American Journal of Environmental Science and Engineering
2017; 1(3): 74-84
http://www.sciencepublishinggroup.com/j/ajese
doi: 10.11648/j.ajese.20170103.13

SciencePG
Science Publishing Group

Estimating the Amount of Carbon Dioxide Emitted Along Traffic Corridors in Eldoret Town, Uasin Gishu County, Kenya

Geofrey Kibiwott Yator[1, *], Fatuma Daudi[1], James Okinyi Manyara[2]

[1]Department of Environmental Monitoring Planning and Management, University of Eldoret, Eldoret, Kenya
[2]Kenya Institute of Highway and Building Technology (KIHBIT), Kisii, Kenya

Email address:

bgeffa@gmail.com (G. K. Yator), fatuma2abdi@gmail.com (F. Daudi), jomsmanyara@gmail.com (J. O. Manyara)
[*]Corresponding author

To cite this article:

Geofrey Kibiwott Yator, Fatuma Daudi, James Okinyi Manyara. Estimating the Amount of Carbon Dioxide Emitted Along Traffic Corridors in Eldoret Town, Uasin Gishu County, Kenya. *American Journal of Environmental Science and Engineering*. Vol. 1, No. 3, 2017, pp. 74-84. doi: 10.11648/j.ajese.20170103.13

Received: March 6, 2017; **Accepted**: April 7, 2017; **Published**: June 2, 2017

Abstract: Climate change is a major challenge in the 21st Century, as calamities and unpredictable weather changes lie on the realm of climate change. Climate change is a product of both anthropogenic and natural causes that emit greenhouse gases to the atmosphere causing a shift in climatic temperatures. Cities and towns are the main emitters of greenhouse gases -contributing 70-80% of the total global greenhouse gases. The prime solution of Greenhouse gases lies in reducing emissions or increasing carbon sinks. This paper aims at estimating the amount of carbon dioxide emitted along major traffic corridors in Eldoret town. Estimated data were obtained for carbon emission in the major emitter which is Transport sector. Data was collected at four control points on road junctions and roundabouts to the east, west, south and central of the central business district, the data collected included vehicles idling time and operating speeds, Vehicle Kilometres Travelled formulae based on the Caltrans software CT-EMFAC, was used in modelling carbon dioxide emissions on roads. An estimated total of 4693.9 tons of carbon dioxide was emitted annually from the roads. It was further observed that vehicles travel at average speeds of 10kmh apart from Control point 1 where vehicles were moving at average speeds of 20-30km/h. Emissions from motor vehicles idling were the highest contribution (93%) of the total emissions while running engines at speeds >5kmh contributed only 7% of the total emissions. Control point 2 had the highest rates of emissions during peak and off-peak hours. Pearsons correlation between speeds and fuel consumption at peak (r=-0.758) and off-peak (r= -0.762) was carried out and an inverse relationship between fuel consumption and operating speeds was observed. The research therefore recommends that the county and environmental organs in the country should increase traffic efficiency to cut on idling emission which is 93% higher than any other emissions from motor vehicles, introduce environmental levy fee for mitigating the effects of global warming due to emissions and encourage vehicles that are fuel efficient with auxiliary power units to aid in idling periods.

Keywords: Climate Change, Carbon Sinks, Global Warming

1. Introduction

Climate change is one of the major challenges facing the world today. The issue of climate change arose from 1992 UNFCCC when countries joined an international treaty, the United Nations Framework Convention on Climate Change, to cooperatively consider what they could do to limit average global temperature increases and the resulting climate change [1]. The Kyoto Protocol in 1997 was adopted and its main agenda is to legally bind developed countries to reduce carbon emissions in order to attain sustainable development, Kyoto Protocol 2008 Article 2 (1) [2]. According to [3] global climate change is a major societal issue that many citizens do not understand, do not take seriously, or do not consider being of major public-policy concern.

Cities and towns' activities-transport and industrial- are majorly considered to be the main emitters of GHGs. It is estimated that cities are responsible for 75–80 per cent of global greenhouse gas emissions today [4]. Kenya emits 10,392 Mt per year translating to 0.03% of total world's emission [5] furthermore it is estimated that emissions of GHGs could double between 2005 and 2030 [6].

Urban sprawl is one of the major challenges hindering development of sustainable cities. Kenya currently has 43% of her population living in urban centres and it is expected that by 2030 more than 65% of her population will be urbanized. Eldoret town is one of the urban centres in Kenya. Waste generation in the town is increasing has population grows and development sets in. The municipal council of Eldoret collects a total of two hundred and fifty tons per day with over 90% of it being organic.

Carbon sink according to UNEP is a stock that is taking-up carbon [7]. Global carbon is held in a variety of different stocks. Natural stocks of carbon include oceans, fossil fuel deposits, the terrestrial system and the atmosphere. In the terrestrial system carbon is sequestered in rocks and sediments, in swamps, wetlands and forests, and in the soils of forests, grasslands and agriculture [8]. The carbon dioxide are emitted from sources that include burning of fossil fuels, cement production, forest/wild fires, change in land use and to some %age volcanic eruptions.

The distinct features of a green city include; improve the quality of the air, lower the use of non-renewable resources, encourage the building of green homes, offices, and other structures, reserve more green space, support environmentally-friendly methods of transportation, and offer efficient recycling programs.

Motor vehicles emit carbon dioxide and water when on idle, running and during cold starts. The carbon dioxide -not considered a pollutant- is a major cause of global warming and it is produced by either burning a fossil fuel, biodiesel or LPG.

Therefore, carbon foot print data is important in developing an inventory for emissions and how much of it to necessitate in planning to cut on emissions by efficient planning through efficient traffic routing, reducing friction, increasing green cover to sink more carbon dioxide and for calculation of carbon tax and credit.

2. Materials and Methods

2.1. Materials

Reconnaissance field studies were done using aerial maps and ground truthing between July and August 2013. The field visits materials included Cameras, eTrek Garmin GPS which was used to map the road networks and trek paths, tape measures, IBM SPSS, Microsoft excel software and ArcGIS 10.2.1 equipment the materials required for the field study and data analysis.

2.2. Sources of Data

To estimate the amount of carbon dioxide emitted along traffic corridors-data was obtained from the transport sector. The data considered information of number of vehicles at peak seasons, major *matatu* bus parks, off peak seasons, parking lots during peak and off-peak and number of idling vehicles at *matatu* stages and traffic jams.

2.3. Data Collection Methods

The data needed to address the objective above will collected from the transport sector along the major and feeder transport corridors. The roads were studied exclusively on road junctions and roundabouts. Manual charts was used was used to collect the data.

