

An Energy Approach to Evaluation of Carbon Dioxide Emissions from Kenya's Road Freight Transport

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Abstract

Information on carbon emission from the different sectors in Kenya is scant. This research was conducted in Kenya in December 20211 with the objective of establishing the fuel efficiency and the associated Carbon dioxide(CO_2) emission from the road freight transport between the port of Mombasa to the capital city of Nairobi along the northern corridor. This was achieved through a week long survey for outbound fright trucks. The fuel efficiency and the CO_2 emitted were then derived using both the activity approach and the energy approach.

The mean fuel efficiency on actual load found was 0.01327 Litres of diesel/ Ton-Km. The two approaches to the calculation of carbon dioxide emission gave different values with the activity based approach giving 595204.4 Tonnes while the energy based approach gave 315635.157 Tonnes of CO_2 per a num. This level of emission from a road section is high and calls for urgent mitigation measures.

Keywords: CO2 emission; fuel efficiency; Road freight transport; Ton-Kilometre.

1. Introduction

The scientific history about man-made climate change and the measures that are needed to counteract such changes is long. In 1896, Arrhenius published his finding on the relation between the atmospheric carbon dioxide (CO_2) concentration and the global mean temperature (Arrhenius 1896). A century later (1988) Intergovernmental Panel on Climate Change (IPCC) was founded resulting in published series of assessment reports that summarize the state of knowledge on the issue. IPCC demands compliance with the emission reduction agreements in the Kyoto protocol where all sectors should contribute to reducing CO_2 emission (IPCC, 2007). Recent global warming is believed to be the result of an "enhanced greenhouse effect". This is the human induced part of global warming.

To meet the carbon reduction targets that most governments have set for the period 2020 and beyond, individual countries are forced to implement decarbonisation strategies. In the development of Carbon reduction strategy, it is necessary to analyze the main sources of CO_2 emissions and identify those activities upon which carbon mitigation measures should be targeted. Higher percentage of CO_2 emission is produced from fossil fuel combustion for different purposes. The transport sector contributes 23% of the total CO_2 emissions in the world according to the latest estimates of the International Energy Agency (Schipper L. et al, 2009). Without any emission reduction from transport, the sector will account for the entire amount of allowable GHG by the year 2050 (Roel te L., 2009). Smart traffic management can cut Carbon emission by about 20% (Barth M. et al, 2008).

Kenya is a major transit country for the landlocked countries served by the northern corridor. Her railway system is nearly collapsed as well as those of the countries in the region plied by the northern corridor. This has left the road freight trucks as the dominant means of cargo transportation. The fuel consumption in the sector is obviously high and the associated carbon emitted. How much could the figures be? This is the question we need to answer. In the absence of carbon intensity data for freight transport operations in a particular country, researchers have often relied on intensity values calculated for other countries or international averages. This should not be adopted as there is a wide international difference in the nature and efficiency of freight transport operations depending on the condition of transport infrastructure. Presently, in Kenya, information on carbon emissions is scant as evidenced in its delayed communication to United Nations Framework convention on Climate Change (UNFCCC) to provide its greenhouse gas (GHG) data since 2002. Fuel sales give aggregate measure which cannot be used as unspecified amounts of these fuels cross the boarders. This research is intended to develop reliable data on freight truck numbers, fuel consumption per ton-Km of road cargo freighting and the corresponding CO_2 emission between Mombasa and Nairobi along the northern corridor

(Note 1 The Northern Corridor is the main high way starting from the port city of Mombasa in Kenya connecting it to the other land locked neighbouring countries in the East and Central African region)

1.1 Justification

Present information on carbon dioxide emission in Kenya is scant. A study on Developing countries monitoring and reporting on green house gas emissions, policies and measures in Kenya found that in preparing the first National communication of Kenya IPCC default values were used in various sectors due to lack of local emission factors (Mott MacDonald, 2010). Fuel sales give aggregate measure but not details. Allowable GHG emission levels for each country are set. It is a requirement of UNFCCC that each country communicates its GHG emission levels. Kenya's first communication to UNFCCC fell short of providing this information due to lack of the relevant data. Carbon trading is becoming a major business for countries with low greenhouse gas emissions. It is important that as a country we take stock of our greenhouse gas emission levels to be in this business. This will also enable us plan and adopt technologies for reducing the emission levels.

