it is attended to. This may also be due to slow personnel at toll booths. This situation creates a possible additional step within the deceleration stage; the queuing stage represented in Figure 1.1 as (FC_q). Another stage in the MTC system is the service stage, represented by (FC_s) in the Figure 1.1. During this stage vehicles literally stop with their engines running to pay the toll fare to the attendant in the booth or slot money in a vending machine, after which a receipt is given. The last stage that is the acceleration stage represented by (U_{ac}) in the Figure 1.1. This comprises the phase where vehicles after collecting their receipts speed off away from the toll booths. All the stages described above are summed up and known as the “Stop and Go” stage.

In order to calculate the total Carbon Dioxide (CO_2) emissions at a toll plaza, not only the stages listed and explained above will be considered. As shown in the framework factors like energy efficiency of the vehicle which look at the amount of CO_2 a particular vehicle category can emit based on the energy it uses are also considered. This is a stage where Carbon Emission Factors (CEF) play a vital role. Also, a factor like carbon intensity is considered in the model. The Carbon intensity depends on the vehicular characteristics such as type of vehicle, age, fuel use etc. and permits us to know how much CO_2 a vehicle can emit while stationary or in motion. The last factor to be considered is the vehicle volume at the toll plaza. This is the volume of traffic that go through the toll plaza over a period of time. In Figure 3.1, this is shown as final block that makes CO_2 emissions estimations at Toll plazas complete. The best way to find an approximate estimate for total emissions of a particular GHG is that one has to take into account the total number of emitters. In this study the number of emitters will be volume of vehicles that move through each toll plaza. This is also known as the circulating fleet. The knowledge of vehicular volume is essential because after all calculations and estimations in an emissions model are done, the study can easily estimate total emissions at the specific toll plazas by multiplying total emissions by vehicle volume.

According to Pérez-Martinez et al. (2011) the calculation to obtain the total rate of CO_2 emissions in grams of CO_2 equivalent per vehicle-kilometer is found by multiplying the energy consumption of each vehicle category by its respective carbon emission factor (CEF) which is a constant that tells how much kgCO2 is produced when one MJ of energy is burnt. According to The Environment and Energy Management Agency (2007) and the USEPA (2014), the grams (kilograms) of CO_2 emitted per mega-joule of energy (g CO_2/MJ) are 81 (0.081kg) for diesel engines and 86 (0.086kg) for petrol/gasoline engines, irrespective of the engine size. The UNFCCC defines emission factor as the average emission rate of a given GHG for a given source, relative to units of activity.

When a toll plaza is considered, additional calculations are required for the "Stop and Go" stage relating to emissions from deceleration, stop and acceleration. These additional calculations will be the resultant per minute emissions due to idle time at the toll plaza. The study sums this up as "waiting time" in the analysis then converts this to effective distance to estimate energy consumption and subsequent CO_2 emissions.

Bearing these factors in mind, total carbon emission rate of a vehicle category of type "i" and motor fuel type "j" (mostly petrol and diesel), is denoted as "$N_{i,j}$" and expressed in kg of CO_2 equivalent per vehicle-kilometer ($kgCO_2$/veh-km) when assuming no toll plazas and also denoted as "$M_{i,j}$" when assuming the presence of a toll plaza. The difference in "$N_{i,j}$" and "$M_{i,j}$" will result in excess CO_2 emissions rates due to waiting time at the toll plaza. "$N_{i,j}$" and "$M_{i,j}$" will be obtained considering two estimations. First, by multiplying the CEF and energy consumption rate when there is no toll plaza $(U_{i,j})$ and second by multiplying CEF and the energy consumption rate $(E_{i,j})$ which considers the waiting time when assuming the presence of a toll station. These are expressed in Equation 1.1a and 1.1b respectively as noted by Hernández et al. (2013) and Pérez-Martinez et al. (2011). Since CEF is a common factor among these equations, the rate of total excess CO_2 emissions of a vehicle type "i" with fuel type "j" due to waiting time at a toll plaza $(C_{i,j})$ can be obtained when CEF is multiplied by the difference in energy consumption rate denoted as $(E_{i,j} - U_{i,j})$[4]. This is shown in equation 1.1c. The difference is attributed to the excess time taken to go through the toll booth which can be converted to distance using the assumptions by Fuzzi et al (2006)

In this study, we applied the rates of energy consumption per km and CO_2 emissions to the two road sections on the Oyibi/Frafraha and the Tema-bound highway to obtain actual excess CO_2 emissions caused by the toll plazas on these roads. This was done by multiplying the rate of CO_2 emissions per vehicle-km by the excess section length travelled due to the

[4] Energy Consumption is higher when there is a toll plaza

excess time spent at the toll plaza. The fact is that, the total distance travelled is not considered since any motor vehicle will burn energy and emit when it is in motion. However, the excess time spent at the toll station that has been converted to distance is the most relevant in this study. The actual carbon emissions of a vehicle type "i" and fuel type "j" is computed using the expression in equation 1.1d where $(CT_{i,j})$ is excess emissions due to the excess time spent at a toll plaza and L_i is the excess section length of a vehicle type "i" due to the excess time spent at a toll plaza. Monthly vehicle volume and shift volume traffic data recorded at the two toll plazas studied is then applied to actual CO_2 emissions to obtain the total emissions at the two study sites.

After total excess CO_2 calculations are obtained, the resulting emissions estimate is multiplied by the current unit value of CO_2 denoted by "CC", to obtain the value of CO_2 emission reduction if there was no toll plaza. The value $V_{i,j}$ is therefore the cost of excess CO_2 emissions of a vehicle type "i" with fuel type "j" at a toll as a result of the excess time spent at the toll station. This valuation can be described by Equation 1.1e.

$$\mathbf{N_{i,j} = U_{i,j} \times CEF_j} \quad \textbf{(1.1a)}$$

$$\mathbf{M_{i,j} = E_{i,j} \times CEF_j} \quad \textbf{(1.1b)}$$

$$\mathbf{C_{i,j} = \left(E_{i,j} - U_{i,j}\right) \times CEF_j} \quad \textbf{(1.1c)}$$

$$\mathbf{CT_{i,j} = C_{i,j} \times L_i} \quad \textbf{(1.1d)}$$

$$\mathbf{V_{i,j} = \left(CT_{i,j}\right) \times CC} \quad \textbf{(1.1e)}$$

In order to calculate the unit energy consumption rate of a vehicle type i with motor fuel type j, a mechanical formula, expressed, in mega-joules per vehicle-kilometer (MJ/veh-km) is employed. The energy consumption model used here is in the form of work energy, and is the product of the distance traveled and the external force that opposes vehicle motion. The initial model consists of five groups of external forces used by Hernàndez, Monzon and Sobrino (2013) as shown in Equation 1.2:

$$\boldsymbol{U_k = U_g + U_i + U_r + U_a + U_c} \quad \textbf{(1.2)}$$

Here $\boldsymbol{U_k}$ is the total energy consumption rate expressed in mega-joules per vehicle kilometer. It depends on the energy consumption due to gravitational losses, $\boldsymbol{U_g}$, the consumption due to inertial acceleration/deceleration, $\boldsymbol{U_i}$; the consumption due to rolling resistance, $\boldsymbol{U_r}$; the consumption due to aerodynamic drag, $\boldsymbol{U_a}$; and the consumption due to cornering losses, $\boldsymbol{U_c}$. The mechanical model can be fully expressed in mega-joules per vehicle-kilometer (MJ/veh-km) as shown in Equation 1.3:

$$\boldsymbol{U_{i,j}= L^{-1}\left[P\sin\theta\, d_g + C_i M_{fr} a d_i + C_r \mathrm{P}\cos\theta\, d_r + 0.5\rho C_d A_f v_r^2 d_a + \left(\frac{m^2 v^4}{R^2 C_{av}}\right) d_c\right]\left(\frac{1}{\eta_{motor}}\right) e_v} \quad \textbf{(1.3)}$$

Where “L” is the section length travelled in km

"P" is the vehicle weight (kg m/s^2) of the various vehicular categories and is calculated as a product of the vehicle mass (kg) and acceleration due to gravity (g) (constant equal to 9.8 m/s^2). However, vehicle mass can be used if effect of gravity losses is assumed to be null

"θ" is the road gradient (m/m) on which the toll plaza is located.

"Ci" is the mass correction factor for rotational inertia acceleration

"M_{fr}" is the rotational mass of vehicle (kg-m^2) "a" is the rate of acceleration (m/s^2).

"Cr" is the rolling resistance.

"ρ" which is the density of air for average tropical temperatures of 30^{o}C (1.164 kg/m^3).

"C_d" is the drag resistance of vehicles.

"A_f" is the frontal area of a vehicle (m^2).

"v_r" is the relative vehicle velocity taking into account the effect of wind (m/s) whereas "v" is the vehicle velocity (m/s).

"R" is the path radius from center of gravity (m).

"C_{av}" is defined as the cornering stiffness.

(e_v) defines the wind exposure factor and

(η_{motor}) defines the efficiency of the engine.

In Equation 1.3, the external forces that determine energy consumption are each multiplied by the total excess distances travelled in km. As seen from the equation, these excess distances are gravitational (d_g), inertial (d_i), rolling (d_r), aerodynamic (d_a) and curve (d_c). These distances are the excess time spent at the toll station as a result waiting time at the toll plaza which have been converted into distance.

Concerning the last part of the theoretical model (Figure 3.1) which is the vehicle volume, the Ghanaian fleet was classified into 5 categories based on the categorization by the Ghana Highway Authority (GHA) and the Driver Vehicle and Licensing Authority (DVLA). They are: saloon cars, pickup vans/4x4/SUV, mini bus/truck, large bus/truck and articulated/heavy trucks (trailers included). This form of categorization will be used in the study. In determining the category to place specific vehicles, the GHA uses the axle load of every vehicle. Also, various weights of each vehicle are also taken into consideration. The average weight of vehicles that fall in the same category are put in the same group. As required by the study objectives, knowledge of CO_2 emissions by specific vehicle category is paramount, therefore the characteristics of these classified vehicles for energy consumption and CO_2 emissions will be sought. Characteristics of vehicular data as well as driving conditions used and their sources is explained in the next section.

Equation 1.3 could not be used for the estimation of energy consumption. This is due to the fact that some variables were not relevant in the context of this study. Hence, the model was modified based on some assumptions. First, no cornering forces or gravitational loses shall be considered based on the knowledge that the toll plazas considered in this study are straight sections of road with no significant gradient, hence the energy consumption due to cornering (U_c) and gravitational losses (U_g) have been considered null. Secondly in a tropical region such as Ghana, excessive wind action usually does not play a major role in driving condition as witnessed in temperate zones. Hence the wind exposure factor will be assumed as minimal where $e_v = 1$.

Based on these assumptions the final expression of the model as deduced is expressed in mega-joules per vehicle-kilometer (MJ/veh-km) as shown in Equation (1.4):

$$\left(E_{i,j} - U_{i,j}\right) = L^{-1}\left[(C_i \times M_{fr} \times a)d_i + (C_r \times P \times \cos\theta)d_r + \left((0.5) \times \rho \times C_d \times A_f \times v_r^2)\right) d_a\right] \times \left(\frac{1}{\eta_{motor}}\right) \times e_v \quad \textbf{(1.4)}$$

The difference in $(U_{i,j})$ and $(E_{i,j})$ is multiplied by CEF for each toll plaza studied. This results in the rate of CO_2 emissions measured in kg of CO_2 per vehicle kilometers (kgCO2/veh-km) after which equation 1.1d is applied to obtain actual excess CO_2 emissions in $kgCO_2$. It should be noted that $\left(C_i M_{fr} a\right) = U_i$, $(C_r P \cos\theta) = U_r$ and $((0.5)\rho C_d A_f v_r^2) = U_a$ irrespective of the presence or absence of a toll station. The difference between $U_{i,j}$ and $E_{i,j}$ is the excess distances,d_i d_r and d_a created as a result the waiting time.

Valuation is done as shown in equation 1.1e. For the purpose of this study the monetary unit that will be used to value the amount of CO_2 emissions will be U.S Dollars ($). This unit will be used because it is the currency that Carbon Credit are valued in. Moreover due to the popularity and the ease at which this currency can be converted to any other currency, the study will not convert the cost of excess CO_2 emission into the local currency.

3.3 Data Types and Sources

Data used for the study can be grouped into three namely, data from literature, data from agencies and data from fieldwork.

Data from literature can be described as data the study obtained from scholarly articles and books and did not require the study to undertake extra effort to recalibrate values pertaining to such data. These data includes engine efficiency, rolling resistance, mass correction factors etc. most of which have been calculated according to literature. Specific variables such as the rotational mass of the vehicle (M_{fr}) has been calculated using the tyre rotational inertia, specifically the rim inertia. However, since all vehicle categories have different rim sizes, the variable here according to literature takes on different values for each vehicle category considered. Rolling resistance coefficient also assumes a constant value based on literature. This also applies to the Drag resistance coefficient which has already been estimated in literature and will be employed by the study. According to the International Union of Pure and Applied Chemistry (IUPAC) standard pressure and temperature measurements, an average tropical temperature of 30^oC will record an air density of 1.164, which was used in the calculations for energy consumption.

Data on engine efficiency is also obtained from literature and considers the average age of a vehicle which plays a vital role in determining vehicular CO_2 emissions. The average age of a vehicle can be determined by the mileage. This in turn provides an estimate for the engine efficiency. According to different studies by Dimopoulos et al (2007), Jahirul et al (2010) as well as Teng et al. (2006), the engine efficiency is 0.27 for petrol engines and 0.4 for diesel ones when considering vehicles that on the average have spent eight (8) years on road. The number of years specified (8 years) was chosen because, due to anecdotal evidence much more older vehicles above the age specified are found mostly in rural areas of which Tema and Frafraha do not form a part since these areas are considered as cities. Another reason for this average age is that the Driver and Vehicle Licensing Authority (DVLA) in Ghana registers vehicles that are above ten (10) years old at a penalty rate which serves as deterrent for individuals who wish to use such vehicles. Table 3.1 summarizes data obtained from literature and their sources used for the energy consumption model.