Transport sector

The study locations on the roads were chosen purposively on junctions, roundabouts, car parks and *matatu* stages. The roads were studied basing on the fact that most vehicles use much fuel while on city than on highways or express ways-City roads are the roads within the municipality that limits speed to less than 50km/hr. According to [9] count periods may range from 5 minutes to 1 year he further explains that typical count periods are 15 minutes or 2 hours for peak periods, 4 hours for morning and afternoon peaks, 6 hours for morning, midday, and afternoon peaks, and 12 hours for daytime periods. The study was undertaken on a 15 Minutes interval being the preferred interval for 5 Days on the specified five locations.

Five Locations were scheduled for study each roundabout being given 15 Minutes interval for study. The 1st Location was on A104, B54 and Nandi road Junction 3Km to the East of Eldoret Town from the 2nd control point on A104 (Uganda Rd)-C50 (Sergoit Rd) intersection adjacent to the Kenya National Library (KNLS) and joining Oginga Odinga street to the south. The 3rd CP was location at the Nandi Park Roundabout the road is an intersection of Nandi road studied in 1st location and Oginga Odinga street to its North, the road lead in and out of town to Langas, Pioneer, Elgon view estates and Kapsabet, Kisumu towns. The 4th point was located at A104 intersection and Mitaa Road (Pauls Bakery Junction) this point was necessary for collecting data from Vehicles entering from Eldoret West, the station is located 2Km from the 2nd location CP.

Secondary information on vehicle standard emission rates were obtained from Motor vehicles manufacturing companies, US EPA websites and the Commonwealth Department of transport and regional services Australia.

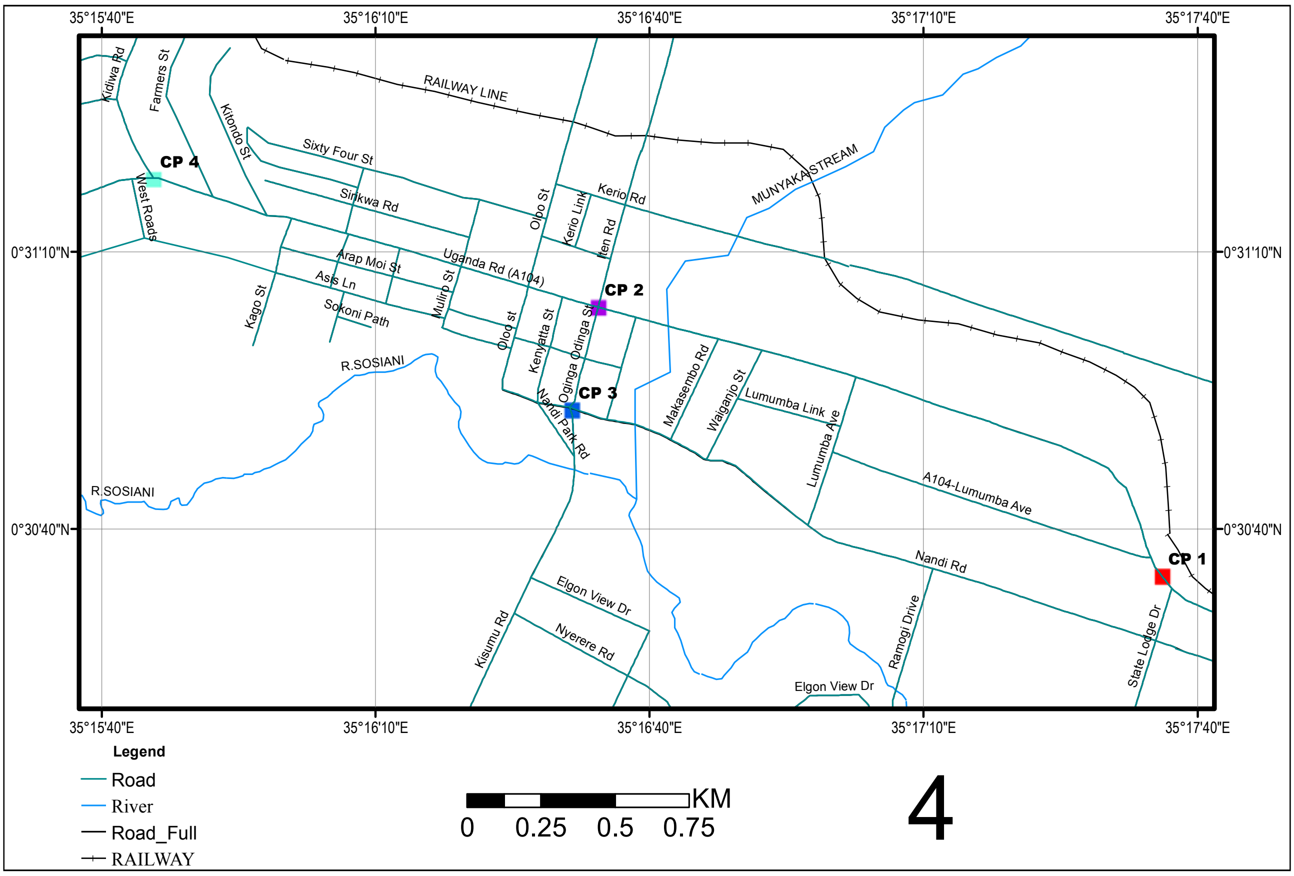

Figure 1. *Map of Study area (Eldoret Town).*

2.4. Data Analysis

Data Analysis for Carbon emissions

To determine CO_2 emissions from motor vehicles the following methodology derived from GHG protocol-which is an initiative of non-governmental organizations, governments and world business council-was used; Vehicle Kilometres Travelled (VKT), this formulae follows amount of fuel of vehicle consumes per km and the type of vehicle used [10]. The VKT adopted was based on CT-EMFAC a tool developed by California Department of Transportation (CALTRANS). The tool was calibrated to suit the Kenyan traffic fleet composition and the batch mode entry option was used as opposed to the automatic emission factor calculator, batch mode was chosen as opposed to manual mode due to its ability to customize data entry to a Kenyan driving cycle pattern.

The formulae is for determining general emissions (E) based on VKT is:

$$E = E_{running} + E_{idling} \quad [1]$$

Where:

E =is the total emission

$E_{running}$ = is the emission produced when the engine is hot

E_{idling}= is the emission from engines while on a stop

Motor vehicles data was divided into the following types, Table 1:

Table 1. *Vehicles category.*

Category	Type	Sub-type
Non Truck	Saloon and medium size cars	Hybrid Non-Hybrid
	SUV and pick up	
Truck 1	Passenger vehicles	14 seater 7 seater
Trucks	Buses Lorries Freight vehicles	

*Inventory was also done on the idling time and vehicles recharge on matatu bus stations.

The fuel used by vehicles was calculated by obtaining general data from KEBS and KRA on vehicles cleared from 2001-2013-It is from the year 2001 that KEBS begun to digitize and post vehicles data online while KRA begun in 2005- and a general age calculation done to ascertain the number of diesel, petrol and hybrid cars within Eldoret town [11].

