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An Assessment of the Contribution of the Corporate Taxi Industry to the Nairobi County Carbon Emission

By

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A project paper submitted in partial fulfilment of the requirements for the Degree of Masters of Arts in Environmental Planning and Management, of the University of Nairobi, Department of Geography and Environmental Studies

DECLARATION

This project is my original work and has not been presented in any other university or institution of learning for any award of a Degree whatsoever.

SIGN……………………………………………DATE……………………………..………

James Chacha Maroa

This research project has been submitted for examination with my approval as University Supervisor.

SIGN……………………………………….. DATE……………………………….............

Dr. J. M. Moronge

DEDICATION

I would like to dedicate this research paper to my family for their support, To Winfred Riziki and Dorcas Nthoki. There is no doubt in my mind that without their continued support I could nothave completed this project. Thank to you all for being there for me.

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ABBREVIATIONS AND ACRONYMS

TAPs	Toxic Air Pollutants
TSP	Total Suspended Particulates
U.S EPA	Environmental Protection Agency
CO	Carbon Monoxide
CxHx	Hydrocarbons
NOx	Nitrogen oxides
SO2	Suffer dioxide
O3	Ozone
KNBS	Kenya National Bureau of Standards
ATIB	Australian Taxi Industry Board
IRU	International Transport Union
IOCA	International Organization of Motor Vehicle Manufacturers
WHO	World Health Organisation
UN HABITAT	United Nations Human Settlements Programme
UNEP	United Nations Environmental Programme
MoNMP	Ministry of Nairobi Metropolitan Development
EUI	Economist Intelligence Unit
LPG	Liquefied petroleum gas
NEMA	The National Environment Management Authority
EMCA	Environmental Management and Coordination Act
SERC	Standards Enforcement and Review Committee
TCR	The Climate Registry

ABSTRACT

The automotive industry is a big contributor to the global carbon emissions. Most developed countries have continued to research towards reaching an agreeable emissions estimate not only at the country level but further into respective economic sectors. It is even possible to accurately calculate a family's daily carbon emissions and make emission friendly decisions. In Africa, beyond the continent estimate, it is impossible to ascertain industry or country specific footprint. This study thus seeks to bridge this gap by use of quantitative research approach to establish the emission potential of corporate taxi industry taking the case of Nairobi County. With the objective of establishing the growth rate of the corporate taxi industry in Nairobi County and further quantify the corporate taxi industry carbon emission contribution to the Nairobi County footprint. This study presents the industry growth rate, challenges experienced by the industry stakeholders, biases to choice of taxi vehicle, the industry preferences and knowledge of existence of other green vehicle alternatives. The study employed calculation based method and a generalised methodology to calculate the carbon emission and defends the null hypothesis. It is evident from findings that there is a consistent growth in the corporate taxi industry and an equal significant contribution of carbon emission. Using the collated information, the study projects the possible industry emissions scenario in the event the current status remains whilst presenting players-felt solutions. The study recommends government initiatives in setting up promotive and control policies and regulation to guide the industry towards adopting clean alternative vehicles to reduce carbon and automotive emissions. This may include control, incentives and public awareness program. Besides the Fossil Fuel Emissions Control Regulations, other sector-specific regulatory controls like Fuel Economy Standards to encourage reduced transport related fuel demand through vehicle fuel efficiency improvements among other controls are recommended. The study recommends areas for further research work for instance the need to research on the emission streams from varied industries into Nairobi carbon footprint i.e. construction, agriculture, manufacturing, transport etc. The research hopes to create awareness and build on past works on urban air pollution in Africa and trigger further research in the area of automotive emissions.

1. CHAPTER ONE: INTRODUCTION

1.1 Background of the study

Nairobi is the largest city in East Africa and the most populated with a population of over 3.2 million people. It covers a spatial area of about 700 km^2 and has the greatest concentration of industrial and vehicle air pollutant sources. (Vision 2030 -Rethinking Road Traffic Report: 2010). It is reputed to be the fastest growing city in the World after Guadaloupe, Mexico City and Maputo (CITE report, 2011). Nairobi does not have any regular air quality management system yet, and any measurements of air pollution have been done on an ad hoc basis. (Kariuki 2003). Out of 20 mainly developing country cities sampled for a UN study on air quality management capability, Nairobi's status was rated as the worst (UNEP/WHO, 1996). Although in general, the current quality of air in Nairobi does not present a critical health or environmental problem, however available data indicates that air quality has been rapidly deteriorating (Ngugi, 1983 and Karue, 1991). The situation can only get worse with the increasing population, growing industrial area, increasing deforestation on the city's fringes, increased construction works and the pacing vehicular traffic.

In 2006, Van and Kinney advanced that, *"motor vehicles are the greatest contributors of air pollution in Nairobi"* (Van and Kinney, 2006:186). In their research, they observed that particulate matter (PM) mean values of 239µg/m3 and 396µg/m3 were found in most of their samples which are higher than the World Health Organization limits of 150µg/m. Their observation of high concentration of SOx, NOx and Carbon during peak traffic hours made them conclude that vehicles are the major source of the pollutants. However, not much has been done to quantify the contribution of vehicular emission to the Nairobi carbon emissions. This research thus seeks to establish the growth rate of the corporate taxi industry and further quantifying their contribution to the Nairobi carbon emission.