Table 3. 1: Data from Literature with their Sources

Parameter	Notation	Units	Value	Source/assumptions
Rolling resistance coefficient	C_r	-	0.01	(Lutsey & Sperling, 2005)
Rotational mass of vehicle	M_{fr}	kg-m^2	Saloon: 43.15 Pick-up:93.94 Mini-bus: 200.50 Large bus:611.42 Heavy Truck:1677.40	(HPWIZARD, 2014)
Drag resistance coefficient	C_d	-	0.35	(Lutsey & Sperling, 2005)
Mass correction factor for rotational inertia acceleration	C_i	-	1.05	(Burgess & Choi, 2003)
Engine efficiency	η_{motor}	m	Diesel Engine: 0.40 Petrol Engine: 0.27	(Dimopoulos, Rechsteiner, Soltic, Laemmle, & Boulouchos, 2007), (Jahirul, et al., 2010)
Air density	ρ	kg/m3	1.164	(IUPAC, 2015)

Data sourced from agencies can be defined as data the study obtained from agencies and firms. This data includes vehicular volume, fleet characteristics and tolling which was sourced from the Ghana Highway Authority (GHA), one of the four departments under the Ministry of Roads and Highways. Also, vehicle specifications were obtained from car makers. Variables such as vehicle mass and vehicle frontal area were obtained from car makers as well as dealers such as VOLVO, Mercedes Benz and Volkswagen, HONDA Palace, Stallion Ghana, Metro Mass Transit Accra and Kumasi among others. These variables take on different values depending on the vehicle category being considered due to the fact that vehicles come in different shapes and sizes.

Table 3.2 summarizes data obtained from agencies and their sources used for the energy consumption model.

Table 3. 2: Data from Agencies with their Sources

Parameter	Notation	Units	Value	Source/assumptions
Vehicle mass	m	kg	Saloon:2100 Pick-up:3,500 Mini-bus: 8,000 Large bus:18,000 Heavy Truck:65,000	(Mercedes-benz, 2014; Volkswagen, 2014)
Frontal area	A_f	m^2	Saloon:2.52 Pick-up:5.13 Mini-bus: 6.02 Large bus:8.67 Heavy Truck:8.62	(Mercedes-benz, 2014; VOLVO(a), 2014)

Data from fieldwork is that type of data that the researcher gathered from field observations. Variables such as section length of road, excess distances considered as a result of waiting time, velocity, rates of acceleration and deceleration, and service/waiting times was obtained from the fieldwork. The study used primary data comprising daily vehicular volume and driving conditions for the year 2014. The year 2014 was chosen because it was the most recent year and data required was available and sourced from the Ghana Highway Authority (GHA). In the next sections, we discuss the project site description as well as the primary data collection process.

3.4 Project Site Selection and Description

In the attempt to select a study area, all toll plazas in the country were considered. However due to constraints on time, money and personnel, two toll plazas were randomly selected and studied. This is because most of the toll stations in the country share similar characteristics as explained in the next paragraphs, hence biases or skewness can be assumed away in results obtained.

The argument for the random selection is that most toll plazas in Ghana are strategically located as connective links to other regions. Moreover they usually link the regional capitals not only to the industrial and maritime sections of the country but also to other important towns and communities. It will be possible to assume that vehicles that ply these tolled roads will on average be the same and will also share similar characteristics like type of vehicle, age, and fuel use. The major difference observed among toll plazas is that, they can be on single carriage or dual carriage roads. This may form a base for comparing the size of a toll station and emission levels as the study sought to select two toll plazas for small case studies. Due to these similarities among toll plazas, the study randomly selected two toll plazas not on any significant reason based on literature but on the number of booths per toll plaza as well as vehicular volume per booth. The steps for the random selection are explained below.

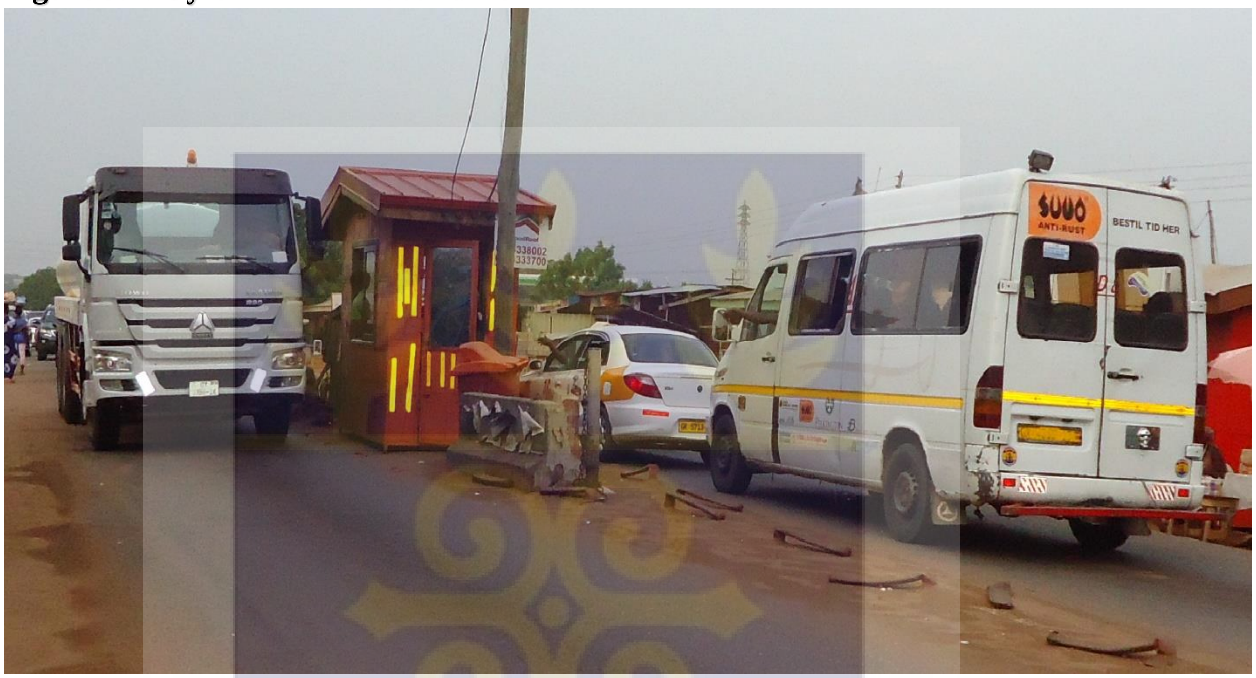
A survey of toll plazas in the country and a brief interview with the Director of Tolls at the Ghana Highway Authority revealed that the Tema motorway toll plaza and the Kasoa toll plaza are the busiest in the country. Those plazas were mentioned not only because of their location but also a look at the number of vehicles that went through each hour was extremely high. According to the Director, on average between 19,500 and 20,000 vehicles went through these toll plazas each day. Hence the researcher in the process of randomly choosing a big toll plaza chose the Tema-motorway toll stations to be studied. However, the study specifically used the vehicular traffic at the Accra end toll plaza i.e. the Tema-bound toll plaza for the analysis since in-bound and out-bound traffic could not be recorded at the same time due to the dual carriage nature of the motorway and the position of the toll plaza. From preliminary surveys at both in-bound and out-bound toll plazas on the motorway and inter-action with the tolls manager at GHA, the researcher realized that vehicular volume did not show any significant difference. From this observation the researcher randomly selected the Tema bound (Accra end) toll plaza with the idea of making generalizations applicable to the Accra bound toll plaza i.e. the Tema end toll plaza.

After the choice was made to select the big plaza, investigations were undertaken to locate a relatively smaller toll plaza with significant vehicular volume where driving conditions will not be different from the relatively big plaza identified. The parameters were that, this toll plaza should be on single carriage road and have not more than two booths in order to be regarded as “small”. A number of suggestions were made to the Director of Toll after which he suggested the Oyibi/Frafraha bound and Atimpoku toll plazas. The researcher randomly selected the Oyibi/Frafraha bound toll plaza to study as the small toll station. For this toll plaza both in-bound and out-bound vehicles were considered since the toll plaza was located in the middle of the road serving both in-bound and out-bound traffic.

After both toll station were chosen, we realised the biases that could arise since the vehicular volume for Frafraha toll plaza considered both traffic directions (in and out-bound traffic) whiles the vehicular volume for the Tema-bound toll plaza only considered one traffic direction (in-bound). Using the notion discussed that vehicular volume at the Accra end and Tema end toll plazas did not show any significant differences, study solved this directional bias by multiplying all the excess emissions and cost results that were obtained at the Tema-bound toll plaza by two (2). This enabled the study capture the excess emissions caused by excess waiting time for the toll plazas at both ends of the Tema motorway

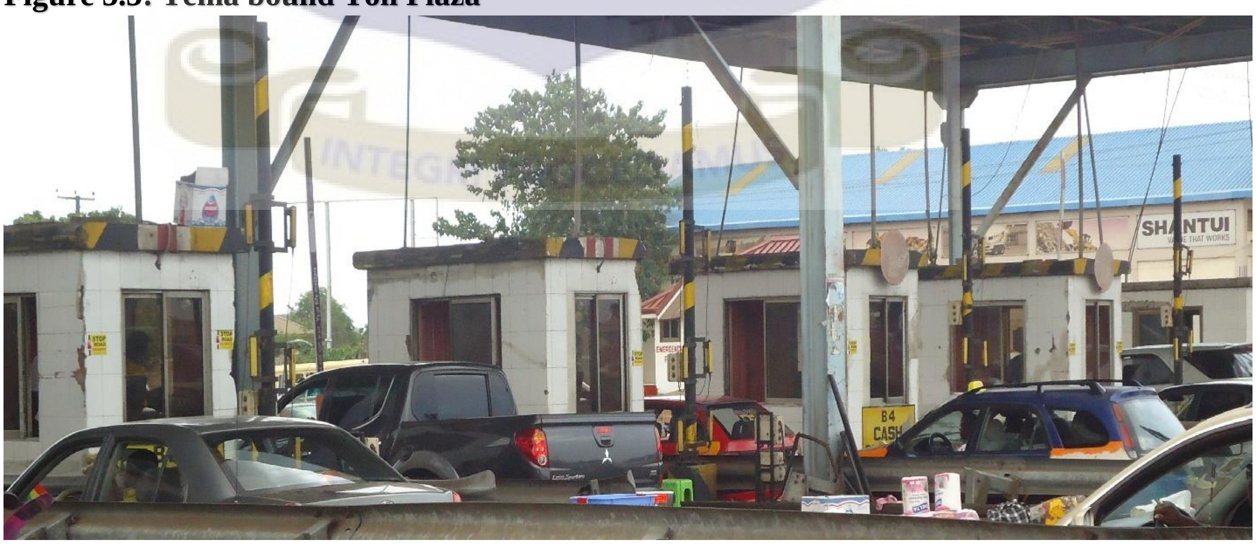
Although randomly chosen, the researcher considered regional balance in an effort to choose the two study areas. As Stock and Watson (2007) describe generalization as regards to the law of large numbers, samples must be independently and identically distributed. Therefore the study wanted to sample vehicles in the same region. It is assumed that vehicles in the same vicinity will have similar characteristics which will reduce errors in measurement as regards to GHG emissions. A pictorial view of the Oyibi/Frafraha bound and Tema bound Toll plazas are shown in Figure 2.1 and 2.2 respectively:

Figure 3.2: Oyibi/Frafraha bound Toll Plaza



Source: Author, 2015

Figure 3.3: Tema bound Toll Plaza



Source: Author, 2015

3.5 Field Data Collection

This section states the data obtained from the field and explains the processes the study went through to obtain the required data and also how some field data assumptions were made.

Prior to the commencement of the study, visits were paid to the two study sites, the Accra toll plaza and the Frafraha toll booth in the Greater Accra region to establish initial contacts. Also, the needed rapport with the management staff at the head office of the Ghana Highway Authority (GHA) was also established since this office is in charge of all toll plazas in the country hence permission needed to be sought from the office. In the process, the consent of the Ghana Police Service was also sought for the use of the Lidar[5] speed gun in order to measure the speed of the various category of vehicles in order to calculate acceleration rates, deceleration rates and also velocities.

During the study an officer from the Ghana Police Service assisted in obtaining values for average deceleration and acceleration rates. A controlled experiment was conducted at each chosen toll plaza and in the process the research obtained the results needed. In the experiment the police officer aims the LiDAR "cross-hairs" specifically on the license place of the target vehicle through a fitted telescope. This allows the police officer to see the target vehicle before the target vehicle operator sees the police officer generally at a distance of between 305 meters and up to 1,200 meters. To operate the device, the police officer presses

[5] LIDAR or LiDAR is a remote sensing technology that measures distance by illuminating a target with a lazar and analyzing the reflecting light. The term was created as a portmanteau for “light” and “radar”

the trigger of the LiDAR gun and it emits very short LiDAR laser pulses with a pulse width (duration of pulse) of 30 nanoseconds or less. The laser pulse "flies" towards the target and hits the target vehicle license plate. At the same time the pulse is released into flight. The LiDAR hence measures time-in-flight of each pulse and requires only 2 pulses over a period of time of as little as 3 milliseconds (theoretically) to determine the velocity of a vehicle. Table 3.3 shows data obtained from fieldwork using the LiDAR gun and a timer.

Table 3. 3: Data from Fieldwork with their Sources

Parameter	Notation	Units	Value	Source/as-sumptions
Relative vehicle veloc-ity	v_r	m/s	Saloon: 13.8 Pick-up:13.5 Mini-bus: 12.5 Large bus:10.6 Heavy Truck: 9.8	LiDAR gun
Rate of deceleration/ac-celeration	a	m/s^2	Saloon: 2.3 Pick-up: 2.2 Mini-bus: 2.1 Large bus: 2 Heavy Truck: 1.5	LiDAR gun

Also, a brief review of service operations at toll booths and how it affects toll collection activities at the two toll plazas considered was carried out together with supervisors in order to have a fair idea of service times at the various booths. In doing this, the study sampled in addition to service time, waiting time which included processes during the 'Stop and Go' stage. The study observed traffic volume around the two study sites considering various deceleration, stop and acceleration periods for each vehicular category using a timer. This was done for a period after which the specific periods were averaged and summed up as waiting time. This excess time was then converted to distance and used to calculate the energy consumption rates and subsequent CO_2 emission rates.