The distance for determining $E_{running}$ was 2.2 km East of Uganda road from CP 1 to CP 2 and 1.5 Km to its west at CP4, 1.1km on North of class C51-Iten-Kisumu road to CP 2 352Metres from CP2 to CP 3 and an extension of 0.5km to the South of C51. E_{idling} was determined from the duration spend on traffic jam and the number of vehicles in idle mode on bus parks.

2.5. Emission Calculations

Vehicle Kilometres travelled approach was adopted for the calculation of CO_2 emissions from vehicles, the approach is suitable because it was developed to harmonize emission model for road transport to provide consistent emission estimates at the national, international and regional level. The emissions of Eldoret town are determined for two driving cycles, the driving cycles were determined during the peak and off peak hours and it was noted that during the peak hours there is less traffic snarl up on major highways and in matatu stages there is a low recharge rate apart from Sosiani and Main bus park which exhibits a constant recharge rate of *matatus*, at this time of the day from 10am-4pm the city driving cycle is not experienced.

Figure 2. *Traffic snarl up along Oloo Street on Peak hour (15: 37).*

Figure 3. *Kenyatta Street on Sunday (18: 32).*

3. Results

3.1. Factors Determining Running Emissions

3.1.1. Driving Patterns

Driving patterns was considered for passenger vehicles and this was achieved by obtaining data for motor vehicle recharge on major bus stations that included; main bus park, Chepkoilel, Sosiani, Iten, Maili nne and Western stage. The recharge data was obtained both for peak and off peak hours for at least 1 hour on 15Min intervals.

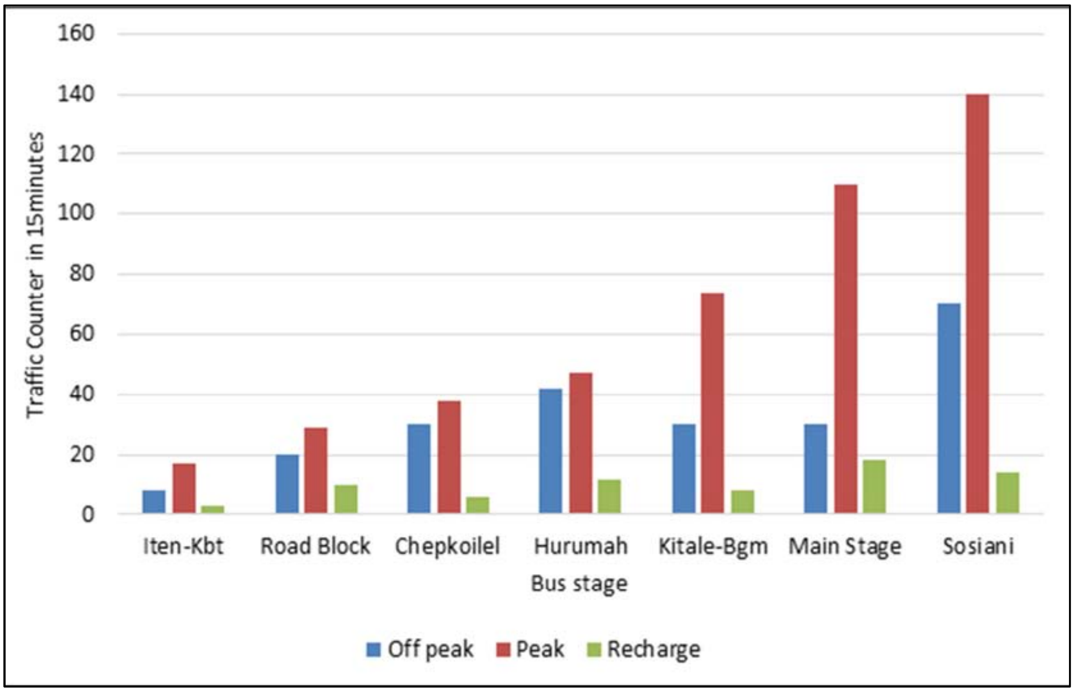

Figure 4. *Recharge, Peak and off-peak graph.*

Sosiani Bus stage during peak Seasons represents the highest number of motor vehicles and it also has the highest recharge rate. The stage serves residential area of Kapsoya, Langas and Annex making it the highest stage serving three main roads (Kisumu, Kaptagat and Uganda Rd. Iten-Kabarnet stage is the smallest stage with a recharge rate of 3 motor vehicles for every 15 minutes.

3.1.2. Load Capacity

Load capacity of vehicles is a key determinant of fuel consumption. Trucks consume much fuel when ferrying loads than when empty, this is also true for passenger, SUV and all other automobiles in the streets.

The road traversing through Eldoret town are major highways that include the Uganda Road which serves has a gateway to Uganda, Rwanda, South Sudan and Democratic Republic of Congo. The road is used by trucks ferrying goods to the above countries and also to western parts of Kenya from Eastern and Coastal Kenya, Sergoit Road-Oginga Odinga Street- which becomes Kisumu road after River Sosiani is also a major Highway –Class C50 road-traversing through the town and it is used by truck ferrying petroleum products to parts of Kapsabet and Nandi Hills, these roads also attract high number of traffic since they are the major roads that lead in and out of the town.

An average of 947 vehicles uses Uganda Road in 1 hours' time that includes vehicles to and from the town. Freight and Lorries composed a total of 212 vehicles -88 on off peak and 124 on peak hours.

3.1.3. Terrain

Eldoret town is found on the Uasin gishu plateau and the relief is undulating with a complete rolling plane covering the town from north to south and west to east. Approaching the town from the east is a descending road and leading off the town to the west is descending and ascending 2.5km on Mwanzo stream. From the North to south is a descending road and from the town to Langas is ascending road profile (Figure 5) indicates the road profile of Eldoret town in (m).