Findings of this study are of great value for they provoke different players in the transport sector, more importantly the corporate taxi industry operators, respective government ministries, taxi services consumers, regulatory authorities e.g. National Environmental Authority (NEMA), Kenya Bureau of Standards (KEBS), Nairobi County Council (NCC), Kenya Air ports Authority (KAA) among others to make informed decision in relation to enforcing their mandate. This mandate encompasses review of regulatory framework and policy formulation, sustainable transport planning and management, standards formulation and enforcement, further research and resource planning among others. These decisions are very important in steering the country towards sustainable green transport as envisaged in the economic, social and political pillars of Kenya Vision 2030 section 2; Infrastructure. The study is also an example to other local researchers interested in doing further studies in motor vehicle emissions with the aim of filling the existing gap in motor vehicle emission in Nairobi County.

1.2 Statement of the Problem

One of the pressing challenges facing cities in both the developed and developing world is how to reduce automotive pollution. Rapid urbanization, increasing demand for mobility, high operational costs and crumbling infrastructure have resulted into a state of deteriorated vehicular transportation services in most urban settings consequently making urban air pollution an important phenomena of study. (Sarokin, 1992:39) and (Schulkin 1996:21). Atmospheric pollution has a harmful impact on health and automobile pollution is one of the key sources. (Gramer, 1991:23) and (Chevreuil,1991:785 – 788). In urban areas, motor vehicles contribute the highest proportion of carbon monoxide/dioxide and other Toxic Air Pollutants (TAPs) such as benzene, formaldehyde, 1,3-butadiene etc. that have the potential to cause serious adverse health impacts on humans like neurological related problems, cardiovascular illnesses, liver, kidney, and respiratory effects or effects on the immune and reproductive systems. (U.S. Environmental Protection Agency, 1999:92). Most local authorities and countries consider this source a threat to its national and local population and have made strict bylaws and regulations to regulate emissions from motor vehicles as much as possible. (Jicha and Katolicky, 2000:343). Kenya is in the process of formulating a policy framework for regulating motor vehicle emission.

Nairobi being a county that dominantly depends on vehicular transport, its inhabitants are exposed to challenges ranging from poor transport systems and infrastructure, traffic jam, poor enforcement of traffic rules, harassment from police and air pollution related impacts. (Fedra, 2000). This compounded by the fact that efficient tools and regulatory policies for comprehensive strategic management which are directly useful to city automotive administrations are lacking, worsens the challenges.

Whilst the government is in its preliminary stages of preparing a Motor Vehicle Emission Reduction Policy Framework, there is need to base it on factual information and modelled research work. Little has been done in this sector. Kenya lacks air quality data and there exists no air quality monitoring station. (Van and Kinney 2006). Existing research work is centred on Nairobi City and is based on spontaneous and spot air quality readings especially along transport corridors. Equally, no air quality modelling has been done to depict the city status. (International Conference on Spatial Information for Sustainable Development Report, 2011)

Fedra (2000), notes that there is need for continued traffic equilibrium modelling to evaluate alternative transportation policies, including multi-modal systems and high-occupancy vehicles. He acknowledges that emission modelling that translates the results of the transportation model such as traffic frequencies and driving conditions together with the fleet composition into air quality modelling is important in forecasting emission scenarios into ambient air quality. Knowledge of the air quality of cities on a real time basis, their sources and the proportion of each source is important in planning for, and implementing practical regulatory and containment measures. (Kariuki -2003).

Taking the case of the corporate taxi industry, this study investigated the growth rate of the corporate taxi industry in Nairobi County, the challenges they face and their contribution to the Nairobi carbon footprint. It further presents potential solutions available in ameliorating this challenge.

1.3 General Research Objective

To establish the contribution of the corporate taxi industry to the Nairobi County carbon footprint and determine available opportunities for improvement.

1.4 Research Objectives

The study was guided by the following objectives:

(i) To establish the growth rate of the corporate taxi industry in Nairobi County since 1990.

(ii) To quantify the corporate taxi industry carbon emission contribution to the Nairobi County.

1.5 Research Questions

This study sought to answer two questions namely?

(iii) What is the growth rate of the corporate taxi industry in Nairobi County?

(iv) What is the contribution of the corporate taxi industry carbon emission contribution to the Nairobi County footprint?

1.6 Research Hypothesis

H_0The corporate taxi industry does not contribute significant carbon emission to the Nairobi County carbon footprint.

H_1The corporate taxi industry contributes significant carbon emission to the Nairobi County carbon footprint.

1.7 Scope of the Study

This study limited itself to registered corporate taxi companies operating within the administrative boundaries of Nairobi County.