Kenya has had very erratic weather in recent years attributed to global warming arising from greenhouse gas effect. It is important for Kenya to establish its contribution to the global pollution.

1.2 Objectives

The objectives of the research are:

i. To study the activities of freight trucks passing through the weighbridges between Mombasa and Nairobi.
ii. To survey and enumerate the freight trucks traffic flow between Mombasa and Nairobi.
iii. To determine the average quantity of fuel required to transport one Ton of Cargo through 1 Km along Nairobi-Mombasa highway.
iv. To quantify carbon dioxide emission from the road freight transport sector between Mombasa and Nairobi

2. Methodology

2.1 Research Design

This research will be conducted through survey.

The determination of sample size was done using formula stated below.

$n=N/(1+N(e)^2)$(Glenn D., 2009)

Where

n= sample size

N=1282- The daily mean total number of freight trucks tally.

e= The confidence level**.**

$n=1282/(1+1282(0.05)^2)=304$. This is rounded off to 300.

2.3 Sampling Technique

A probability sampling technique will be adopted. Stratified random sampling will be used. The freight transport Lorries will first be categorized (stratified) in terms of capacity and form. Samples will then be drawn from the various strata in relative proportion to the number of a particular category in relation to the total freight traffic in the survey.

2.4 Monitoring and analysis of outbound freight transport activities

To achieve this through the survey, data is obtained on the vehicle model, its category, number of axles, load, destination, average speed, and turnaround time and route dedication by administering a questionnaire to the truck drivers as they queue for weighing at the Mariakani weigh bridge.

2.5 Road freight transport flow survey

This entails a week long actual count of the trucks passing through the weigh bridge daily (24 hours) according to their respective categories. This is then used to project the year's freight traffic flow. In Kenya only trucks from a minimum legal weight of 24 tonnes pass through the weigh bridge hence the trucks covered in the survey are from this minimal legal weight to a maximum legal weight of 48 tonnes.

2.6 Determination the fuel efficiency

To determine the fuel efficiency, the sampled trucks tonnages are obtained from the weigh bridge readings. The fuel efficiency is then determined by dividing the mean fuel used by the sampled trucks by the product of their mean load and the Mombasa Nairobi distance (470 Km)

2.7 Measurement and projection of CaO_2 Emission

This will be done using two approaches:-

1. Energy approach

   Where the CO_2 emitted will be calculated on the basis of the amount of fuel used by the freight trucks in litres and then multiplied by the carbon dioxide emission factor per litre of diesel.

   In this research, the amount of energy/fuel used to transport trucks full load and empty load between Mombasa and Nairobi will be obtained by interviewing the sample truck drivers on the amount of fuel they use in both cases. The actual amount of fuel used is then calculated using the formulae $FC_{LF} = FC_{empty} + (FC_{full} – FC_{empty}). LF$

   Where

   FC_{LF} = Mean fuel consumption at the specified load factor (litres per KM)

   FC_{empty} = Mean fuel consumption of empty vehicle

   FC_{full} = Mean fuel consumption of fully loaded vehicle

   LF = Specified load factor

2. Activity based approach

   In the absence of energy data it is possible to make an estimate of the carbon footprint of a transport operation by applying a simple formula:-

   CO_2 emission = tonnes transported x average distance travelled x CO_2 emissions factor per ton-kilometre. The tonnage is obtained from the Mariakani weigh bridge, the distance between Mombasa port and Mlolongo Weigh Bridge is pre established (470 Km) while an emission factor of 62g CO_2/ton-Km is adopted from a loading factor of 80%. [Tonnes CO_2 emissions = tonnes x km x g CO_2 per ton-km/1,000,000].

To carry out this calculation two main steps are required;

Step 1; Collect data on ton-km transported by vehicle type and fuel type

Step 2; Convert ton-km of the freight transported to CO_2 emissions by multiplying the results by an appropriate Ton-Km emission factor.