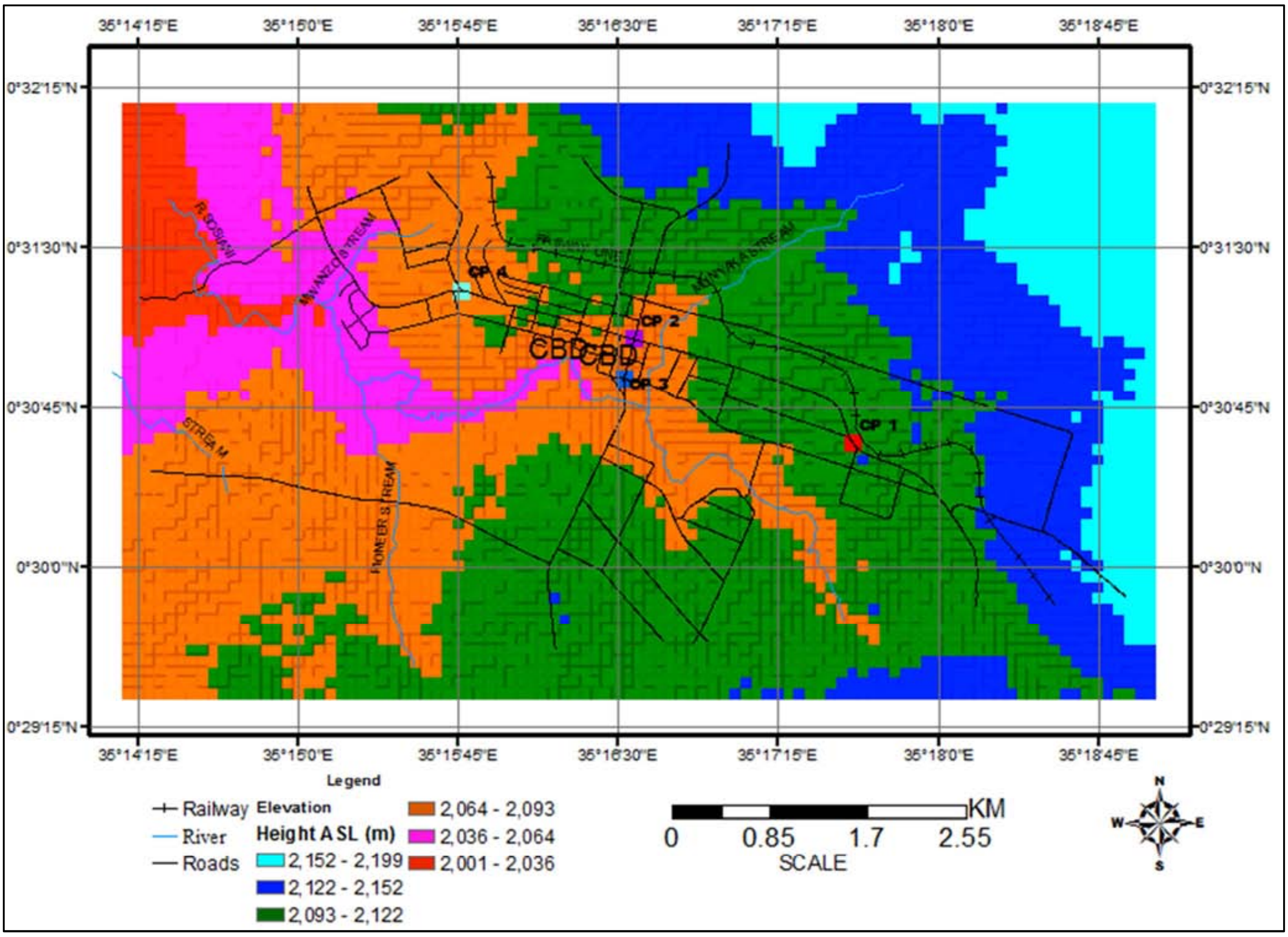

Figure 5. *Elevation of Eldoret town in respect to Road Network.*

This terrain affects vehicles fuel consumption rates since most of the traffic on these roads requires much power to counter natural forces of gravity when going uphill and for trucks and heavy vehicles they also need more torgue when going downstream to encounter gravity and avoid freewheeling.

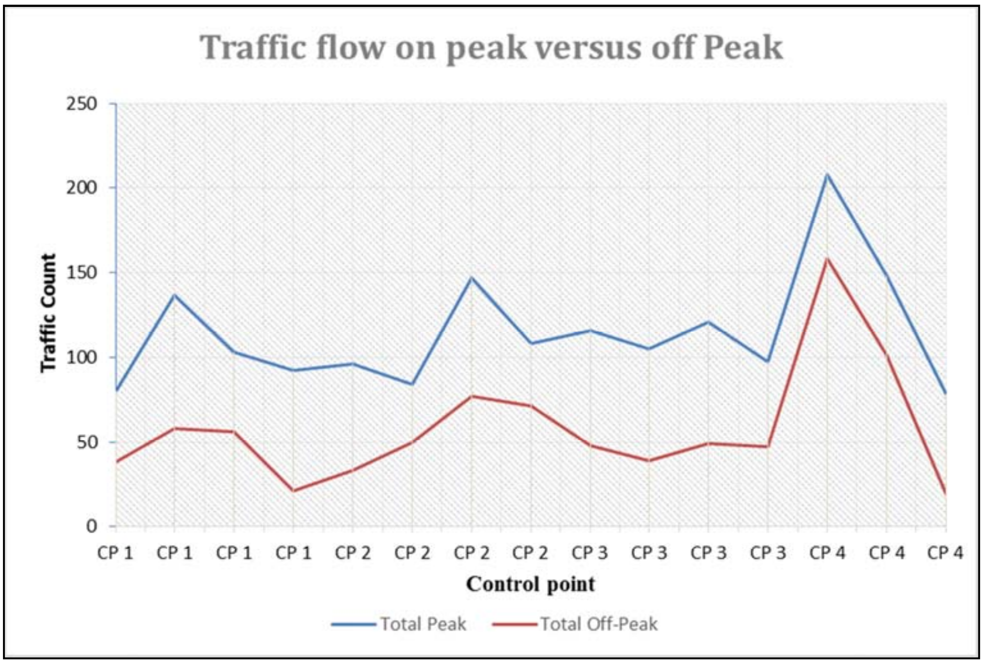

Figure 6. *Traffic flow on peak versus off peak times.*

3.1.4. Vehicular Composition

CT-EMFAC software requires that vehicle composition per link (Control point) be identified in three categories that is Truck (Light heavy duty trucks including passenger vehicles), Truck 2 (Medium heavy duty trucks) and Non-Truck which include small cars. The mix for off peak count depicts that there is a higher percentage of Truck 1 vehicles in peak times and a same percentage of 38% in off peak season with non-truck vehicles. The 46% of truck 1 vehicles in peak hours is because of the high rate of *matatus* and this is also depicted by the *matatus* recharge rate in respective bus stops. Pearson's correlation was calculated for recharge rate and truck 1 category at off peak and peak and there was a significant positive relationship of r=0.826 and r=0.893 respectively.

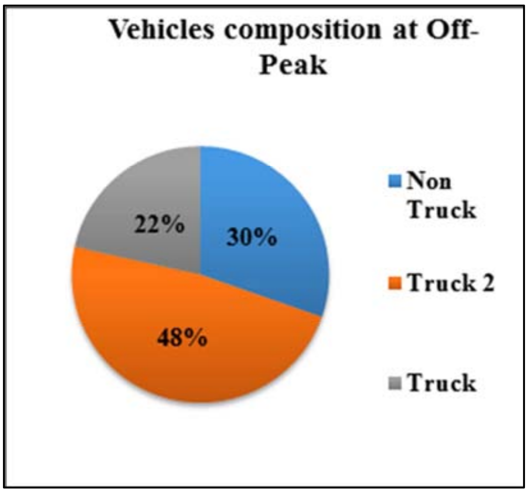

Figure 6. *Vehicular mix at off-peak.*

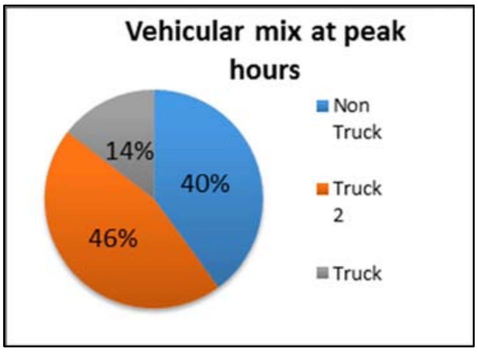

Figure 7. *Vehicular mix at peak hours.*

3.2. Eldoret Carbon Dioxide Emissions

Emissions from traffic along the corridors in Eldoret town per day stands at 12.86 tons. Idling emissions account for 93% of the total emissions in Eldoret town at 11.92 tons per day. Running emissions account only for 7% of the emissions on the roads.