On the field, the study also chose specific start and end point on both trunk roads where the toll plazas were found. These are the two points on the trunk road before and after the Tema-bound and Oyibi/Frafraha toll. This was done in order to obtain accurate emission levels of sampled vehicles, first when they are in motion and second when they come to a gradual stop at the toll plaza. The assumption behind this is that toll plazas are seen as barriers to vehicular movement. Without the toll plaza there will be no stoppage and vehicles will not emit excess CO_2 due to idle time at the toll station. On the Tema motorway, the start point was 150 meters to the Tema-bound toll station and the end point was 150 meters after the same toll plaza, making up a section length of 300 meters. On the Frafraha-Dodowa motorway the start point was from the Christian University College junction which is 150 meters to the toll plaza with the end point being 150 meters after the toll plaza, a section length of 300 meters.

Lastly the study also collected data on vehicular volume. The GHA provided daily and shift volume data for the Tema-bound and the Oyibi/Frafraha bound toll plazas from which the researcher aggregated to obtain monthly traffic volume. However, this data from GHA did not have hourly vehicular traffic which could cater for peak and off peak periods.

3.6 Sampling

Since the toll station is run in shifts, primary data on vehicular volume is sampled in terms of morning, afternoon and night shifts which enabled the study know approximately the period where volume is high and may increase the level of emissions. The monthly traffic data as shown in Table 3.4 and 3.5 was also collected and aggregated from the various shifts run at the toll plazas. The morning shift runs from 6am to 1pm, afternoon shift runs from 1pm to 8pm and night shift runs from 8pm to 6am. Monthly shift data for both case studies can be found in Appendix I and II. Various service/waiting times were sampled after which an average waiting time was selected and used in the model.

Table 3. 4: Monthly Vehicular Traffic on Tema bound Toll plaza by Vehicle Category 2014

Month	Saloon cars	Mini bus/Mum wagon	Large bus/truck (tourist coaches)	pick-up vans/4x4/ SUV	Articu-lated trucks (trailer in-cluded)
January	296,478	203,723	41,463	55,960	25,041
February	278,127	188,054	35,767	50,394	22,577
March	303,676	179,409	48,703	55,954	22,810
April	276,675	191,816	40,339	56,693	23,032
May	278,404	189,941	45,246	54,039	25,036
June	301,577	216,029	48,534	66,414	33,831
July	300,279	208,349	48,694	57,077	25,093
August	294,548	203,122	46,144	59,275	21,594
September	291,848	208,295	44,683	54,219	22,369
October	312,816	213,867	48,510	58,657	25,039
November	293,520	192,003	47,874	59,210	21,016
December	299,936	195,932	55,295	64,520	22,201
TOTAL	**3,527,884**	**2,390,540**	**551,252**	**692,412**	**289,639**

Source: Compiled with data on daily traffic from GHA, 2015

Table 3. 5: Monthly Vehicular Traffic on Oyibi-Dodowa Motorway by Vehicle Category, 2014.

Month	Saloon cars	Mini bus/Mum wagon	Large bus/truck (tourist coaches)	pick-up vans/4x4 SUV	Articulated trucks (trailer included)
January	104,998	49,499	4,087	42,868	2,132
February	97,069	46,898	4,449	40,128	1,646
March	105,004	51,120	5,170	44,821	2,447
April	97,951	45,876	4,413	39,864	1,767
May	104,489	50,569	4,844	42,777	1,033
June	91,661	46,439	4,314	41,462	749
July	99,722	50,007	3,715	42,267	1,357
August	100,406	49,996	3,469	43,962	1,283
September	98,223	49,414	3,929	44,016	1,231
October	99,122	50,032	3,953	42,849	1,730
November	98,867	48,618	3,707	41,903	2,057
December	102,281	50,663	3,739	43,934	2,366
TOTAL	**1,199,793**	**589,131**	**49,789**	**510,851**	**19,798**

Source: Compiled with data on daily traffic from GHA, 2015

3.7 Empirical Estimations

This section deals with the empirical estimations of excess CO_2 emissions at toll plazas. The estimations that will be discussed here are the vehicular energy consumption and total CO_2 emission. In both cases, estimations will explain calculations that apply to the Tema bound and the Oyibi/Frafraha bound toll plazas

Energy Consumption rates $(\boldsymbol{E_{i,j}} - \boldsymbol{U_{i,j}})$ for a specific vehicle category "i" with fuel type "j" due to excess waiting time at a toll plaza, were calculated for all the different vehicular categories using Equation 1.4. In employing this model, specific variables corresponding to specific vehicular categories were used. This enabled the study obtain the different energy consumption rates for specific vehicle categories.

Based on the work by Fuzzi et al. (2006) on Italian Highways, if a car stopped for 3 min at a toll plaza with its engine running it pollutes and consumes the equivalent of 1 km route. This idea was used to estimate energy consumption when there was a toll plaza. For the goal of this study to calculate actual excess emissions in kilograms of CO_2 ($kgCO_2$) due to waiting time at toll plazas to be achieved, we multiply the rate of excess CO_2 emission by the excess section length due to the additional time caused by the presence of a toll plaza for each vehicle category. Monthly vehicular volumes are applied to per unit excess CO_2 emissions to obtain total excess CO_2 emissions for the year 2014.

3.8 Valuation of CO_2 Emissions

This section explains how the study deals with valuing the cost of emissions at toll plazas considered by this study by using the Carbon Credits approach.

Concerns over global warming have led to proposals for the establishment of markets for greenhouse gas emission reductions. Although formal markets are now being recognized, a number of international exchanges have occurred, whereby power companies and other energy-intensive industries have invested in 'green' projects, to partially offset their emissions of carbon dioxide (CO_2) and other greenhouse gases (Hassall and Associates, 1999). This is known as Carbon Finance which is done through the sale of Carbon Credits. Studies have shown that there are significant CO_2 emission levels around toll plazas and by investing in some 'green project' to reduce carbon emissions caused by toll booth operation, the country could benefit from the monetary value of these credits.

The main gases that are considered when calculating Carbon Credits are: Carbon Dioxide (CO_2) of which 1 ton is equivalent to a Carbon Credit (CC) and Methane CH_4 of which 1 ton is equivalent to 21 Carbon Credits (TopoGeo, 2014). Climate Change mitigation by taking CO_2 out of the atmosphere through carbon sequestration by trees is also considered when calculating Carbon Credits. In such cases the hectares of plantations are considered.

Carbon Credits, just as any other commodity (gold, cocoa, cotton, foreign currency etc.) is traded on the stocks, options and futures market and does not have a constant price. Its price also depends on market forces. The state of California in the United States being the world's fourteenth largest emitter according to the California Carbon Dashboard (Climate Policy Initiative, 2015), in its efforts to reduce excess emissions and gain some revenue trades its emissions reductions using Carbon Credit prices quoted by the New York Stock Exchange (NYSE).

In this study, after total excess CO_2 emissions has been estimated as described, this estimated value will be converted into Carbon Credits using the current price as quoted by the NYSE after which the actual cost in monetary terms will be obtained as shown in Equation 1.1d. The monetary value would be the current cost of excess emissions at Toll plazas due to inefficiencies or congestion but would be a gain to the country if these Toll plazas are re-moved or managed efficiently.

To obtain the exact per unit emission earnings in monetary terms that Ghana can obtain by managing CO_2 emissions through efficient measures, the study will convert the kilograms of CO_2 emitted (kg CO_2) for a single vehicle in each category as obtained using the method-ology into tons (Long ton) of CO_2 (tCO2), which will then be multiplied by the current rate of Carbon Credit as quoted by the NYSE. Finally, monthly vehicular volumes are applied to per unit earnings to obtain total excess CO_2 emission for the year 2014.

CHAPTER FOUR

ESTIMATION AND DISCUSSION OF RESULTS

4.1 Introduction

In this chapter, we present the analysis of the influence of Toll Plazas on the level of CO_2 emissions. There will be a discussion of the results of the estimations. This chapter will have four sections. The first section will discuss of the distribution and summary statistics of vehicle count at the toll plazas considered. The second section will discuss the types of data that were employed in the various toll plaza scenarios considered for the estimations. The third section will entail the actual presentation of how total vehicular energy consumption and CO_2 emission rates were obtained and converted to actual emissions for each vehicle category. The fourth section will then deal with the value calculation of CO_2 emissions through the Carbon Credit approach. In these discussion the particular results of each section will be discussed in the process.

4.2 Distribution of Vehicular Count

Aggregated values of vehicular traffic forming the primary data for the survey was analyzed in terms of the categories they fell into. In the survey it was observed that 7,451,727 vehicles comprising the five vehicle categories passed through the Tema bound (one direction) toll plaza in the year 2014. The Oyibi/Frafraha bound toll booth (both directions) recorded a total value of 2,369,362 vehicles for that same year. As discussed in chapter three vehicular data was collected in relation to the shifts run at each toll plaza. This enabled vehicle counts to be aggregated in terms of the morning, afternoon and night shifts and also ascertain the shift that will reveal the highest level of emissions. Tables 4.1a and 4.1b show the total vehicle volume for the Tema-Bound Toll and Oyibi/Frafraha bound toll Plaza in Shifts[6] for the various vehicular categories. The monthly breakdown for each vehicle category for the two study sites is found in tables 3.4 and 3.5 in chapter three.

Table 4. 1a: Total Vehicle Volume in Shifts at the Tema bound Toll Plaza, 2014

SHIFT	Saloon Cars	Mini Bus/Mum Wagon	Large Bus/ Large Truck	Pick-up/ 4X4/ SUV	Articula-tor/Heavy Trucks	**Total Shift Volume**
Morning	1,365,397	990,166	236,478	276,344	103,785	**2,972,170**
Afternoon	1,403,388	932,609	235,484	269,184	135,354	**2,976,019**
Night	765,099	468,263	79,290	146,884	48,920	**1,508,456**
Total Yearly Volume	**3,533,884**	**2,391,038**	**551,252**	**692,412**	**288,059**	**7,456,645**

Source: Compiled with data on daily traffic from GHA, 2015.

Table 4.1b: Total Vehicle Volume in Shifts at the Oyibi/Frafraha bound Toll Plaza, 2014

SHIFT	Saloon Cars	Mini Bus/Mummy Wagon	Large Bus/ Large Truck	Pick-up/ 4X4/ SUV	Articula-tor/Heavy Trucks	**Total Shift Volume**
Morning	505,173	261,983	21,672	229,054	10,509	**1,028,391**
Afternoon	526,934	262,298	22,104	231,251	7,291	**1,049,878**

[6] Morning: 6am-1pm, Afternoon: 1pm-8pm and Night: 8pm-6am

Night	167,686	64,850	6,013	50,546	1,998	**291,093**
Total Yearly Volume	**1,199,793**	**589,131**	**49,789**	**510,851**	**19,798**	**2,369,362**

Source: Compiled with data on daily traffic from GHA, 2015

As regards to vehicular traffic at the Tema bound Toll plaza in the year 2014, the morning shift recorded a total morning shift figure of 2,972,170 with the Saloon/Passenger vehicle category recording the highest number of vehicles (1,365,397) and the Articulated/Heavy Trucks recoding the lowest number of vehicles (103,785). The afternoon shift in the same regard following closely recorded approximately 2,976,019 vehicles going through the toll plaza with the same vehicle categories recording the highest (1,403,388) and lowest (135,354) vehicle count as observed in the morning shift. The night shifts also recorded a total vehicular count of 1,508,456 with the same category of vehicles as observed above recording the highest (765,099) and lowest (48,920) vehicle counts respectively. It was also observed that the total count observed for the afternoon count was the highest in terms of vehicular traffic at the Tema bound toll plaza followed by the morning with the night shifts recoding the lowest vehicular volume among the shifts. Specific breakdowns of monthly vehicular category count in terms of the various shifts at the Tema-bound toll plaza can be found in the Appendix I.

As regards to vehicular traffic at the Oyibi/Frafraha bound Toll booth, the afternoon shift recorded a total shift figure of 1,049,878 with the Saloon/Passenger vehicle category recording the highest number of vehicles (526,934) and the Articulated/Heavy Trucks recoding the lowest number of vehicles (7,291). The morning shift however recorded approximately 1,028,391 vehicles going through the toll booth with the same vehicle categories recording the highest (505,173) and lowest (10,509) vehicle count as observed in the morning shift. The night shifts then recorded a total vehicular count of 291,093 with the same category of vehicles as observed in the two other shifts recording the highest (167,686) and lowest (1,998) vehicle counts respectively. It was also observed in this case that the total vehicle volume count observed for the afternoon shift was the highest in terms of vehicular traffic at the toll booth followed by the morning and then the night shift. Monthly totals of the different vehicular categories not mentioned above but obtained for the various shifts at the Oyibi/Frafraha bound toll plaza can also be found in the Appendix II.

4.3 Results from Toll Scenarios

One objective of this paper was to estimate the volume of emissions resulting from vehicular idle time using specific toll plazas as case studies. To reach this objective, different case scenarios relating to different contributing factors of idleness were set in order to make concrete conclusions. For all the scenarios, the area of modeling included a 300 m road section which included the tolling station roughly located in the mid-section of the road considered. The study considers two cases using a Saloon car at the two toll plazas. This has been described as scenario “A” and “B” in Table 4.2. Scenario A shows there is a free flow of traffic without any obstruction such as a toll plaza and the vehicle does not totally stop at the toll station and scenario B, where there is a pause to pay the toll and communicate with the toll staff. Information on vehicular driving conditions at the tolls was obtained with the help of a LiDAR gun.

Table 4. 2: Scenarios of different toll systems and driving conditions for both Case Studies.