2.8 Data analysis method

Statistical Package for Scientific Students (SPSS) is used to enter and analyze data in the research work.

3. Results and analysis

3.1 Road freight trucks activity analysis

The main trucks models along the Mombasa-Nairobi highway are Mercedes Benz, Scania, Nissan, Faw and Mitsubishi in that order accounting for 84% of the total trucks plying that route (Fig.1). The key factor for the dominance of Mercedes Benz as the truck of choice in Kenya is probably due to its low operational cost. The majority of the trucks empty load empty load ranges between 16 tonnes and 19.9 tonnes (79.7%) (Fig.2) while 70.4% of the trucks full loads are lie between 40 tonnes and 49.9 ones. (Fig.4).The maximum legal tonnage allowed on the Kenyan roads is 48 tonnes. A few trucks carry more than the legal weight

Of the trucks leaving Mombasa with cargo, 97% (Fig.3) reach or pass Nairobi. The choice of using Mariakani Weigh Bridge just off Mombasa was ideal as there is no branch before this weigh bridge. Again, the high percentage of trucks that leave Mombasa and either reach or pass Nairobi make the data obtained to be credible for calculating the CO_2 emission from the freight trucks on this road. The turnaround time for most trucks lies between one and four days and are mostly driven at 60-70 Kilometres per hour. Higher percentage of the trucks is destined to either Nairobi or Kampala. The preferred average speed is optimal compromise between fuel consumption and turnaround time. The mean fuel consumption over the specified is 275.75 litres on full load and 161.54 litres on empty load. The mean fuel consumption obtained is for the Kenyan roads and more specifically the Mombasa Nairobi Road.

3.2 Freight trucks tallying survey

In conducting the tallying survey of the road freight trucks, they are first categorized as Ten wheeler trucks (rigid body), Twenty two wheeler oil tanker, Twenty two wheeler tipper trailer capable of offloading its cargo using a hydraulic mechanism and Twenty two wheeler semi/pulling trailer. A daily 24 hour count of the different truck categories was conducted for a week. The tallies are as in table 1. The majority of the trucks are the twenty two wheeler semi/pulling trailer which are flexible in the type of cargo they can carry, containerized or loose cargo.

3.3 Freight trucks Fuel efficiency

From the data collected of fuel consumption on full and empty loads (Table 2), the fuel consumption at a specified load factor can be calculated using the following formula:

From the data collected of fuel consumption on full and empty loads (Table 2), the fuel consumption at a specified load factor can be calculated using the following formula:

$FC_{LF}=FC_{empty} + (FC_{full}-FC_{empty)*}LF$

Where the unknown parameters are as defined earlier

LF= Specified load factor

(Full load-Actual load)/ (Full load-Empty load)=(41.34-17.65)Tons/(45.69-17.65)Tons=0.85

Actual load fuel consumption=$FC_{LF=}$161.54L + (275.4L-161.54L) (0.845) =275.75Litres

Mean Ton-Km on full loading=45.67Ton*470Km=21464.9Ton-Km

Mean Ton-Km on empty load=17.65Ton*470Km=8294.1Ton-Km

Mean Ton-Km on actual load=41.34Ton*470Km=19429.8Ton-Km

$$\frac{\text{Mean fuel consumption on full load}}{\text{Mean Ton}-\text{Km on full load}} = \frac{275.4\ \text{Litres}}{21464.9\ \text{Ton}-\text{Km}} = 0.01283\ \text{Litres/Ton-Km}$$

$$\frac{\text{Mean fuel consumption on empty load}}{\text{Mean Ton}-\text{Km on empty load}} = \frac{257.75}{8294.1\ \text{Ton}-\text{Km}} = 0.01948\ \text{Litres/Ton-KM}$$

$$\frac{\text{Mean fuel consumption on actual load}}{\text{Mean Ton}-\text{Km on actual load}} = \frac{257.75}{19429.8} = 0.01327\ \text{Litres/ Ton-Km}$$