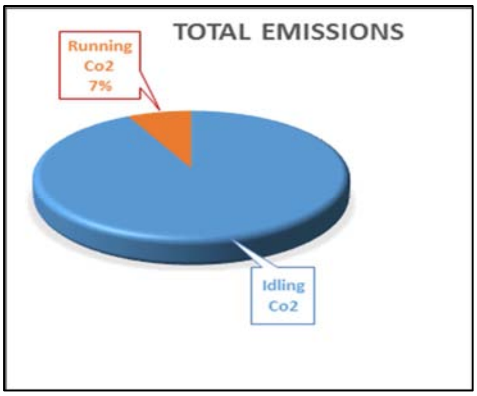

Figure 8. *Total emissions per day.*

Emissions were higher at idling at all selected control points except at CP 1 where idling contributed for 42% of the total emissions, this could be due to the less traffic congestion and the 42% was contributed by vehicles entering or driving out of the main highway. CP 2 recorded the highest idling rate at 4.58 tons per day.

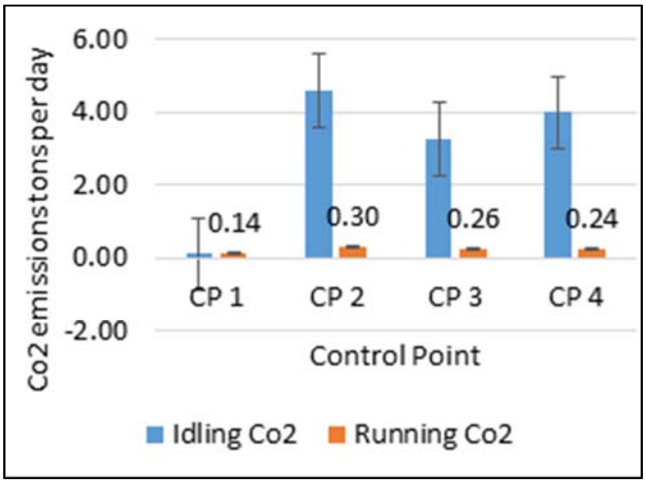

Figure 9. *Idling versus running engine emissions on CPs.*

3.3. Running Emissions

Running emissions are emissions emanation when the engines are operating at its full conditions. These are emissions from highways and other linking roads. The vehicles should be travelling at speeds greater than 5km/hr. $E_{running}$ was conducted on the control points selected on the three major roads leading in and out of town.

$E_{running}$ was calculated by obtaining the number of vehicles in each category on off peak hours that pass by the control points and vehicles at CP1 were considered for both peak and off-peak because they were operating at speeds above 10km/hr.

3.3.1. Emission Rates and Operating Speeds

According to [12] operating speeds affect fuel consumption and it was observed that a 2007 Toyota Camry vehicle returned 7 L/100 km at 88 km/h, but that reduces to almost 8.1 L/100km when the speed moves up to 104 km/h and drops to almost 9.4 L/100km when speeds reach 120 km/hr.

This was true for all other vehicles regardless of its average fuel economy. Speed is inversely proportional to fuel consumption which translates that emissions are also inversely proportional to speed, a pearsons correlation of carbon dioxide and speed was done and there was a strong negative correlation of r= -0.762 and r= -0.758 at off peak and peak times respectively. Most of the vehicles on the roads are travelling at speeds below 20km/h apart from CP1 where vehicles were cruising at speeds greater than 50km/h, this is because of less traffic friction and provision that the road is an highway, the lowest speeds were recorded on Uganda Road and Oginga Odinga street were average speeds were almost stall between 2km/hr-10km/hr. At CP4, CP3, CP2 the vehicles operate at speeds below 10km/hr which translates to high rate of fuel consumption and increased idling instances.

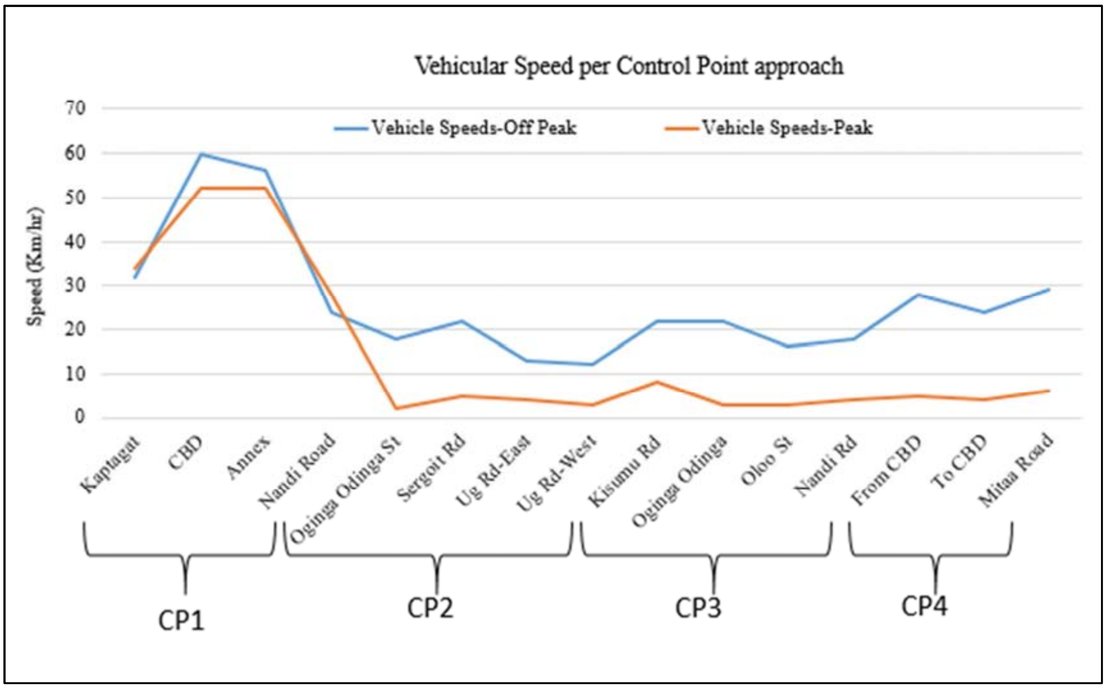

Figure 10. *Vehicular speeds at Peak and off peak.*

3.3.2. Emissions at Control Points

It was observed that emissions at control were higher on roundabouts and on zones where speeds were less than 20km/h or 11m/h. The emission trend was inversely proportional with speed and at speeds greater than 35m/h 500g/mile of carbon dioxide was emitted 75% less than emissions at speeds <5m/h at both peak and off-peak factors. Off peak emissions were higher at all operating speeds, the emissions were greater than 500g/mile at all times regardless of speeds, this could be attributed to the higher number of traffic at this times of the day. The emissions at speeds ≥70m/h increase to 600g/mile and this is so because the group is final in the category and it comprises all vehicles at speeds ranging from 70 to 200m/h and any high achievable possible speed beyond 70m/h.