Scenario/toll system	Description	Driving condition			
Scenario A	Free flow: vehicles pass toll without stop	Constant velocity: 13.8 m/s (Oyibi) 13.8 m/s (Tema) Distance travelled: 300 m (Both)			
Scenario B	Traditional toll: Vehicles pass toll, there are three steps of the procedure: deceleration (dec) – stop – acceleration (acc)		Deceleration	Acceleration	Units
		dec/acc	1.8	2.3	m/s^2
		Initial Velocity	13.8	0.0	m/s
		Final velocity	0.0	13.8	m/s
		Distance travelled	150	150	m

Source: Authors Computations using results from LiDAR Gun, 2015

It was observed in scenario ‘A’ that when there was no toll plaza, all the vehicles travelled the 300 m section at the Tema bound and the Oyibi bound toll plazas with a constant velocity of 13.8 m/s since the distance being travelled is the same. In scenario B however, due to the stop and go processes present at the toll plaza, values observed were different. In this scenario, vehicles travelled 100m then decelerated while approaching the toll plaza to pay the toll which covered 100m, then proceeded to accelerate 100m after toll payment. The deceleration and acceleration rates at the Tema bound and Oyibi/Frafraha bound toll plazas were 1.8 m/s^2 and 2.3 m/s^2 respectively. Observed data for initial and final velocity in the above case did not differ from constant velocities observed scenario "A".

4.4 Average Waiting Time

Average waiting time in a toll plaza plays a vital role in transportation emissions as stated by Beevers and Carslaw (2005) as well as Smit et al. (2008). In this study throughput/service period measured the volume of traffic per unit time departing from each of the toll plaza surveyed. As a result of this assertion, efforts were made to know exactly how long it takes for each vehicle category to move through a toll booth at the two study sites. This analysis for waiting time deals with the "Stop and Go" stage comprising deceleration, queuing, service and finally acceleration. Service time and throughput data were collected for MTC toll-booths during morning, afternoon and night shifts over a one week period to obtain accurate average waiting times for both study sites

It should be noted that according to Fuzzi et al. (2006) a vehicle that is stationary with its engine running for 3 minutes pollutes and consumes the equivalent of 1km. Table 4.3 and Table 4.4 shows the breakdown of average waiting time at the Oyibi/Frafraha and the Tema-bound toll plazas respectively for all the vehicle categories considered with their excess distances calculated in km for energy consumption calculations.

Table 4. 3: Average waiting Time At the Oyibi/Frafraha Toll Plazas with Excess Distance

	SALOON CARS (Secs)	MINI BUS,MUM WAGON (Secs)	LARGE BUS, LIGHT TRUCK (Secs)	PICK UP, VANS, 4X4, SUV's (Secs)	ARTICULATED TRUCK (Secs)
Deceleration (U_d)	10	10	25	10	35
Queuing (FC_q)	125	125	125	125	125
Service Stage (FC_s)	6	6	10	6	15
Acceleration (U_{ac})	9	9	20	9	35
Total Waiting Time (Secs)	**150**	**150**	**180**	**150**	**210**
Total Excess Distance (km)	**0.833**	**0.833**	**1**	**0.833**	**1.167**

Source: Authors Computations using measurements from fieldwork, 2015

Table 4. 4: Average waiting Time At the Tema-bound Toll Plazas with Excess Distance

	SALOON CARS (Secs)	MINI BUS,MUM WAGON (Secs)	LARGE BUS, LIGHT TRUCK (Secs)	PICK UP, VANS, 4X4, SUV's (Secs)	ARTICULATED TRUCK (Secs)
Deceleration (U_d)	15	15	15	15	20
Queuing (FC_q)	60	60	60	60	60
Service Stage (FC_s)	6	6	10	6	15
Acceleration (U_{ac})	9	9	20	9	25
Total Waiting Time (Secs)	**90**	**90**	**105**	**90**	**120**
Total Excess Distance (km)	**0.5**	**0.5**	**0.583**	**0.5**	**0.667**

Source: Authors Computations using data from Fieldwork, 2015

These waiting periods for each vehicle category was obtained by means of averaging the processes observed at every 15 minutes vehicular flow during the survey period of the toll-booths as done by Padayhag and Sigua (2003) in the Philippines. This mode of measurement records the representative processing time at the tollbooth in a way that calculation is applicable to different modes of toll payment namely: manual scheme, mixed-modes and the dedicated Electronic-pass lane.

From the tables above tables, service stage time for Large buses and Articulator was observed to be higher than normal because of the nature of such vehicles similar to average service time results obtained by Padayhag and Sigua (2003) in Manila (Philippines). The sizes of such vehicles prevent the drivers from easy access to the toll attendants for payment. Usually both attendant and driver have to stretch their hands for money/receipt exchange. Also there are instances of some load carrying articulated vehicles hitting the booths and scratching against the medians in an attempt to use the toll lanes. Acceleration and Deceleration times of the heavier vehicles are also greater than the lighter vehicles. All this contributes to increased waiting time for heavy vehicles as compared to lighter ones.

4.5 Results for Energy Consumption Rates

The Table 4.5 shows the parameters for each vehicle category used to calculate energy consumption based on the scenarios discussed.

Table 4.5: Specific Vehicle Category Parameters Used For Energy Consumption Calculations for Both Case Studies

Parameter	Notation	Units	Saloon Cars	Mini Bus/Mum Wagon	Large bus/ Large truck	Pickup/ 4x4/ SUV	Articulated/ Heavy Truck
Rotational mass of vehicle	M_{fr}	kg/m^2	43.15	200.5	611.42	93.94	1677.4
Frontal area	A_f	m^2	2.52	6.02	8.67	5.13	8.62
Relative vehicle velocity	v_r	m/s	13.8	12.5	10.6	13.5	9.8
Rate of acceleration	a	m/s^2	2.3	2.1	2	2.2	1.5
Engine Efficiency	η_{motor}		0.27	0.4	0.4	0.4	0.4
Vehicle Mass	m	kg	2,100	8,000	18,000	3,500	40,000
Air density	ρ	kg/m^3	1.164	1.164	1.164	1.164	1.164
Slope/Gradient	θ	rad	0	0	0	0	0
Actual Section Length	L	km	0.3	0.3	0.3	0.3	0.3
Excess Distance (Oyibi)	*di*, *dr*, and *da*	km	0.833	0.833	1	0.833	1.167
Excess Distance (Tema)	*di*, *dr*, and *da*	km	0.467	0.467	0.583	0.467	0.667

Source: Authors computations using data from LiDAR and Fieldwork, 2015

From the mechanical model in Equation 1.4 energy consumption rates were obtained for each vehicle category “i” with fuel type “j”. For Saloon cars the result obtained for energy consumption at the Oyibi/Frafraha bound and the Tema bound toll plaza is calculated using Equations 2.1 and 2.2 respectively. As revealed by field observations, driving conditions relating to speed did not vary at the two study sites when measured by the LiDAR gun but service time and queuing time which make up waiting time at the two toll plazas varied. The difference in the two equations are the excess distance travelled which is the waiting time converted to distance. Like equations 2.1 and 2.2, all subsequent equations of this form are based on Equation 1.4 for the Oyibi/Frafraha-bound and the Tema-bound plazas respectively.

$$\left(\boldsymbol{E}_{i,j} - \boldsymbol{U}_{i,j}\right)_{Oyibi} = 0.3^{-1}[(1.05 \times 43.15 \times 2.3)0.833 + (0.01 \times 2100 \times \cos 0)0.833 + (0.5 \times 1.164 \times 0.35 \times 2.52 \times (13.8)^2)0.833)] \times \frac{1}{0.27} \times 1.0 \quad \textbf{(2.1)}$$

$$= 2{,}292.95768$$

$$\left(\boldsymbol{E}_{i,j} - \boldsymbol{U}_{i,j}\right)_{Tema} = 0.3^{-1}[(1.05 \times 43.15 \times 2.3)0.467 + (0.01 \times 2100 \times \cos 0)0.467 + (0.5 \times 1.164 \times 0.35 \times 2.52 \times (13.8)^2)0.467)] \times \frac{1}{0.27} \times 1.0 \quad \textbf{(2.2)}$$

$$= 1{,}285.487680$$

Calculations show that excess energy consumption rate for saloon cars on the Oyibi/Frafraha toll plaza is 2,293 MJ/veh-km and excess energy consumption rate is 1,285 MJ/veh-km on the Tema bound toll plaza for the same vehicle category.

For the Mini bus/Mummy wagon category Equations 3.1 and 3.2 describe the equations employed to obtain energy consumption values at the Oyibi/Frafraha and the Tema bound toll plazas respectively.

$$\left(\boldsymbol{E}_{i,j} - \boldsymbol{U}_{i,j}\right)_{\boldsymbol{Oyibi}} = 0.3^{-1}[(1.05 \times 200.5 \times 2.1)0.833 + (0.01 \times 8{,}000 \times \cos 0)0.833 + (0.5 \times 1.164 \times 0.35 \times 6.02 \times (12.5)^2)0.833)] \times \frac{1}{0.4} \times 1.0 \quad \textbf{(3.1)}$$

$$= 4{,}954.321732$$

$$\left(\boldsymbol{E}_{i,j} - \boldsymbol{U}_{i,j}\right)_{\boldsymbol{Tema}} = 0.3^{-1}[(1.05 \times 200.5 \times 2.1)0.467 + (0.01 \times 8{,}000 \times \cos 0)0.467 + (0.5 \times 1.164 \times 0.35 \times 6.02 \times (12.5)^2)0.467)] \times \frac{1}{0.4} \times 1.0 \quad \textbf{(3.2)}$$

$$= 2{,}777.512904$$

Calculations show that excess energy consumption rate is 4,954 MJ/veh-km for mini bus/mummy wagons on the Oyibi/Frafraha toll plaza whiles excess energy consumption rate is 2,778 MJ/veh-km on the Tema bound toll plaza for the same vehicle category.

For the next vehicle categories i.e. Large bus/Light truck, pick-up/4x4/SUV and Articulated/Heavy truck, Equations 4.1 through to 6.3 are employed respectively to calculate energy consumption values for these vehicle categories for the two toll plazas considered.

$$\left(\boldsymbol{E}_{i,j} - \boldsymbol{U}_{i,j}\right)_{\boldsymbol{Oyibi}} = 0.3^{-1}[(1.05 \times 611.42 \times 2.0)1.0 + (0.01 \times 18{,}000 \times \cos 0)1.0 + (0.5 \times 1.164 \times 0.35 \times 8.67 \times (10.6)^2)1.0)] \times \frac{1}{0.4} \times 1.0 \quad \textbf{(4.1)}$$

$$= 13{,}853.489$$

$$\left(\boldsymbol{E_{i,j}} - \boldsymbol{U_{i,j}}\right)_{\boldsymbol{Tema}} = 0.3^{-1}[(1.05 \times 611.42 \times 2.0)0.583 + (0.01 \times 18{,}000 \cos 0)\ 0.583 + (0.5 \times 1.164 \times 0.35 \times 8.67 \times (10.6)^2)0.583)] \times \frac{1}{0.4} \times 1.0 \qquad \textbf{(4.2)}$$

$$= 8{,}076.5838$$

Calculations show that excess energy consumption rate is 13,853 MJ/veh-km for Large bus/Light trucks at the Oyibi/Frafraha toll plaza and excess energy consumption rate is 8,077 MJ/veh-km on the Tema bound toll plaza for the same vehicle category.

$$\left(\boldsymbol{E_{i,j}} - \boldsymbol{U_{i,j}}\right)_{\boldsymbol{Oyibi}} = 0.3^{-1}[(1.05 \times 93.94 \times 2.2)0.833 + (0.01 \times 3{,}500 \times \cos 0)0.833 + (0.5 \times 1.164 \times 0.35 \times 5.13 \times (13.5)^2)0.83)] \times \frac{1}{0.4} \times 1.0 \qquad \textbf{(5.1)}$$

$$= 3{,}071.33477$$

$$\left(\boldsymbol{E_{i,j}} - \boldsymbol{U_{i,j}}\right)_{\boldsymbol{Tema}} = 0.3^{-1}[(1.05 \times 93.94 \times 2.2)0.467 + (0.01 \times 3{,}500 \times \cos 0)0.467 + (0.5 \times 1.164 \times 0.35 \times 5.13 \times (13.5)^2)0.467)] \times \frac{1}{0.4} \times 1.0 \qquad \textbf{(5.2)}$$

$$= 1{,}721.86475$$

Calculations show that excess energy consumption rate is 3,071 MJ/veh-km for Pick up vans/4x4's on the Oyibi/Frafraha toll plaza and excess energy consumption rate is 1,722 MJ/veh-km for the Tema bound toll plaza regarding the same vehicle category.

$$\left(\boldsymbol{E}_{i,j} - \boldsymbol{U}_{i,j}\right)_{Oyibi} = 0.3^{-1}[(1.05 \times 1677.4 \times 1.5)1.167 + (0.01 \times 40{,}000 \times \cos 0)1.167 + (0.5 \times 1.164 \times 0.35 \times 8.62 \times (9.8)^2)1.167)] \times \frac{1}{0.4} \times 1.0 \quad \textbf{(6.1)}$$

$$= 31{,}222.5118$$

$$\left(\boldsymbol{E}_{i,j} - \boldsymbol{U}_{i,j}\right)_{Tema} = 0.3^{-1}[(1.05 \times 1677.4 \times 1.5)0.667 + (0.01 \times 40{,}000 \times \cos 0)0.667 + (0.5 \times 1.164 \times 0.35 \times 8.62 \times (9.8)^2)0.667)] \times \frac{1}{0.4} \times 1.0 \quad \textbf{(6.2)}$$

$$= 17{,}845.25739$$

Calculations show that excess energy consumption rate for Articulator/Heavy trucks on the Oyibi/Frafraha bound toll plaza is 31,223MJ/veh-km whiles excess energy consumption rate is 17,845 MJ/veh-km for this same category on the Tema-bound toll plaza

From the above it can be concluded that in all the different types of energy consumption estimated for the two toll different toll plazas the Articulator/Heavy truck category has the highest level of energy consumption rate followed by the Large bus/Light truck category, Mini vans/ Mummy wagons, Pick-up/Vans/4x4/SUV category, and the Saloon Car category.

4.6 Results for Vehicular CO_2 Emission

After the estimations for energy consumption, Equations 1.1c was applied to obtain the rate of total excess CO_2 emissions. Table 4.6a shows how energy consumption rates obtained at the two toll plazas and Carbon Emissions Factors (CEF) were multiplied to obtain per vehicle excess CO_2 emissions rates in kilograms of CO_2 (kg CO_2/veh-km) for each vehicle category at the two study sites. Since this excess CO_2 value obtained is a rate, Table 4.6b goes ahead to multiply this rate by the excess section length travelled by each vehicle category at both toll plazas to obtain actual CO_2 emissions as shown in Equation 1.1d. This is then converted to tons[7] (long ton) for valuation purposes.