The fuel efficiency on pay load Ton-Km=

$$\frac{\text{Mean fuel consumption on actual load}-\text{Mean fuel consumption on empty load}}{\text{Mean Ton}-\text{Km on actual load}-\text{Mean Ton}-\text{Km on empty load}}$$

$$=\frac{257.75\text{Litres}-161.54\ \text{Litres}}{19429.8\ \text{Ton}-\text{Km}-8294.1\ \text{Ton}-\text{Km}}$$

= 0.00864litres/Ton-Km

These fuel efficiency factors show that it is more economical to operate trucks with higher load factors while it is most expensive to run empty loads. This condition is made worse by the Kenyan Policy on transit trucks not being allowed to carry any load from within on return journey. The fuel consumption for payable load per Ton-Km can then be used to model the fuel consumption for a truck in this category with any specified payable load so long as its empty load is known.

3.4 Carbon dioxide emission from outbound freight trucks between Mombasa and Nairobi

3.4.1 *Energy Approach*

Using the mean fuel consumption and mean actual loads from table two:-

The year's Ton-Km= Mean actual load* Weekly Traffic flow*Distance* 52.1428571weeks/year =41.34*8978*52.1428571*470=9095838808Ton-Km

Fuel consumed= Yearly Ton-Km*0.01327Litres/Ton-Km

=9095838808Ton-Km*0.01327Litres/Ton-Km =120701781 metre

Using the emission factor derived for Carbon dioxide of 2.615 kg/ Litre of diesel

120701781Litres emits = 120701781 L * 2.615 Kg/L = 315635157.315kg

=315635.157 Tonnes of Carbon dioxide.

3.4.2 *Activity based approach*

Employing the activity based Carbon dioxide emission Template in table 3, and using the data derived thereof:-

From the total weekly emission, the per annum emission= 11414.87912*365/7

=595204.4 Tonnes

The Carbon dioxide emitted from the outbound freight trucks as calculated from the two approaches are different as the activity based approach is never very accurate but provides a quick means of estimating the CO_2 emitted from the sector. The figure obtained from the energy approach is more reliable and was found to be in agreement with the records of a few companies that keep their fuel consumption records.

4. Conclusion

The outbound trucks have a relatively high load factor (85%) which is economical in term fuel consumption, but the twenty two wheeler tipper trailers have a much higher load factors due to the nature of the cargo they carry. A compromise between the fuel consumption and the turnaround time has resulted in the preferred speed of between 60-70Km per hr.

The number of freight trucks plying this route is worryingly high. The case is worsened by the fact that the road is two ways and all trucks from the different countries served by the northern corridor converge to this route as they head to the port of Mombasa to pick cargo as there is no alternative route.

The fuel efficiencies show that the higher the load factor the higher the fuel efficiency. The amount of Carbon emitted is high and is correlated to truck numbers, their tonnage and distance.

5. Recommendation

There is urgent need for modal shift from Road freight trucks to other modes of transport that are relatively less carbon emitters. In this case the shift should be to Rail transport. This would reduce the traffic congestion that has greatly hampered the timely service delivery in the sector

The policy barring the trucks not to carry cargo on return trips from within should be reviewed in light of the findings of this research.

This research should be extended to other roads and vehicle categories to complete the audit of carbon emission from this sector. More deliberate effort needs to be put by the Kenyan Government to complete its carbon audit to enable its communication to UNFCCC.

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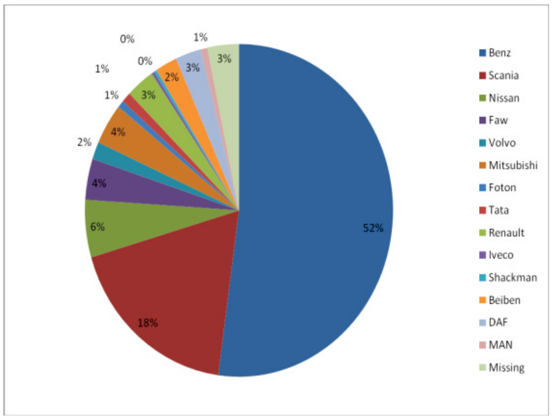