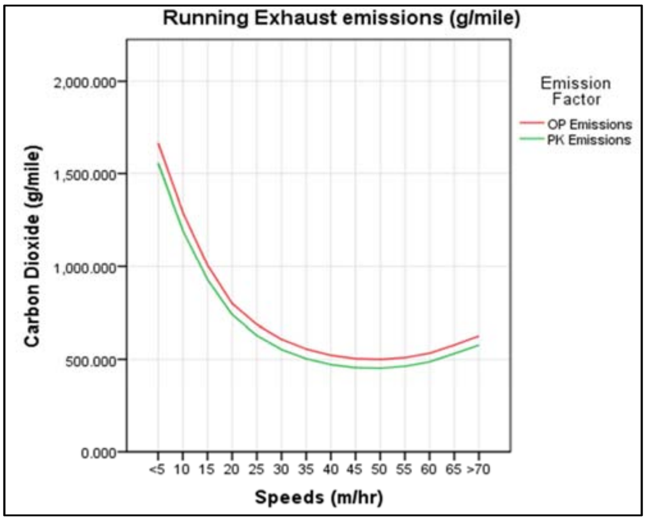

Figure 11. *Running exhausts emission versus speed.*

The highest emission were at Uganda road and this was experienced at CP 2 which contributed 38% (4.88 tons) of the total emissions per day and Uganda road stretch at CP 1 was the lowest emitter only contributing 2% of the total emissions. The emissions at CP1 could be explained due to low traffic volumes and the driving patterns. Though the road experienced high number of trucks at 18% and 26% in peak and off peak hours respectively than CP 4 on the

Figure 12. *Weekend off peak traffic flow 10M to CP1.*

same highway the low CO_2 volumes are credited to operating speeds where 53% of the total vehicles were traveling at speeds ≥30m/h or 52km/h compared to CP 2 90.3% ≤5km/h and CP 4 97.8% ≤5km/h.

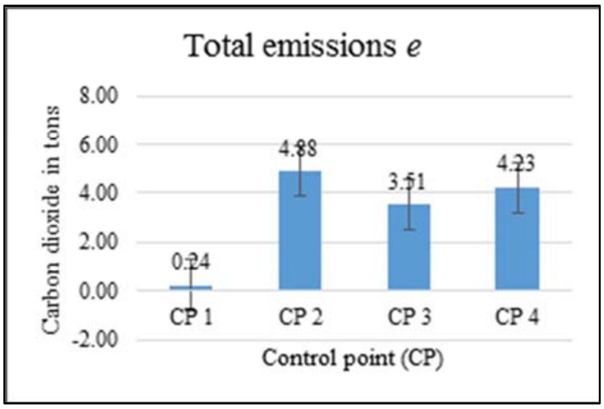

Figure 13. *CO_2 Emission per day on control points.*

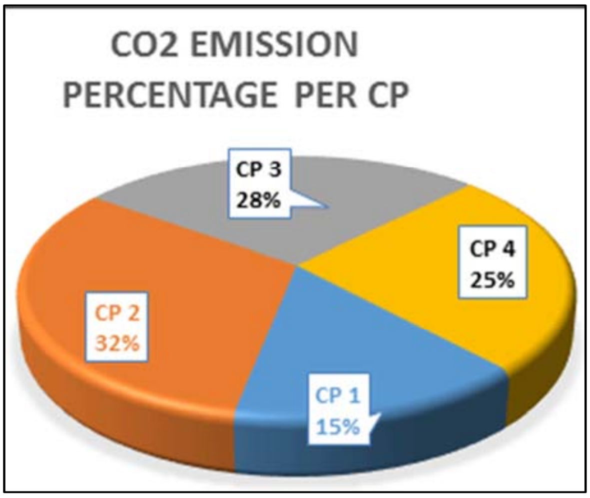

Figure 14. *Control point emissions by percentage.*

i. Emissions at Control Point 1

Control point 1 at Uganda Road, Kaptagat and Nandi Road-East intersection the trucks count at peak and off peak accounted for 18% and 26% of the total fleet composition, at peak hours truck 2 category were represented by 52% and 42% at off peak while Non Trucks category were 32% both at off peak and peak hours. Fifty three percent of the total fleet count was travelling at speeds ≥52km/h combined –for both peak and off peak hours.

The running exhaust emissions from vehicles passing control point 1 at average speeds of 19-60km/h were the lowest among all the control points. The total emissions were 1.409E-01(tons/day). The emissions were contributed mostly by Vehicles entering in and out of Nandi and Kaptagat road which had to slow down to make the turns causing increase in emissions.

The emissions for CP1 covered stretch road of 4.9Km that combines 2.1km from CP1 to CP 2, 1.8km of Nandi road and 1Km of Kaptagat road. The total carbon dioxide emitted daily from traffic using this road was 56kg at peak and slightly higher at off peak 60kg this could be attributed to high number of trucks using the road during peak hours as opposed to peak hours when there are more non- trucks and truck 2 vehicles.

ii. Emissions at Control Point 2

Control point 2 (CP2) is located on Longitude 35.276264 E and latitude 0.517761 N, it is a major intersection point of two major highways that's Class C and Class A 104 road. The CP is characterized by high traffic rates both at peak and off peak hours. Seventeen percent trucks on average are traversing through the CP on peak hours while at off peak the traffic mix is composed of 25%.

The operating speeds of the CP is characterized by 90.3% of the fleet composition moving at speeds ≤5 km/h the remaining 9.7% is composed of vehicles moving at 5-35km/h and this is particularly on off peak hours on weekends and holidays.

The total emissions at CP 2 amounted to 38% of the total emissions in the entire town. Thirty one percent of the emissions from running exhaust within the town were contributed by this CP and it amounted to 2.977E-01 tons per day.

iii. Emissions at Control Point 3

Control point 3 (CP 3) was located on Nandi Park round about. The CP was chosen to count on traffic from Oginga odinga, South Oloo Streets, Nandi and Kisumu roads. It is spatially located on longitude 35.275413 E and Latitude 0.514710 N.