Table 4.6a: Calculation for CO_2 Emission Rates in kgCO_2/veh-km at the two toll plazas

Vehicle Type	Energy Consumption at Frafraha $(E_{i,j} - U_{i,j})_{oyibi}$ **MJ/veh-km**	Energy Consumption at Tema $(E_{i,j} - U_{i,j})_{tema}$ **MJ/veh-km**	Carbon Emission Factor (CEF) **kgCO_2/MJ**	Rate of CO2 Emissions at Frafraha $(E_{i,j} - U_{i,j})_{oyibi}$ (CEF) **kgCO_2/veh km**	Rate of CO2 Emissions at Tema $(E_{i,j} - U_{i,j})_{tema}$ (CEF) **kgCO_2/veh km**
Saloon Car	2,292.957682	1,285.48768	0.086	197.19	110.55
Mini bus	4,954.321732	2,777.51290	0.081	401.30	224.98
Large bus	13,853.4886	8,076.58388	0.081	1,122.13	654.20
Pick up/4x4	3,071.334775	1,721.864754	0.081	248.78	139.47
Heavy truck	31,222.51181	17,845.25739	0.081	2,529.02	1,445.47

Source: Authors Computations, 2015

These total excess emissions in tCO_2 for a single vehicle in each vehicle category were multiplied by the monthly vehicular traffic volume to obtain the total monthly CO_2 emissions

[7] 1kg=0.00098tons

for the two toll plazas considered. The same was done for shift vehicular volume to obtain shift emissions. Tables for monthly CO_2 emissions for the year 2014 at the two toll plazas studied using volume data obtained from GHA (Tables 3.4 and 3.5) can be found in the Appendix V. Total yearly and shift emissions for the vehicular categories at the Accra/Tema bound and the Oyibi/Frafraha bound toll plazas is summarized in Tables 4.7a and 4.7b respectively. It should however be noted that, since vehicle traffic data obtained from GHA for the Tema bound toll plaza was for one way traffic, the study obtained excess emissions for two-way traffic by multiplying excess emissions calculated from Table 4.1a by 2 to obtain the approximate shift emissions due to excess waiting time at the two toll plazas located on the Tema motorway as shown in Table 4.7b.

It can be observed that the Articulator/Heavy truck category records the highest level of excess emissions at the Oyibi/Frafraha bound toll plaza followed by the Large bus/Light truck vehicle category, Mini bus/Mummy wagon category, the Pick-up/Van/SUV category and least being the Saloon car category. With regards to excess CO_2 emissions at the Tema bound toll plaza the Articulator/Heavy truck category still records the highest level of emissions followed by the Large bus/Large truck category, the Mini bus/Mummy wagon category, the Pick-up/Van/SUV category and finally the Saloon car category.

These excess emissions are high as compared to studies by Hernàndez, Monzon and Sobrino (2013) as well as Pérez-Martinez et al. (2011). This is due to the fact that in those studies, research considers queuing and service time only, and aggregates these processes as 'waiting time'. Moreover, Opoku-Boahen, Adams, & Salifu (2013) also consider waiting time as the difference between a specific vehicles arrival and departure time at a toll plaza. In so doing waiting time is relatively smaller as a result of the bias that only two stages are observed at a toll plaza. In this study however, additional processes such as deceleration and the initial acceleration of vehicles witnessed as a result of the presence of a toll station are included in the calculation of 'waiting time'.

Table 4.6b: Excess CO_2 Emissions in $kgCO_2$ and tCO_2 Due To the Presence of Toll Plazas at the Two Study Sites

Vehicle Type	Rate of CO_2 Emissions at Frafraha $(C_{i,j})_{Oyibi}$ **kgCO2/km**	Rate of CO_2 Emissions at Tema $(C_{i,j})_{Tema}$ **kgCO2/km**	Excess Section Length at Frafraha $(L_i)_{Oyibi}$ **km**	Excess Section Length at Tema $(L_i)_{Tema}$ **km**	Actual CO_2 Emissions at Frafraha Toll $(C_{i,j} \times L_i)_{Oyibi}$ **$kgCO_2$**	Actual CO_2 Emissions at Tema Toll $(C_{i,j} \times L_i)_{Tema}$ **$kgCO_2$**	Actual CO_2 Emissions at Frafraha Toll $(CT_{i,j})_{Oyibi}$ **tCO_2**	Actual CO_2 Emissions at Tema Toll $(CT_{i,j})_{Tema}$ **tCO_2**
Saloon Car	197.19	110.55	0.833	0.5	164.26	55.28	0.162	0.054
Mini bus	401.30	224.98	0.833	0.5	334.28	112.49	0.329	0.111
Large bus	1,122.13	654.20	1	0.58	1,122.13	379.44	1.104	0.373
Pickup/4x4	248.78	139.47	0.833	0.5	207.23	69.74	0.204	0.069
Heavy truck	2,529.02	1,445.47	1.167	0.67	2,951.37	968.46	2.905	0.953

Source: Authors Computations, 2015

Table 4.7a: Total Vehicular CO_2 emissions (tCO_2) by vehicle category in Shifts at the Oyibi/Frafraha bound Toll Plaza, 2014

SHIFT	Saloon Cars	Mini Bus/Mum Wagon	Large Bus/ Large Truck	Pick-up/ 4X4/ SUV	Articula-tor/Heavy Trucks	**Total Shift Emissions**
Morning	81,838	86,192	23,926	46,727	30,529	**269,212**
Afternoon	85,363	86,296	24,403	47,175	21,180	**264,418**
Night	27,165	21,336	6,638	10,311	5,804	**71,255**
Total Yearly Emissions	**194,366**	**193,824**	**54,967**	**104,214**	**57,513**	**604,884**

Source: Authors Computations using data from Fieldwork and GHA, 2015

Table 4.7b: Total Vehicular CO_2 Emissions (tCO_2) by vehicle category in Shifts at the Accra and Tema bound Toll Plazas, 2014

SHIFT	Saloon Cars	Mini Bus/Mum Wagon	Large Bus/ Large Truck	Pick-up/ 4X4/ SUV	Articula-tor/Heavy Trucks	**Total Shift Emissions**
Morning	147,463	219,817	176,413	38,135	197,814	**779,642**
Afternoon	151,566	207,039	175,671	37,147	257,985	**829,408**
Night	82,631	103,954	59,150	20,270	93,242	**359,247**
Total Yearly Emissions	**381,659**	**530,810**	**411,234**	**95,553**	**549,040**	**1,968,297**

Source: Authors Computations using data from Fieldwork and GHA, 2015

At the Oyibi/Frafraha bound toll plaza, the Saloon car category recorded the highest annual excess emissions of 194,366 tCO_2 whereas the Large bus/Light truck category recoded the least of 54,967 tCO_2 at the same toll plaza. On the Tema motorway it is seen that the Articulator/Heavy truck category recorded the highest annual excess emissions of 549,040 tCO2 whiles the Pick-up/4x4/SUV category recorded the least annual excess emissions of 95,553 tCO_2.

4.7 Results for Carbon Credit Allocation (Valuation)

The valuation of cost for CO_2 emissions is done by employing the Carbon Credit (CC) approach as discussed in chapter three. As the excess total emissions is known, the study goes ahead to calculate how much Carbon Credit can be accessed from avoidance of the excess CO_2 emissions obtained through efficient tolling such as the introduction of the Electronic Toll Collection (ETC) systems. This gives the study the opportunity to estimate in monetary terms how much the country can make from managing toll plaza efficiently. As at 30th June 2015, the current price of Carbon Credit as listed by the New York Stock Exchange (NYSE) was \$12.72 (Climate Policy Initiative, 2015) and was used to calculate the cost of excess emissions at the study sites.

Excess CO_2 emissions calculated for the two study sites for each vehicle category is multiplied by the current price of a ton of CO_2 to obtain the earning that can be realised if waiting time is avoided at the toll plaza. Table 4.8 summarizes the valuation of excess CO_2 per vehicle category in Carbon Credits for the two study sites based on Equation 1.1e.

Table 4.8: Valuation of CO_2 in Carbon Credits (CC) by Vehicle Categories

Vehicle Type	Actual CO_2 Emissions at Frafraha Toll $\left(CT_{i,j}\right)_{Oyibi}$	Actual CO_2 Emissions at Tema Toll $\left(CT_{i,j}\right)_{Tema}$	Value of Carbon Credit per tCO_2 **($CC)**	Value of Excess CO_2 at Frafraha (US$) $\left(CT_{i,j}\right)_{Oyibi}(CC)$	Value of Excess CO_2 at Tema (US$) $\left(CT_{i,j}\right)_{Tema}(CC)$
Saloon Car	0.162	0.054	12.72	2.06	0.69
Mini bus	0.329	0.111	12.72	4.19	1.41
Large bus	1.104	0.373	12.72	14.04	4.75
Pick up/4x4	0.204	0.069	12.72	2.60	0.88
Heavy truck	2.905	0.953	12.72	36.95	12.12

Source: Authors Computations using data from fieldwork, 2015

From Table 4.8, it is seen that for the Saloon car category it is estimated that Ghana can earn about $2.06 on a single vehicle in this category at the Oyibi/Frafraha bound toll station if waiting time is avoided and $ 0.69 on this same vehicle category at the Tema bound toll plaza. For the Mini bus/mummy wagon vehicle category it is estimated that Ghana can earn about $ 4.19 on a single vehicle in this category at the Oyibi/Frafraha bound toll station if waiting time is avoided and $ 1.41 on this same vehicle category at the Tema bound toll plaza if the same measures are taken. Also, for the Large bus/Large truck category it is estimated that if waiting time is avoided the country can earn $14.04 on a single vehicle in this category at the Oyibi/Frafraha bound toll station if waiting time is avoided whereas the presence of the Tema bound toll station creates excess emissions worth $ 4.75 in Carbon Credits if waiting time at this toll station is avoided. For the Pick-up/vans/SUV category it is also estimated that Ghana can earn about $2.60 on a single vehicle in this category at the Oyibi/Frafraha bound toll station if waiting time is avoided whereas $0.88 on this same vehicle category can be earned at the Tema-bound toll plaza if waiting time is avoided.

Lastly, the country can earn $36.95 on a single vehicle in the Articulator/Heavy truck category by avoiding the excess emissions caused by waiting time at the Oyibi/Frafraha bound toll plaza. Also, an amount of $12.12 can be earned from Carbon Credits from a single vehicle in the same category when waiting time is avoided at the Tema-bound toll plaza.

Knowledge on the amount the country can earn on each vehicle category can help deduce the average monthly CO_2 emission earnings from Carbon Credits for the Tema-bound toll plaza (Big plaza) and the Oyibi/Frafraha toll plaza (Small plaza) using volume data from GHA. The monthly earnings on total shift emissions is found in Appendix VI and VII whiles total monthly vehicular traffic excess emissions at the same study sites can be found in Appendix VII. The study wanted to ascertain the total shift earnings from traffic emission for the year 2014 based on GHA data at the two study sites if average waiting time (idle time) exacerbating excess CO_2 is reduced. In doing this total average shift vehicular CO_2 emissions from Tables 4.7a and 4.7b were multiplied by the CC value per vehicle category from Table 4.8 depending on the study site. Tables 4.9a and 4.9b summarize the calculations for these Carbon Credit earning for the Accra/Tema bound and the Oyibi/Frafraha bound Toll plazas respectively for the shift periods.

Table 4.9a: Total CC Earnings (US$) for Shift Periods at the Oyibi/Frafraha bound Toll Plaza in 2014

SHIFT	Saloon Cars	Mini Bus/Mum Wagon	Large Bus/ Large Truck	Pick-up/ 4X4/ SUV	Articula-tor/Heavy Trucks	**Total Earn-ings**
Morning	168,586	361,146	335,919	121,490	1,128,033	**2,115,176**
Afternoon	175,848	361,580	342,616	122,656	782,614	**1,785,314**
Night	55,960	89,396	93,202	26,810	214,465	**479,833**
Total Yearly Earnings	**400,395**	**812,123**	**771,737**	**270,955**	**2,125,112**	**4,380,323**

Source: Authors Computation using data from fieldwork and GHA, 2015

Table 4.9b: Total CC Earnings (US$) for Shift Periods at the Accra and Tema-bound Toll Plazas in 2014

SHIFT	Saloon Cars	Mini Bus/Mum Wagon	Large Bus/ Large Truck	Pick-up/ 4X4/ SUV	Articula-tor/Heavy Trucks	**Total Earnings**
Morning	101,749	309,942	837,960	33,559	2,397,508	**2,842,759**
Afternoon	104,580	291,925	834,438	32,690	3,126,775	**3,555,970**
Night	57,015	146,576	280,964	17,838	1,130,087	**1,351,516**
Total Yearly Earnings	**263,345**	**748,443**	**1,953,361**	**84,087**	**6,654,370**	**7,750,245**

Source: Authors Computation using data from fieldwork and GHA, 2015

Total annual earnings from the Tema bound toll plaza show that if toll plazas are removed the country can earn about $4,946,719 whiles a total annual earing of $4,824,132 can be earned if the Oyibi/Frafraha toll plaza is removed. The combined earning from the removal of the two toll plazas located on the Tema motorway can earn the country about $7,750,245. Emissions earnings from shifts also revealed that for the Tema toll plazas the afternoon shift earns the highest in Carbon Credits. For the Oyibi/Frafraha toll plaza the morning shifts recorded the highest earnings. Monthly earnings in the three shifts can be found in the Appendix VI and VII.

4.8 Conclusions

The study found that at the Oyibi/Frafraha toll plaza, lighter vehicles wait an average of 150 seconds from deceleration, queuing, service time (toll payment) to acceleration whereas heavy vehicles wait an average of between 180 and 210 seconds. At the Tema-bound toll plaza, waiting time for light vehicles was 90 seconds from deceleration, queuing, service time (toll payment) to acceleration and also between 105 and 120 seconds for heavy vehicles for the same stages. This can be attributed to the fact that bigger toll plazas like the Tema bound toll plaza have more booths compared to smaller toll plazas like the Oyibi/Frafraha bound toll plaza that have just a single booth attending to vehicles from all directions. Also, at the Oyibi/Frafraha toll plaza, the study observed that the presence of a Police barrier close to the toll plaza also contributed to the increase in waiting time there. Since these waiting times are converted to excess distances that affect CO_2 emissions, the study confirms the fact based on the above results that, the presence of a toll station can result in excess emissions when there is waiting time.