Fig. 1 Trucks model distribution

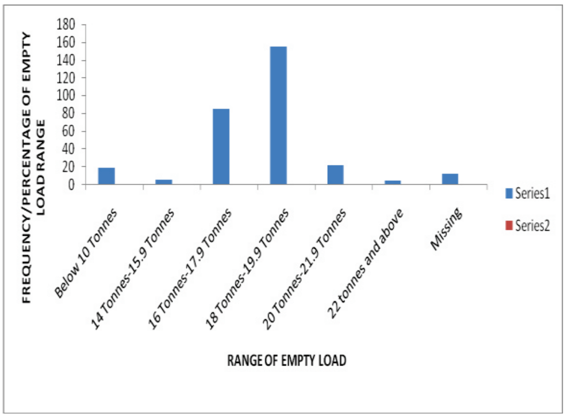

Fig. 2 Trucks range of full load

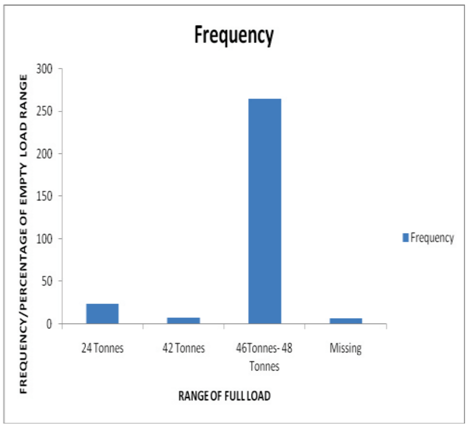

Fig. 3 Trucks full load range

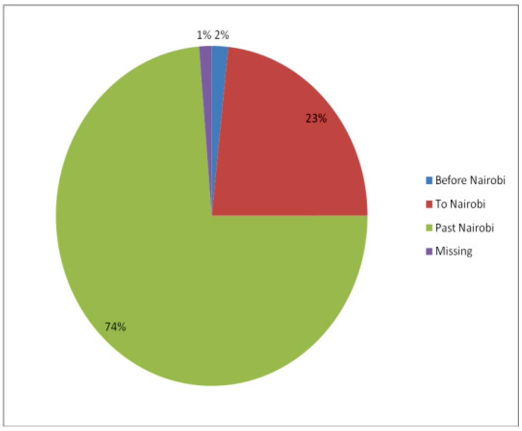

Fig. 4 Destination

Table 1Trucks daily count

DAY	TRUCK TYPE TALLY				TOTAL 1
	1	2	3	4	
1	50	70	316	926	1362
2	75	200	300	787	1362
3	56	206	297	921	1480
4	23	38	307	607	975
5	57	199	244	603	1103
6	53	198	285	677	1213
7	72	211	316	884	1483
TOTAL 2	387	1124	2065	5405	8978
MEAN	55.14286	160.2857	295	772.1429	1282.571
STD V	17.06291	73.33193	25.01999	143.4671	192.9826

Table 2 Fuel consumption data

	EMPTY LOAD	FULL LOAD	ACTUAL LOAD	FUEL CONSUMPTION WHEN FULL	FUEL CONSUPTION WHEN EMPTY
TOTAL	5099.9	13190.5	11946.6	79592	46685
MEAN	17.65	45.67	41.34	275.4	161.54
STDV	2.6	5.64	7.66	44.27	30.1

Table 3 Activity based Carbon dioxide emission Template

CATEGORY	MEAN TONNAGE	DISTANCE (Km)	TON-KM	CARBON EMITTED/ TON-KM	WEEKLY CO2 EMISSION
TEN WHEELER	8771.078	470	4122406.66	0.000062	255.5892129
TWENTY TWO WHEELER OIL TANKER	51764.255	470	24329199.9	0.000062	1508.410391
TWENTY TWO WHEELER TIPPER TRAILER	96162.3	470	45196281	0.000062	2802.169422
TWENTY TWO WHEELER SEMI/PULLING TRAILER	235027.8	470	110463066	0.000062	6848.710092
TOTAL					11414.87912

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