The CP was ranked 3rd in total emission-both idling and running-it contributed to 27% of the total emissions in the town with 3.510 tons per day. The CP in exhaust running emissions was ranked 2nd emitting 2.598 tons of carbon dioxide per day. The total operating speeds at Nandi Park at peak hours was characterized by 99% of the vehicles moving at speeds below 5km/h at off peak the operating speeds range from 10km/h-40km/h.

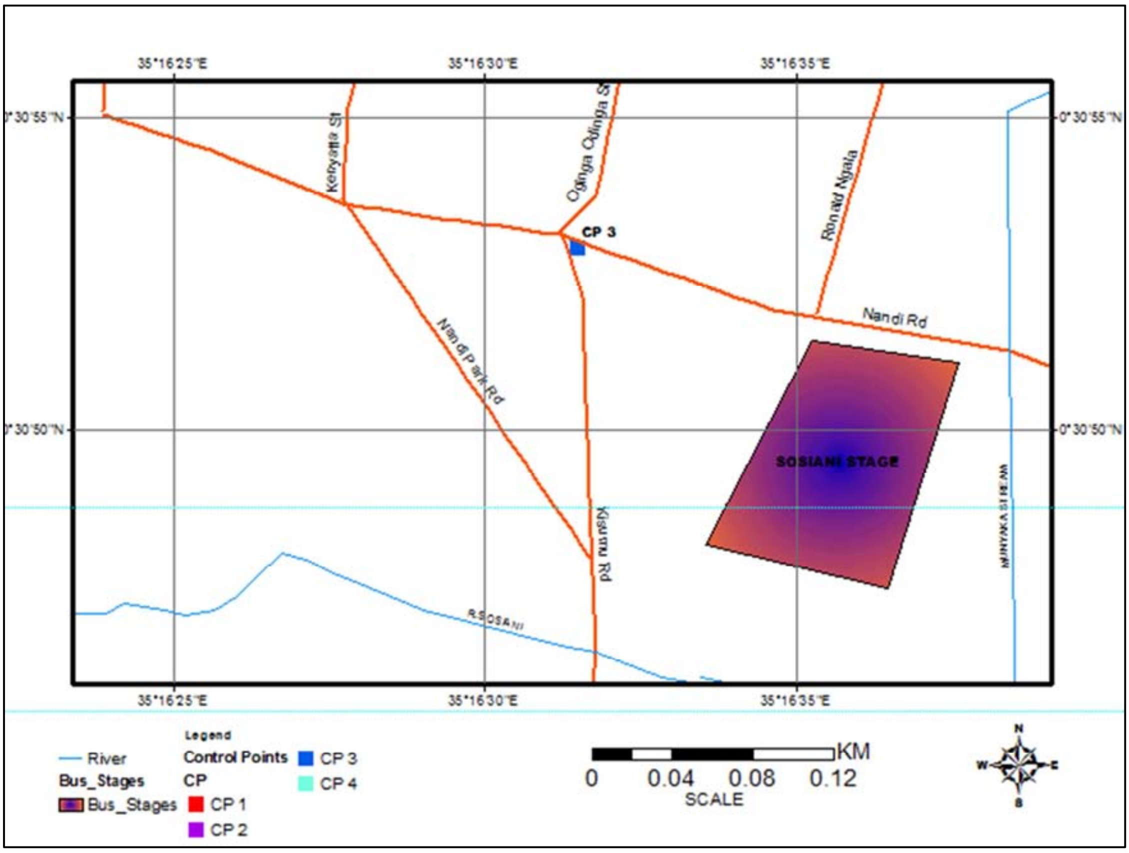

Figure 15. *Control point 3 Location.*

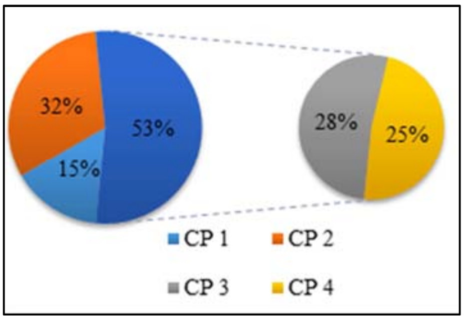

Figure 16. *Emissions percentage at CP per day.*

iv. Emissions at Control Point 4

Control Point 4 (CP4) was located to the west of the town, this CP was the 3rd point along the busy Uganda Road, and it was at this CP that the highest number of traffic was recorded representing 27% of the total fleet count. The total E running emission on this road accounted for 25% (See figure 16 above) (0.239 tons/day) of the total emissions, despite its high traffic flow this low running emissions at the CP could be explained by the constant movement of vehicles at steady speeds ranging from 5kmh-30kmh with the mean speed at 20kmh for both peak and off peak.

3.4. Idling on Roads

It was found that the idling time in peak hours was higher than any other time per car and it occurred on almost all roads. The idle time per vehicle on Uganda road was the highest, on Uganda road it was observed that on peak hours for a 542m distance approaching from Sergoit road towards KNLS junction (CP2) takes an average of 18min based on four test instances, from Nandi road round about at CP3 on off-peak hours takes an average of 22minutes for a 352m distance. The approach to CP2 from east and west of Uganda Road takes an average of 18min from Waiganjo Street Junction and from Muliro Street junction takes and average of 24minutes respectively. From CP4 to CP2 a distance of 1.5km it takes an average of 47minutes and in some instances-rainy seasons and Fridays-more than 1hour to traverse through the town the average speeds are almost stall speeds at 1.9km/hr.

In South Oloo street and Nandi Road idling time on average can take up to 30min per vehicle, this idling time is for all vehicles approaching from Kisumu road towards CP3 from Oloo street and Nandi road, there is less traffic approaching from Nandi Street on off-peak hours this is due to change in bus stage by *matatus* plying Kisumu road, the *matatus* shift from the Sosiani bus park to South Oloo street and uses Nandi park Road through and out of town. Figure 12 left shows Southern Oloo street approaching Kenyatta street roundabout on a heavy traffic at peak hour.

3.4.1. Bus Parks Idling

Idling was also established from bus parks, it was observed that the highest number of idling engines was in Sosiani Bus Park, this might be due to the nature of the bus park. Sosiani Bus park servers the entire South and East of Eldoret town making it the second biggest bus park and with short range distances and the second highest recharge rate of 14 vehicles per 15 minutes after the main bus park, the Main bus park peak count is majorly contributed by the shift of vehicles plying roadblock Maili nne route from their main stage at Moi street to the main Bus park this actually contributes to a higher recharge rate in peak hours. It should be noted that the town service routes at off peak hours have the lowest number of vehicles on idling but a high rate of recharge. Iten Kabarnet stage had the lowest recharge rate at 3 vehicles per 15minutes.