As similar to results obtained by Pérez-Martinez et al. (2011) in Spain, this study also concluded that the Articulator/Heavy truck category records the highest level of per vehicle excess emissions at the Tema-bound toll plaza followed by the Large bus/Light truck vehicle category, Mini bus/Mummy wagon category, the Pick-up/Van/SUV category and least being the Saloon car category. With regards to excess emissions at the Oyibi/Frafraha bound toll plaza, the Articulator/Heavy truck category still records the highest level of emissions followed by the Large bus/Large truck category, the Mini bus/Mummy wagon category, the Pick-up/Van/SUV category and finally the Saloon car category. Case studies also showed that energy consumption and CO_2 emissions were directly related to vehicle mass, engine efficiency, acceleration rate and the amount of waiting time. As was seen in the analysis, when these variables increased, energy consumption and CO_2 emissions also increased

Although the Articulator/Heavy truck vehicle tops in terms of individual emissions, this is not the case in terms of results for the total emissions per vehicle going through the Oyibi/Frafraha bound toll plazas. As GHA vehicular volume confirmed, Saloon cars are the most common at this toll plaza, hence that category records the highest amount of total emissions followed by Mini buses/mummy wagons, Pick-up/Vans/SUV's, Large buses/truck and the least volume recorded being the Articulator/Heavy trucks. As a result of the small nature of the toll plaza, heavy trucks are not very frequent at this toll plaza, making the aggregation of total emissions lower as compared to the other categories. As regards to the Tema bound toll plaza although GHA data also confirms the Saloon car category as the most common, total CO_2 emissions recorded at this toll plaza showed that the Articulator/Heavy truck records the highest amount total emissions followed by Mini buses/mummy wagons, the Large buses/truck, Saloon cars and the Pick-up/Vans/SUV category. This is mainly because the Tema-bound toll plaza is a major connective link to one of the industrial cities in the country. As a result most heavy and articulated trucks carrying loads to the port use this toll plaza.

Conclusions also drawn for revenue creation through excess emission costs at small toll stations such as the Oyibi/Frafraha toll station differed so much to the conclusions for CO_2 emission costs at big toll plazas such as the Tema toll plazas in terms of the amount of Carbon Credits that can be generated. The cost of emissions at the Oyibi/Frafraha bound toll station was $4,824,132 whiles that of the combined Tema toll plazas was $7,750,245. A big difference of $2,926,113 although waiting time at the Accra and Tema bound toll plazas was lower than that of the Oyibi/Frafraha bound toll plaza. This is because total excess emissions generated at a toll plaza depends significantly on the waiting time at the particular toll plaza and also the vehicular traffic. The Accra/Tema bound toll plaza has significant vehicular traffic but a lower waiting time since there are more booths and personnel to cater for the volume. The Oyibi/Frafraha bound toll plaza on the other hand has lower vehicular volume but a higher waiting time. Total emissions and subsequent valuation shows that each of the toll plazas studied has either vehicular volume or waiting time being higher, hence the disparity in Carbon Credit revenue.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Introduction

This chapter concludes the research by providing a summary of the entire study. Moreover, the findings of the entire research are also summarized in this chapter. The major conclusions on findings that were made while estimating the cost of emissions at the toll plazas used are also discussed in this chapter. These conclusions serve as a basis on which recommendations have been made for policy makers to consider.

5.2 Summary and Conclusions

A central implication of Climate Change is that, the amount of greenhouse gases in the atmosphere is increasing of which there is a vast body of studies that attest to this fact. Although there is no overall consensus among researchers on the varying amounts and magnitudes of GHG's currently in the atmosphere in fields such as Agriculture, Transport and Industry; none dispute the fact that the amount of GHG emissions are increasing.

Despite these enormous studies, there still remains a gap to be filled because studies aimed at estimating CO_2, a greenhouse gas, at specific areas in the fields mentioned above is lacking. For instance the contribution of toll plazas to overall transport emissions in Ghana or Sub Saharan Africa can be said to be a grey area to researchers. Although these toll stations have been found to be significant hubs for excess CO_2 generation the exact quantity has eluded research.

Hence the necessity of this study to estimate and value the level of vehicular CO_2 emissions resulting from vehicular idle time at toll plazas and ascertain if the reduction in excess CO_2 emissions through efficient management could earn Ghana some Carbon Credits to supplement the road fund. This was done in three major steps, first calculating the energy consumption values for each vehicle category, second calculating total CO_2 emissions by multiplying energy consumption by Carbon Emission Factors (CEF) depending on fuel type and thirdly valuing the amount of emissions using the going rate for a ton of CO_2 in Carbon Credit terms.

The relevant theoretical literature reviewed showed that the transport sector produces significant amounts of pollutants that are global in nature. Meaning that the impacts of one ton of carbon dioxide emissions are the same no matter where it is emitted. Moreover narrowing the review to Ghana, literature also showed that the most abundant greenhouse gas produced and emitted in Ghana is CO_2. This has necessitated the development of a variety of definitions and procedures for the calculation of transport carbon footprints. Literature further showed that car use, road, freight and aviation are the principal contributors to greenhouse gas emissions from the transport sector. It continues to state that the increasing temperatures observed in recent years is very likely due to the increase in man-made greenhouse gas concentrations coming from the transport sector.

Empirical reviews also concluded that there is potential positive effect of the introduction of Intelligent Transport System (ITS) technologies on the environmental impacts of toll plazas and how its introduction can reduce GHG emissions. Through this, the study sought to investigate another dimension of revenue generation through Carbon Finance from the reduction in transport emissions at toll plazas.

As a result the study's specific objectives was to ascertain the vehicle category in Ghana that contributes most to CO_2 emissions at tool booths, identify the average waiting time at Ghanaian Toll Plazas, ascertain how much will Ghana earn in carbon Credits if waiting time is reduced and finally advice policy makers on changing the current manual toll collection to more fast and efficient tolling systems.

To achieve the above objectives, the study randomly selected one big (Tema-bound toll plaza) and one small (Oyibi/Frafraha bound) toll plaza based on the criteria explained. After, the study with the help of GHA vehicle classifications, grouped vehicles that went through these toll plazas for the year 2014 into categories. This helped the study obtain results desired by the study objectives in terms of energy consumption, CO_2 emissions and Carbon Credit allocation. After a vehicular cross category analysis based on model variables obtained from literature, fieldwork and agencies was done, some concrete conclusions were drawn in terms of how toll plazas affect CO_2 emissions. The mechanical model used to calculate energy consumption rates revealed that in per vehicle terms, the Articulator/Heavy truck has the highest level of energy consumption followed by the Large bus/Light truck category, Mini vans/ Mummy wagons category, Pick-up/Vans/SUV category and the Saloon car category for both the Tema-bound toll plaza and the Oyibi/Frafraha bound toll plazas.

This rate was then applied to the CEF to obtain total CO_2 emissions rates at the two study sites. However, since the study wanted to know the effect on emissions as a result of idle/waiting time at these toll plazas, the study went further to collect information on average waiting time. This excess time spent at the toll stations was converted to distance and multiplied by the CO_2 emission rates to obtain actual CO_2 emissions per vehicle due to the presence of the toll plaza. Finally excess per vehicle CO_2 emissions was applied to vehicular traffic data on the Frafraha and the Tema toll plazas to obtain total annual vehicular excess CO_2 emissions for the year 2014.

One of the major additions of this study to literature stems from the idea of revenue creation through a reduction of the CO_2 emissions from toll plazas estimated in the study. The study confirms the fact based on the results obtained that if waiting time is removed completely through efficient measure at the toll booths, the country can earn some amount of revenue from Carbon Credits by selling the reduced cost of CO_2 emissions to supplement the Road Fund. On a monthly as well as shift basis, Ghana can earn huge amounts of revenue in

Carbon Credits at both toll plazas studied by reducing average waiting time of all vehicle categories that pass through such toll stations.

5.3 Recommendations for Policy and Future research

This study which aimed at valuating CO_2 emissions at toll plazas using case studies of the Tema and Oyibi/Frafraha toll plazas has shown results that are similar to related studies and predictions of certain theories. Based on the findings of the study the following recommendations are offered:

Due to the nature of vehicular volume sampled in the year 2014 as well as methodological procedures, this study which sought to value the amount of vehicular emissions at two toll plazas as other studies have done found that, toll plazas are significant niches for excess CO_2 generation. This casts no doubt on the application of efficient measures such as Intelligent Transport Systems (ITS) discussed in the next paragraphs to remedy the situation and in the long run reduce Climate Change as stated by Chapman (2007). Therefore Ghana should also employ efficient and effective means of toll collection that reduce excess humans interaction to ensure reduction in vehicular emissions in order to tap into the monetary gains shown by the study.

This can be done by employing some modern means of revenue collection at toll plazas. As research by Saka et al. (2001) and Teng et al. (2006) have shown, the employment of a modern system such as Electronic Toll Collection (ETC) can greatly reduce toll transaction time, human interaction and thereby increase service capacity. With this system human interaction at the toll plaza is minimal due to the fact that drivers would need just prepaid cards known in some countries like Singapore as “Cash Cards”. The driver swipes the card at a vending machine when at a toll booth and is allowed passage. In this case there is no need engaging the toll attendants to change bigger denominations which increase idle time.

Another modern measure the country can adopt to ensure efficiency and a reduction in excess emissions at toll plazas is the adoption of the Open Road Tolling (ORT). ORT is a kind of toll collection system where service time is zero and this has been proven by Klon-dzinski et al. (2012) and also Lin and Yu (2009) to be better than ETC when comparing air quality where these two systems are used. The country can adopt this system with the help of the DVLA. Vehicles, whiles undergoing yearly registration can be mandated to pay in addition to Road Worthiness some amount of money as Road Fund to serve as a toll fare. The drivers can be supplied with stickers to be pasted on their windscreens after payment. In such a scenario toll plazas will not serve as revenue collection points but as check points to ensure that each vehicle going through has paid through the recognition of the stickers given to them. This can greatly reduce emissions due to avoidance of deceleration and service time.

If the above recommendations are farfetched, then the country should improve on efficient management strategies at the toll stations. Toll stations should be expanded to have about ten (10) booths on each side of the road as explained by Opoku-Boahen et al. (2013) in an effort to reduce waiting time at smaller toll plazas. They explain that although this approach might be expensive it is a sure way of vehicular emissions reduction since a lot of vehicles can be served at once reducing waiting time. Moreover he suggests that if the proportion of manual lane usage is not reduced substantially in the short term then additional manual lanes would have to be provided to improve the level of service. These additional lanes could be retrofitted into ETC zone lanes in the future. This can be applied to small toll plaza that have a single booth on the truck road serving vehicles from both directions.

Also in relation to the Tema toll plaza efforts should be made to increase the proportion of E-zone lanes usage through attractive packages such as discounts per a number of trips, while some days and hours with very low traffic volume could have no toll charges at all. Though the E-zone lane is an improvement over the manual lanes, the fact that it uses a barrier for enforcement reduces its capacity, much lower waiting/queuing periods could be obtained if the barriers were removed and a system of cameras, backed by appropriate legal framework, were used for the enforcement of toll collection. The Police barrier at the Oyibi/Frafraha toll plaza should also be replaced by the measures explained above.

One other efficient toll management strategy is the creation of Truck only Toll (TOT) lanes where on approaching toll plazas, vehicles in the Articulator/Heavy truck category will have some toll booths designated for only such vehicles so as to be served separately. Based on the study it was concluded that Articulated/Heavy trucks have the highest level of emissions compared to other vehicle categories due to size and service time. Special lanes with special booths can be designed for the truck to facilitate their movement through the toll plaza so as to reduce emissions from these types of vehicles. Studies done in Atlanta, USA have verified this and shown that emissions can be reduced from such a strategy.

Lastly it should be noted that if some or most of all these management strategies are employed the country can go ahead to access the monetary benefits that go with it to supplement the Road Fund. This is the Carbon Credits Ghana can earn as a result of significantly reducing CO_2 emissions generated at toll plazas. It is advised that policy makers pursue Environmental Plans such as these that go a long way to reduce Climate Change impacts. Also in doing so the country will be ensuring its commitment to the environmental pacts and protocols it has appended its name to.

Future research on transport emissions should be expanded to look for other niches of excess CO_2 generation such as stop lights and very heavily congested traffic. Research should focus on these areas to find out the exact amounts in these CO_2 generation areas and also how to significantly reduce them. Moreover, research should also investigate other efficient toll management measures that are less expensive but can equally meet the goal of reducing CO_2 emissions. Measures like expanding the number of toll station can reduce waiting time but may incur costs to the government. Hence more cost friendly measures should be sought. Lastly future research should also concentrate on the analysis on vehicle volume variation during peak and non-peak periods since waiting time greatly varies according to these periods. Such studies will enable policy makers gain in-depth knowledge on how peak and non-peak period influence CO_2 emissions at toll plazas and how to work assiduously to minimize such transport emissions.

