and M Development Consultant PLC (2006). Technology Needs Assessment in Climate Change Mitigation in Energy Sector. Climate Change Enabling Activity Phase II: National Meteorological Agency, Addis Ababa, Ethiopia.

Belew Dagnew (2012). Introduction to Transportation System. Ethiopian Civil Service University, Department of Transport Management, Addis Ababa.

CRGE (2011). Ethiopia's Climate Resilient Green Economy Strategy. The path to sustainable development: Federal Democratic Republic of Ethiopia, Addis Ababa.

Ethiopian Road Transport Authority (2012). Total Number of Vehicles by Capacity in 2005 Fiscal Year. http://www.rta.gov.et/datacollection.htm. Retrieved on 25th November, 2013.

European commission (2013). Road transport. Reducing CO_2 emissions from vehicles: http://ec.europa.eu/clima/policies/transport/vehicles/index_en.htm. Retrieved on 2nd January, 2014.

Godden, B. (2004). Sample Size and Con fidence Interval Tutorial. http://shar epdf.net/find/bill-godden-january-2004. Retrieved on 19th December, 2013.

Hao, C., Andrew, B., and Michael, W. (2013). Updated Emission Factors of Air Pollutants from Vehicle Operations in GREET Using MOVES. Systems Assessment Section Energy Systems Division: Argonne National Laboratory.

Institute of Environmental Management and Analysis Corporate Member (2012). Carbon footprint calculator Ltd. Le icester, Midlands UK. Available at http://www.carbonfootprint.com/ab outus.html.

Intergovernmental Panel on Climate Change (2001). Fourth assessment report. Transport and its infrastructure. http://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-chapter5.pdf. Retrieved on 7th April, 2014.

Intergovernmental Panel on Climate Change (2007). Climate Change Impacts, Adaptation and Vulnerability. Working group II, contributing to the forth assessment report of the IPCC. http ://www.ipcc.ch/pdf/assessmentrepo rt/ar4/wg2/ar4_wg2_full_report.pdf . Retrieved on 9th December, 2013.

Mekelle City Transport Office (2014). Mekelle City Transport Profile. Existing Road Network of Mekelle City: Prepared and submitted by development partners.

Michel, C. and Eckward, H. (2013). Critical Evaluation of the European Diesel Car Boom. Global Comparison, Environmental Effects, and Various National Strategies: Environmental Sciences Europe, 25:15.

Sue, E. (2010). Ethiopian Environmental Review. Forum for Environment: Addis Ababa, Ethiopia.

Tsehaynesh Tefera (2014). Reducing vehi cle emissions in Ethiopia. www.une p.org/transport/pcfv/PDF/eac_lows ulphur/EAC_ReducingVehicleEmis sionsEthiopia.pdf. Retrieved on 19th November, 2013.

United Nations Framework Convention on Climate Change (2011). Carbon Dioxide Emissions of Road Transport. http://unfccc.int/. Retrieved on November 2th, 2013.

United States Environmental Protection Agency (2012). Comparison of Fuel Economy of Cars. Office of Transportation and Air Quality: available at http://www .fueleconomy.gov/feg/Find.do?actio n=sbs&id=23549&id=24321.

United States Environmental Protection Agency (2012). EPA and NHTSA Set Standards to Reduce Greenhouse Gases and Improve Fuel Economy for Model Years 2017-2025 Cars and Light Trucks: Regulatory Announcements. Office of Transportation and Air Quality, EPA.