Table 2. *Average Idling vehicles per Bus Park.*

Bus Stage Name	Average Off-Peak count	Average Peak count	Average Recharge rate	Average Idling Vehicles
Iten-Kabarnet	17	8	3	3
Road Block, Maili nne	29	0	10	4
Chepkoilel, Marura	38	30	6	12
Hurumah	47	42	12	3
Kitale-Bungoma-Kakamega	74	30	8	14
Main Stage	110	52	18	26
Sosiani Bus park	140	70	14	31
Total Public Vehicles count	455	232	71	93

A total of 93 vehicles are on idle mode on all bus parks on a given 15 minutes time interval. Sosiani Bus park is the leading with 31 vehicles on idle mode at any given time this could be explained by its plying routes which contributes to high passenger recharge rate too and this is depicted by its recharge rate- at 14 vehicles per every 15 minutes-, though it is second in recharge rate the main bus park has got the highest number of recharge rate but less idling vehicles and this could be due to its long distance travel routes which is related to passenger recharge rate, a correlation of recharge rate versus idling time depicts a strong relations of r=0.965. Hurumah and Iten-Kabarnet routes have the lowest number of idling vehicles see Table 2 above.

Figure 17. *View of Main Bus Park at off peak Hour (1100hrs) on a weekday.*

Figure 18. *Chepkoilel Bus Park at Evening peak Hour (1700hrs).*

3.4.2. Emissions from Idling

Emission rates are higher during stop-and-go, congested traffic conditions than at free flow conditions operating at an average speed. According to L. Gaines a vehicles emits 2.4mg of CO for a 30seconds idling compared to a hot restart which emits 1.25 mg this was found out after conducting a study on 2.5L 4cylinder engine with 175hp.

3.4.3. Idling Emissions on Roads

It was observed that CP 2 had the highest rate of emissions and this occurred on peak hours where vehicles could idle for over 18-30 minutes on regular peak day and 48 minutes- 1 hr on an extreme peak season/day. Control point 1 recorded the lowest emissions 0.10 tons per day compared to CP 2 which records 4.58 tons per day.

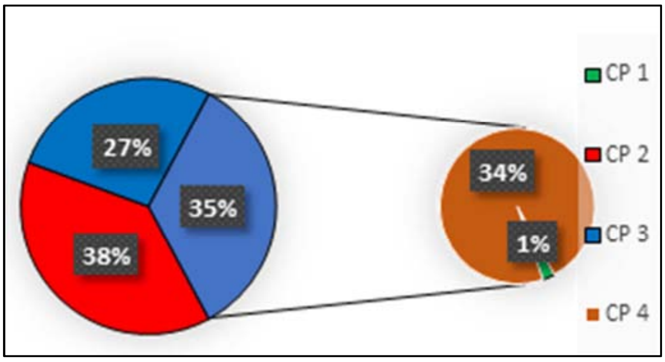

Figure 19. *Idling Co2 emissions per CP.*

4. Conclusions

The production of carbon dioxide is linked to motor vehicles and in Eldoret vehicles emit 4693 tons of carbon dioxide annually and the major source is through idling which contributes 4350 tons per annum, running emissions contribute to 342 tons per annum. Due to the growing town size and expanding economic base more cars –vehicles ownership increased by 100% from 2001-2009-more build up less trees, low sinking potential more carbon dioxide in the atmosphere.

Recommendations

The research proposes a system where the polluter bears his own responsibility and vehicle owners are to pay for carbon emission tax for any new vehicle being imported to the country depending on the carbon dioxide emitted per kilometer, an Environmental conservation fuel levy fee should also be charged for every litre of fuel that goes into the tank, the more fuel a car consumes the more mitigation fee you pay. The rate of how much to be charged per litre that goes into a tank should be calculated by how much damage a gram of carbon dioxide causes to the environment.

Encourage the driving of Motor vehicles that are powered by electricity or hybrid class, hybrid vehicles will reduce emissions by almost 50% to the current rate. An hybrid vehicle does 3.8 L/100 km compared to a conventional car that does 7.0L/100km, the hybrid vehicles fitted with stat-stop system and auxiliary power unit (APU) switches the engine off automatically during idling causing less E idling and the APU provides alternative power for running auxiliary services like air conditioners.

Hybrid Electric vehicles (HEVs) are also energy efficient due to its regenerative braking system where breaking energy is turned in electric energy and stored in a batteries. The existing hybrid vehicles include Toyota Rav 4EV (electric), 2012 Ford Focus, Nissan Leaf, Chevrolet Volt, Honda accord (hybrid), Ford fusion (start-stop) and Porsche plug-in Panamera S E-Hybrid are among the vehicles that do less than 4L/100km.

Emissions from idling contribute 93% of the total emissions in the town therefore efficiency in the town should be enhance to reduce idling and traffic jams. Since most of our vehicles on the roads are not fitted with start-stop systems they are left on idling mode for more than 20-40 minutes cumulatively- an engine restart uses fuel approximately equal to 10 seconds of idling-. Traffic management should be enhanced within the town to limit this idling and cut on emissions.

From the emissions in running data it was observed that the highest emitters were small size and medium size motor vehicles which include *matatus* while buses and freight vehicles e=running on diesel emitted less, public transport should therefore be encouraged in order to cut emissions from small and medium size motor vehicles.

References

[1] UNFCC, 2014. Background on the UNFCCC: The international response to climate change.

[2] Kyoto Protocol to the United Nations Framework Convention on Climate Change: United Nations, 1998.

[3] DiMento, J. F., & Doughman, P. (2007). Climate Change. What It Means for Us. Our Children, and Our Grandchildren. Cambridge: MIT Press.

[4] Satterthwaite. D 2008. Cities' contribution to global warming: notes on the allocation of greenhouse gas emissions. Environment and Urbanization 2008 20: 539.

[5] The World Bank. 2014, Carbon Dioxide Information Analysis Center, Environmental Sciences Division, Oak Ridge National Laboratory, Tennessee, United States. World Development Indicators.

[6] COP15. Economics of Climate Change Kenya: Proceedings of Stockholm Environment Institute Project Report, 1 December 2009.

[7] United Nations Human Settlements Programme (UN-HABITAT). State of the World's Cities Report 2012/2013: Prosperity of Cities Urban Infrastructure: Bedrock of Prosperity.

[8] Warran, A., & Patwardhan, A. (2008). Carbon sequestration potential of trees in and around pune city. Case study Department of Environmental Sciences, University of Pune.

[9] Robertson, H. D, D. C. Nelson. 1994. Volume Studies. In Manual of Transportation Engineering Studies, ed: Prentice Hall, Inc., pp. 6–31.

[10] Jennings, M., Gallachóir, B. P. Ó., & Schipper, L. (2013). Irish passenger transport: Data refinements, international comparisons, and decomposition analysis. Energy policy, 56, 151-164.

[11] Kenya registered vehicles, 2001-2009. Kenya Revenue Authority Database.

[12] Network, I. C. (2007). Assessment of GHG Emission Reduction Alternatives in the Canadian Context.