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APPENDICES

Appendix I: Vehicle Volume for Tema-Bound Toll Plaza in Shifts

		Vehicular Count for Morning Shift (TEMA)			
	SALOON CARS	MINI BUS,MUM WAGON	LARGE BUS, LIGHT TRUCK	PICK UP, VANS, 4X4, MED BUS	ARTICULATED TRUCK
January	112,984	89,355	18,866	23,568	8,754
February	115,432	68,885	15,923	19,548	7,352
March	113,861	73,689	17,830	22,158	8,672
April	111,322	67,938	19,025	26,516	8,354
May	116,427	83,286	18,309	23,864	9,201
June	114,732	90,009	20,136	25,068	10,462
July	113,745	88,362	21,057	23,216	9,210
August	109,342	95,426	19,953	18,568	8,720
September	115,321	80,675	17,469	22,954	8,813
October	115,432	90,289	23,589	26,294	8,671
November	113,923	78,598	19,753	23,012	7,347
December	112,876	83,654	24,568	21,578	8,229
Total	**1,365,397**	**990,166**	**236,478**	**276,344**	**103,785**

		Vehicular Count for Afternoon Shift (TEMA)			
	SALOON CARS	MINI BUS,MUM WAGON	LARGE BUS, LIGHT TRUCK	PICK UP, VANS, 4X4, MED BUS	ARTICULATED TRUCK
January	110,733	77,361	18,785	23,698	11,462
February	102,468	74,985	14,922	20,567	10,247
March	126,384	70,417	23,639	20,932	9,766
April	101,755	89,439	15,579	19,522	11,254
May	110,648	67,841	21,355	18,954	11,925
June	132,697	78,442	19,675	26,598	19,477
July	123,678	80,628	20,419	18,471	12,237
August	121,483	76,201	19,496	25,987	8,513
September	113,646	83,568	21,556	17,823	9,578
October	124,127	86,047	16,684	22,148	13,058
November	108,722	70,152	19,615	25,691	8,710
December	127,047	77,528	23,759	28,793	9,127
Total	**1,403,388**	**932,609**	235,484	**269,184**	**135,354**

		Vehicular Count for Night Shift (TEMA)			
	SALOON CARS	MINI BUS,MUM WAGON	LARGE BUS, LIGHT TRUCK	PICK UP, VANS, 4X4, MED BUS	ARTICULATED TRUCK
January	72,761	37,007	3,812	8,694	4,825
February	60,227	44,184	4,922	10,279	3,497
March	63,431	35,803	7,234	12,864	4,372
April	63,598	34,438	5,735	10,655	3,424
May	51,329	38,814	5,582	11,221	3,910
June	60,148	47,578	8,723	14,748	3,892
July	62,856	39,358	7,218	15,390	3,646
August	63,723	31,495	6,695	14,720	4,361
September	62,881	44,052	5,658	13,442	3,978
October	73,257	37,531	8,237	10,215	3,310
November	70,875	43,253	8,506	10,507	4,959
December	60,013	34,750	6,968	14,149	4,746
Total	**765,099**	**468,263**	**79,290**	**146,884**	**48,920**

Appendix II: Vehicle Volume for Oyibi/Frafraha-Bound Toll Plaza in Shifts

		Vehicular Count for Morning Shift (FRAFRAHA)			
	SALOON CARS	MINI BUS,MUM WAGON	LARGE BUS, LIGHT TRUCK	PICK UP, VANS, 4X4, MED BUS	ARTICULATED TRUCK
January	44,037	22,206	1,781	18,793	1,199
February	40,903	20,274	1,979	17,723	980
March	43,092	22,475	2,180	19,733	1,392
April	41,136	20,940	1,895	18,594	999
May	44,717	22,760	2,118	19,144	645
June	39,572	20,735	1,848	18,909	435
July	43,159	22,519	1,580	19,476	466
August	41,360	22,440	1,495	19,533	451
September	41,495	22,440	1,643	20,100	611
October	42,021	22,122	1,741	18,934	968
November	41,231	21,188	1,751	18,477	1,067
December	42,450	21,884	1,661	19,638	1,296
Total	**505,173**	**261,983**	**21,672**	**229,054**	**10,509**

		Vehicular Count for Afternoon Shift (FRAFRAHA)			
	SALOON CARS	MINI BUS,MUM WAGON	LARGE BUS, LIGHT TRUCK	PICK UP, VANS, 4X4, MED BUS	ARTICULATED TRUCK
January	46,917	21,772	1,803	19,806	870
February	42,787	21,105	1,965	18,219	612
March	46,589	22,839	2,249	20,715	932
April	42,808	19,872	1,958	17,233	704
May	45,663	22,466	2,180	19,589	326
June	39,684	20,780	2,034	18,593	274
July	44,249	22,202	1,698	18,565	523
August	45,658	22,588	1,566	20,256	505
September	43,790	21,915	1,855	19,935	415
October	42,413	22,158	1,735	19,586	587
November	43,065	22,054	1,517	19,175	772
December	43,311	22,547	1,544	19,579	771
Total	**526,934**	**262,298**	**22,104**	**231,251**	**7,291**

		Vehicular Count for Night Shift (FRAFRAHA)			
	SALOON CARS	MINI BUS,MUM WAGON	LARGE BUS, LIGHT TRUCK	PICK UP, VANS, 4X4, MED BUS	ARTICULATED TRUCK
January	14,044	5,521	503	4,269	63
February	13,379	5,519	505	4,186	54
March	15,323	5,806	741	4,373	123
April	14,007	5,064	560	4,037	64
May	14,109	5,343	546	4,044	62
June	12,405	4,924	432	3,960	40
July	12,314	5,286	437	4,226	368
August	13,388	4,968	408	4,173	327
September	12,938	5,059	431	3,981	205
October	14,688	5,752	477	4,329	175
November	14,571	5,376	439	4,251	218
December	16,520	6,232	534	4,717	299
Total	**167,686**	**64,850**	**6,013**	**50,546**	**1,998**

Appendix III: Total Vehicular Monthly Emissions (tCO_2) For Tema-bound Shift Periods

		Total Monthly Emissions for Morning Shift (TEMA)			
	SALOON CARS	MINI BUS,MUM WAGON	LARGE BUS, LIGHT TRUCK	PICK UP, VANS, 4X4, MED BUS	ARTICULATED TRUCK
January	6,101.14	9,918.41	7,037.02	1,626.19	8,342.56
February	6,233.33	7,646.24	5,939.28	1,348.81	7,006.46
March	6,148.49	8,179.48	6,650.59	1,528.90	8,264.42
April	6,011.39	7,541.12	7,096.33	1,829.60	7,961.36
May	6,287.06	9,244.75	6,829.26	1,646.62	8,768.55
June	6,195.53	9,991.00	7,510.73	1,729.69	9,970.29
July	6,142.23	9,808.18	7,854.26	1,601.90	8,777.13
August	5,904.47	10,592.29	7,442.47	1,281.19	8,310.16
September	6,227.33	8,954.93	6,515.94	1,583.83	8,398.79
October	6,233.33	10,022.08	8,798.70	1,814.29	8,263.46
November	6,151.84	8,724.38	7,367.87	1,587.83	7,001.69
December	6,095.30	9,285.59	9,163.86	1,488.88	7,842.24
Total	**73,731.44**	**109,908.43**	**88,206.29**	**19,067.74**	**98,907.11**

		Total Monthly Emissions for Afternoon Shift (TEMA)			
	SALOON CARS	MINI BUS,MUM WAGON	LARGE BUS, LIGHT TRUCK	PICK UP, VANS, 4X4, MED BUS	ARTICULATED TRUCK
January	5,979.58	8,587.07	7,006.81	1,635.16	10,923.29
February	5,533.27	8,323.34	5,565.91	1,419.12	9,765.39
March	6,824.74	7,816.29	8,817.35	1,444.31	9,307.00
April	5,494.77	9,927.73	5,810.97	1,347.02	10,725.06
May	5,974.99	7,530.35	7,965.42	1,307.83	11,364.53
June	7,165.64	8,707.06	7,338.78	1,835.26	18,561.58
July	6,678.61	8,949.71	7,616.29	1,274.50	11,661.86
August	6,560.08	8,458.31	7,272.01	1,793.10	8,112.89
September	6,136.88	9,276.05	8,040.39	1,229.79	9,127.83
October	6,702.86	9,551.22	6,223.13	1,528.21	12,444.27
November	5,870.99	7,786.87	7,316.40	1,772.68	8,300.63
December	6,860.54	8,605.61	8,862.11	1,986.72	8,698.03
Total	**75,782.95**	**103,519.60**	**87,835.53**	**18,573.70**	**128,992.36**

		Total Monthly Emissions for Night Shift (TEMA)			
	SALOON CARS	MINI BUS,MUM WAGON	LARGE BUS, LIGHT TRUCK	PICK UP, VANS, 4X4, MED BUS	ARTICULATED TRUCK
January	3,929.09	4,107.78	1,421.88	599.89	4,598.23
February	3,252.26	4,904.42	1,835.91	709.25	3,332.64
March	3,425.27	3,974.13	2,698.28	887.62	4,166.52
April	3,434.29	3,822.62	2,139.16	735.20	3,263.07
May	2,771.77	4,308.35	2,082.09	774.25	3,726.23
June	3,247.99	5,281.16	3,253.68	1,017.61	3,709.08
July	3,394.22	4,368.74	2,692.31	1,061.91	3,474.64
August	3,441.04	3,495.95	2,497.24	1,015.68	4,156.03
September	3,395.57	4,889.77	2,110.43	927.50	3,791.03
October	3,955.88	4,165.94	3,072.40	704.84	3,154.43
November	3,827.25	4,801.08	3,172.74	724.98	4,725.93
December	3,240.70	3,857.25	2,599.06	976.28	4,522.94
Total	**41,315.35**	**51,977.19**	**29,575.17**	**10,135.00**	**46,620.76**

Appendix IV: Total Vehicular Monthly Emissions (t/CO2) for Oyibi/Frafraha Shift Periods

	Total Monthly Emissions for Morning Shift (FRAFRAHA)				
	SALOON CARS	MINI BUS,MUM WAGON	LARGE BUS, LIGHT TRUCK	PICK UP, VANS, 4X4, MED BUS	ARTICULATED TRUCK
January	7,133.99	7,305.77	1,966.22	3,833.77	3,483.10
February	6,626.29	6,670.15	2,184.82	3,615.49	2,846.90
March	6,980.90	7,394.28	2,406.72	4,025.53	4,043.76
April	6,664.03	6,889.26	2,092.08	3,793.18	2,902.10
May	7,244.15	7,488.04	2,338.27	3,905.38	1,873.73
June	6,410.66	6,821.82	2,040.19	3,857.44	1,263.68
July	6,991.76	7,408.75	1,744.32	3,973.10	1,353.73
August	6,700.32	7,382.76	1,650.48	3,984.73	1,310.16
September	6,722.19	7,382.76	1,813.87	4,100.40	1,774.96
October	6,807.40	7,278.14	1,922.06	3,862.54	2,812.04
November	6,679.42	6,970.85	1,933.10	3,769.31	3,099.64
December	6,876.90	7,199.84	1,833.74	4,006.15	3,764.88
Total	**81,838.03**	**86,192.41**	**23,925.89**	**46,727.02**	**30,528.65**

	Total Monthly Emissions for Afternoon Shift (FRAFRAHA)				
	SALOON CARS	MINI BUS,MUM WAGON	LARGE BUS, LIGHT TRUCK	PICK UP, VANS, 4X4, MED BUS	ARTICULATED TRUCK
January	7,600.55	7,162.99	1,990.51	4,040.42	2,527.35
February	6,931.49	6,943.55	2,169.36	3,716.68	1,777.86
March	7,547.42	7,514.03	2,482.90	4,225.86	2,707.46
April	6,934.90	6,537.89	2,161.63	3,515.53	2,045.12
May	7,397.41	7,391.31	2,406.72	3,996.16	947.03
June	6,428.81	6,836.62	2,245.54	3,792.97	795.97
July	7,168.34	7,304.46	1,874.59	3,787.26	1,519.32
August	7,396.60	7,431.45	1,728.86	4,132.22	1,467.03
September	7,093.98	7,210.04	2,047.92	4,066.74	1,205.58
October	6,870.91	7,289.98	1,915.44	3,995.54	1,705.24
November	6,976.53	7,255.77	1,674.77	3,911.70	2,242.66
December	7,016.38	7,417.96	1,704.58	3,994.12	2,239.76
Total	**85,363.31**	**86,296.04**	**24,402.82**	**47,175.20**	**21,180.36**

	Total Monthly Emissions for Night Shift (FRAFRAHA)				
	SALOON CARS	MINI BUS,MUM WAGON	LARGE BUS, LIGHT TRUCK	PICK UP, VANS, 4X4, MED BUS	ARTICULATED TRUCK
January	2,275.13	1,816.41	555.31	870.88	183.02
February	2,167.40	1,815.75	557.52	853.94	156.87
March	2,482.33	1,910.17	818.06	892.09	357.32
April	2,269.13	1,666.06	618.24	823.55	185.92
May	2,285.66	1,757.85	602.78	824.98	180.11
June	2,009.61	1,620.00	476.93	807.84	116.20
July	1,994.87	1,739.09	482.45	862.10	1,069.04
August	2,168.86	1,634.47	450.43	851.29	949.94
September	2,095.96	1,664.41	475.82	812.12	595.53
October	2,379.46	1,892.41	526.61	883.12	508.38
November	2,360.50	1,768.70	484.66	867.20	633.29
December	2,676.24	2,050.33	589.54	962.27	868.60
Total	**27,165.13**	**21,335.65**	**6,638.35**	**10,311.38**	**5,804.19**

Appendix V: Total Monthly Vehicular Emissions (t/CO_2) For Both Toll Stations

	TEMA-BOUND MONTHLY EMISSIONS			
SALOON CARS	MINI BUS/MUM WAGON	LARGE BUS/LIGHT TRUCK	PICKUP/VANS/4X4/MED BUS	ARTICULATED TRUCK
16,009.81	22,613.25	15,465.70	3,861.24	23,864.07
15,018.86	20,873.99	13,341.09	3,477.19	21,515.88
16,398.50	19,914.40	18,166.22	3,860.83	21,737.93
14,940.45	21,291.58	15,046.45	3,911.82	21,949.50
15,033.82	21,083.45	16,876.76	3,728.69	23,859.31
16,285.16	23,979.22	18,103.18	4,582.57	32,240.94
16,215.07	23,126.74	18,162.86	3,938.31	23,913.63
15,905.59	22,546.54	17,211.71	4,089.98	20,579.08
15,759.79	23,120.75	16,666.76	3,741.11	21,317.66
16,892.06	23,739.24	18,094.23	4,047.33	23,862.17
15,850.08	21,312.33	17,857.00	4,085.49	20,028.25
16,196.54	21,748.45	20,625.04	4,451.88	21,157.55
190,505.74	**265,349.94**	**205,617.00**	**47,776.43**	**276,025.97**

		FRAFRAHA MONTHLY EMISSIONS			
	SALOON CARS	MINI BUS/MUM WAGOI	LARGE BUS/LIGHT TRUC	PICKUP/VANS/4X4/MED BUS	ARTICULATED TRUCK
January	17009.68	16285.17	4512.05	8745.07	6193.46
February	15725.18	15429.44	4911.70	8186.11	4781.63
March	17010.65	16818.48	5707.68	9143.48	7108.54
April	15868.06	15093.20	4871.95	8132.26	5133.14
May	16927.22	16637.20	5347.78	8726.51	3000.87
June	14849.08	15278.43	4762.66	8458.25	2175.85
July	16154.96	16452.30	4101.36	8622.47	3942.09
August	16265.77	16448.68	3829.78	8968.25	3727.12
September	15912.13	16257.21	4337.62	8979.26	3576.06
October	16057.76	16460.53	4364.11	8741.20	5025.65
November	16016.45	15995.32	4092.53	8548.21	5975.59
December	16569.52	16668.13	4127.86	8962.54	6873.23
TOTAL	**194366.47**	**193824.10**	**54967.06**	**104213.60**	**57513.19**

VI. Total Monthly Shift Carbon Credit Earnings (US$) at the Tema Bound Toll Plaza

	Total Monthly Earnings for Morning Shift (TEMA)				
	SALOON CARS	MINI BUS,MUM WAGON	LARGE BUS, LIGHT TRUCK	PICK UP, VANS, 4X4, MED BUS	ARTICULATED TRUCK
January	$ 4,209.78	$ 13,984.95	$ 33,425.84	$ 1,431.05	$ 101,111.85
February	$ 4,301.00	$ 10,781.19	$ 28,211.58	$ 1,186.95	$ 84,918.25
March	$ 4,242.46	$ 11,533.07	$ 31,590.30	$ 1,345.43	$ 100,164.72
April	$ 4,147.86	$ 10,632.98	$ 33,707.54	$ 1,610.05	$ 96,491.71
May	$ 4,338.07	$ 13,035.09	$ 32,438.97	$ 1,449.02	$ 106,274.86
June	$ 4,274.91	$ 14,087.31	$ 35,675.96	$ 1,522.13	$ 120,839.87
July	$ 4,238.14	$ 13,829.54	$ 37,307.74	$ 1,409.68	$ 106,378.82
August	$ 4,074.08	$ 14,935.12	$ 35,351.73	$ 1,127.45	$ 100,719.14
September	$ 4,296.86	$ 12,626.44	$ 30,950.70	$ 1,393.77	$ 101,793.32
October	$ 4,301.00	$ 14,131.13	$ 41,793.81	$ 1,596.57	$ 100,153.17
November	$ 4,244.77	$ 12,301.37	$ 34,997.38	$ 1,397.29	$ 84,860.49
December	$ 4,205.76	$ 13,092.69	$ 43,528.35	$ 1,310.22	$ 95,047.91
Total	**$ 50,874.69**	**$ 154,970.88**	**$ 418,979.90**	**$ 16,779.61**	**$ 1,198,754.11**

	Total Monthly Earnings for Afternoon Shift (TEMA)				
	SALOON CARS	MINI BUS,MUM WAGON	LARGE BUS, LIGHT TRUCK	PICK UP, VANS, 4X4, MED BUS	ARTICULATED TRUCK
January	$ 4,125.91	$ 12,107.77	$ 33,282.32	$ 1,438.94	$ 132,390.23
February	$ 3,817.96	$ 11,735.90	$ 26,438.05	$ 1,248.83	$ 118,356.54
March	$ 4,709.07	$ 11,020.96	$ 41,882.40	$ 1,270.99	$ 112,800.82
April	$ 3,791.39	$ 13,998.10	$ 27,602.09	$ 1,185.38	$ 129,987.75
May	$ 4,122.74	$ 10,617.79	$ 37,835.72	$ 1,150.89	$ 137,738.04
June	$ 4,944.29	$ 12,276.96	$ 34,859.18	$ 1,615.03	$ 224,966.36
July	$ 4,608.24	$ 12,619.09	$ 36,177.36	$ 1,121.56	$ 141,341.76
August	$ 4,526.46	$ 11,926.22	$ 34,542.04	$ 1,577.93	$ 98,328.21
September	$ 4,234.45	$ 13,079.23	$ 38,191.84	$ 1,082.21	$ 110,629.35
October	$ 4,624.97	$ 13,467.22	$ 29,559.88	$ 1,344.83	$ 150,824.60
November	$ 4,050.98	$ 10,979.49	$ 34,752.88	$ 1,559.96	$ 100,603.64
December	$ 4,733.77	$ 12,133.91	$ 42,095.01	$ 1,748.31	$ 105,420.14
Total	**$ 52,290.24**	**$ 145,962.63**	**$ 417,218.78**	**$ 16,344.85**	**$ 1,563,387.43**

	Total Monthly Earnings for Night Shift (TEMA)				
	SALOON CARS	MINI BUS,MUM WAGON	LARGE BUS, LIGHT TRUCK	PICK UP, VANS, 4X4, MED BUS	ARTICULATED TRUCK
January	$ 2,711.07	$ 5,791.97	$ 6,753.91	$ 527.90	$ 55,730.49
February	$ 2,244.06	$ 6,915.24	$ 8,720.55	$ 624.14	$ 40,391.61
March	$ 2,363.44	$ 5,603.53	$ 12,816.84	$ 781.10	$ 50,498.17
April	$ 2,369.66	$ 5,389.89	$ 10,160.99	$ 646.97	$ 39,548.43
May	$ 1,912.52	$ 6,074.78	$ 9,889.91	$ 681.34	$ 45,161.91
June	$ 2,241.11	$ 7,446.43	$ 15,454.98	$ 895.50	$ 44,954.00
July	$ 2,342.01	$ 6,159.92	$ 12,788.49	$ 934.48	$ 42,112.61
August	$ 2,374.32	$ 4,929.28	$ 11,861.87	$ 893.80	$ 50,371.12
September	$ 2,342.95	$ 6,894.58	$ 10,024.56	$ 816.20	$ 45,947.33
October	$ 2,729.56	$ 5,873.98	$ 14,593.90	$ 620.25	$ 38,231.69
November	$ 2,640.80	$ 6,769.53	$ 15,070.51	$ 637.99	$ 57,278.24
December	$ 2,236.08	$ 5,438.72	$ 12,345.55	$ 859.13	$ 54,818.01
Total	**$ 28,507.59**	**$ 73,287.84**	**$ 140,482.06**	**$ 8,918.80**	**$ 565,043.61**

Appendix VII: Total Monthly Carbon Credit Earnings (US$) at the Oyibi/Frafraha Bound Toll Plaza

	Total Monthly Emissions for Morning Shift (FRAFRAHA)				
	SALOON CARS	MINI BUS,MUM WAGON	LARGE BUS, LIGHT TRUCK	PICK UP, VANS, 4X4, MED BUS	ARTICULATED TRUCK
January	90,716.22	93,043.14	25,005.24	48,861.80	44,303.05
February	84,260.18	84,948.06	27,785.16	46,079.80	36,211.00
March	88,769.52	94,170.25	30,607.20	51,305.80	51,434.40
April	84,740.16	87,738.60	26,605.80	48,344.40	36,913.05
May	92,117.02	95,364.40	29,736.72	49,774.40	23,832.75
June	81,518.32	86,879.65	25,945.92	49,163.40	16,073.25
July	88,907.54	94,354.61	22,183.20	50,637.60	17,218.70
August	85,201.60	94,023.60	20,989.80	50,785.80	16,664.45
September	85,479.70	94,023.60	23,067.72	52,260.00	22,576.45
October	86,563.26	92,691.18	24,443.64	49,228.40	35,767.60
November	84,935.86	88,777.72	24,584.04	48,040.20	39,425.65
December	87,447.00	91,693.96	23,320.44	51,058.80	47,887.20
Total	**1,040,656.38**	**1,097,708.77**	**304,274.88**	**595,540.40**	**388,307.55**

	Total Monthly Emissions for Afternoon Shift (FRAFRAHA)				
	SALOON CARS	MINI BUS,MUM WAGON	LARGE BUS, LIGHT TRUCK	PICK UP, VANS, 4X4, MED BUS	ARTICULATED TRUCK
January	96,649.02	91,224.68	25,314.12	51,495.60	32,146.50
February	88,141.22	88,429.95	27,588.60	47,369.40	22,613.40
March	95,973.34	95,695.41	31,575.96	53,859.00	34,437.40
April	88,184.48	83,263.68	27,490.32	44,805.80	26,012.80
May	94,065.78	94,132.54	30,607.20	50,931.40	12,045.70
June	81,749.04	87,068.20	28,557.36	48,341.80	10,124.30
July	91,152.94	93,026.38	23,839.92	48,269.00	19,324.85
August	94,055.48	94,643.72	21,986.64	52,665.60	18,659.75
September	90,207.40	91,823.85	26,044.20	51,831.00	15,334.25
October	87,370.78	92,842.02	24,359.40	50,923.60	21,689.65
November	88,713.90	92,406.26	21,298.68	49,855.00	28,525.40
December	89,220.66	94,471.93	21,677.76	50,905.40	28,488.45
Total	**1,085,484.04**	**1,099,028.62**	**310,340.16**	**601,252.60**	**269,402.45**

	Total Monthly Emissions for Night Shift (FRAFRAHA)				
	SALOON CARS	MINI BUS,MUM WAGON	LARGE BUS, LIGHT TRUCK	PICK UP, VANS, 4X4, MED BUS	ARTICULATED TRUCK
January	28,930.64	23,132.99	7,062.12	11,099.40	2,327.85
February	27,560.74	23,124.61	7,090.20	10,883.60	1,995.30
March	31,565.38	24,327.14	10,403.64	11,369.80	4,544.85
April	28,854.42	21,218.16	7,862.40	10,496.20	2,364.80
May	29,064.54	22,387.17	7,665.84	10,514.40	2,290.90
June	25,554.30	20,631.56	6,065.28	10,296.00	1,478.00
July	25,366.84	22,148.34	6,135.48	10,987.60	13,597.60
August	27,579.28	20,815.92	5,728.32	10,849.80	12,082.65
September	26,652.28	21,197.21	6,051.24	10,350.60	7,574.75
October	30,257.28	24,100.88	6,697.08	11,255.40	6,466.25
November	30,016.26	22,525.44	6,163.56	11,052.60	8,055.10
December	34,031.20	26,112.08	7,497.36	12,264.20	11,048.05
Total	**345,433.16**	**271,721.50**	**84,422.52**	**131,419.60**	**73,826.10**

Appendix VIII: Total Monthly Vehicular Earnings (US$) For the Tema-bound and the Oyibi/Frafraha Toll Stations

	TEMA MONTHLY EARNINGS				
	SALOON CARS	MINI BUS/MUM WAGON	LARGE BUS/LIGHT TRUCK	PICKUP/VANS/4X4/MED BUS	ARTICULATED TRUCK
January	$ 11,046.77	$ 31,884.69	$ 73,462.07	$ 3,397.89	$ 289,232.56
February	$ 10,363.01	$ 29,432.33	$ 63,370.18	$ 3,059.92	$ 260,772.48
March	$ 11,314.97	$ 28,079.30	$ 86,289.54	$ 3,397.53	$ 263,463.71
April	$ 10,308.91	$ 30,021.12	$ 71,470.62	$ 3,442.40	$ 266,027.89
May	$ 10,373.33	$ 29,727.67	$ 80,164.60	$ 3,281.25	$ 289,174.81
June	$ 11,236.76	$ 33,810.70	$ 85,990.11	$ 4,032.66	$ 390,760.23
July	$ 11,188.40	$ 32,608.70	$ 86,273.59	$ 3,465.72	$ 289,833.18
August	$ 10,974.86	$ 31,790.62	$ 81,755.63	$ 3,599.18	$ 249,418.47
September	$ 10,874.26	$ 32,600.25	$ 79,167.11	$ 3,292.18	$ 258,370.00
October	$ 11,655.52	$ 33,472.32	$ 85,947.59	$ 3,561.65	$ 289,209.46
November	$ 10,936.56	$ 30,050.39	$ 84,820.76	$ 3,595.23	$ 242,742.37
December	$ 11,175.62	$ 30,665.32	$ 97,968.92	$ 3,917.65	$ 256,429.54
TOTAL	**$ 131,448.96**	**$ 374,143.42**	**$ 976,680.73**	**$ 42,043.26**	**$ 3,345,434.72**

	FRAFRAHA MONTHLY EARNINGS				
	SALOON CARS	MINI BUS/MUM WAGOI	LARGE BUS/LIGHT TRUC	PICKUP/VANS/4X4/MED BUS	ARTICULATED TRUCK
January	$ 35,039.93	$ 68,234.87	$ 63,349.15	$ 22,737.19	$ 228,848.35
February	$ 32,393.87	$ 64,649.36	$ 68,960.21	$ 21,283.89	$ 176,681.23
March	$ 35,041.93	$ 70,469.43	$ 80,135.83	$ 23,773.06	$ 262,660.37
April	$ 32,688.21	$ 63,240.52	$ 68,402.21	$ 21,143.87	$ 189,669.34
May	$ 34,870.07	$ 69,709.87	$ 75,082.78	$ 22,688.92	$ 110,881.96
June	$ 30,589.11	$ 64,016.63	$ 66,867.69	$ 21,991.44	$ 80,397.47
July	$ 33,279.23	$ 68,935.15	$ 57,583.09	$ 22,418.42	$ 145,660.04
August	$ 33,507.49	$ 68,919.99	$ 53,770.06	$ 23,317.44	$ 137,716.90
September	$ 32,778.98	$ 68,117.69	$ 60,900.13	$ 23,346.09	$ 132,135.23
October	$ 33,078.99	$ 68,969.61	$ 61,272.13	$ 22,727.11	$ 185,697.77
November	$ 32,993.90	$ 67,020.40	$ 57,459.09	$ 22,225.35	$ 220,797.87
December	$ 34,133.22	$ 69,839.45	$ 57,955.10	$ 23,302.59	$ 253,965.85
TOTAL	**$ 400,394.92**	**$ 812,122.97**	**$ 771,737.47**	**$ 270,955.37**	**$ 2,125,112.37**