1.8 Justification of the Study

Nairobi is one of the unique counties in Kenya acting as both the country's capital city and the county administrative centre. It is the most populated county and has the greatest concentration of industrial and vehicle air pollutant sources in Kenya. (Vision 2030 - Rethinking Road Traffic Report: 2010, EIU 2014). It was found to be one of the fastest growing city in the world at position 115 after Guadaloupe, Mexico and Maputo (CITE report, 2011) and out of the twenty capital cities of African countries samples by the UNEP and WHO study on air quality management capability in 2009, Nairobi was ranked last with most of the parameters exceeding the WHO permissible levels. This made Nairobi an interesting county of my study. It would also further benefit highly from the findings of this undertaking.

This study intended to model the wholesome automotive emission from mobile sources including both the public and private vehicles. However, due to the challenges of how to measure key variables of this study arising from how this industry is run made it impossible. Preliminary review revealed that most of the public service vehicles for instance do not keep records of fuel consumption, and if they do it was for a short period of time. One cannot trace back record to one or two years back. Frequency of servicing was not defined and the business proponents did not run the businesses for a long time. This made it difficult and influenced the study to focus on corporate taxi companies which unlike the public and private vehicles operated their businesses in an organization-like nature. Records of key variables were well kept and this made this study practical and thus corporate taxi industry was the better choice. .

1.9 Significance of the Study

The findings of this study are very helpful to the Ministry of Environment, Water and Natural Resources that are spearheading the formulation of the "Motor Vehicle Carbon Reduction Strategy" in collaboration with other partnering ministries and non-governmental organizations. The knowledge serves the purpose of informing and further forms a basis to trigger detailed research in the automotive industry.

The knowledge of existing industry challenges, un-exploited potential and possible solution to the current state, together with the recommended controls will continue to improve the corporate taxi industry stakeholders' awareness thus obliging them to change their attitude towards adopting green car solutions. With these continued adoptions, automotive emissions will reduce leading to improved air quality and a better environment in which we live in.

1.10 Definition of Operational Terms

Carbon footprint: It is the amount of carbon (C02) we emit individually or per specific activity or category of operation in any one-year period.

Taxi: An automobile that carries passengers for a fare usually determined by the distance or time travelled usually hired along with its driver to carry passengers to specified destination.

Corporate Taxi: Private companies providing taxi services but limited to organised corporate companies like banks, industries, non-governmental organizations etc.

Automotive: A moving machine which operates by a self-contained engine or motor and is controlled by humans.

Car: A road vehicle, typically with four wheels, powered by an internal combustion engine and able to carry a small number of people.

LPG: Liquefied petroleum gas, also called LPG, GPL, LP Gas simply is a flammable mixture of hydrocarbon gases used as a fuel in heating appliances and vehicles. When specifically used as a vehicle fuel it is often referred to as auto gas.

Petrol: Is transparent, petroleum-derived oil that is used primarily as a fuel in internal combustion engines. It consists mostly of organic compounds obtained by the fractional distillation of petroleum, enhanced with a variety of additives. It is sometimes referred to as gasoline.

CNG: Compressed natural gas/(Methane) stored at high pressure is a naturally occurring hydrocarbon gas mixture consisting primarily of methane, but commonly includes varying amounts of other higher alkenes and even a lesser percentage of carbon dioxide, nitrogen, and hydrogen sulphide. It can be can be used in place of gasoline (petrol), Diesel fuel and propane/LPG.

Green car: A vehicle that is considered to be environmentally friendly and has less of a damaging impact on the environment than conventional cars. It consumes less petroleum than conventional cars or uses renewable energy sources to fuel its engine.

Air Pollution: Any atmospheric condition in which certain substances are present in such concentrations and duration that they may produce harmful effects on man and his environment

Air Quality: The degree to which the ambient air is pollution-free, assessed by measuring a number of indicators of pollution.

Toxic Air Pollutants: Toxic Air Pollutants or Hazardous Air Pollutants (HAPs) are those pollutants that have the potential to cause serious adverse health effects in humans.

2. CHAPTER TWO: LITERATURE REVIEW

This chapter collates literature related to the study. It examined the global and local concern on the subject of urban air pollution with a major focus on the motor vehicle transport industry. It employed a funnel approach in examining the situation of carbon emission at the global level, Africa and Kenyan level before focusing on Nairobi County. It further examined government legislations and policies in existence and those in draft that are triggered by the transport and motor vehicle industry in relation to air quality and emissions.

2.1 Global Growth in Production of Motor Vehicles

The growth in the production of motor vehicles since the end of World War II has been quite dramatic. It has risen from approximately one million motor vehicles per year in 1950s to about 55 million in 2011. Regional dominance in production equally shifted from North America in 1950s to Europe through 1960s and currently the Asian region led by Japan. (MacKenzie,1992). Africa however poised to grow substantially in future decades from its present unexploited and demanding market due to its increasing population growth, amplified urbanization and high rate of industrialization. (Walsh, 1990).

A study done by the International Organization of Motor Vehicle Manufacturers (IOCA, 2007) revealed that cars make up to approximately 74% of the annual total motor vehicle produced in the world. The remaining 26% are made up of light commercial vehicles and heavy trucks, buses, coaches and minibuses. The total number of cars produced this year alone as at 4th June 2012(12:23hrs) as displayed on the online worldometer website was: 35,962,667. The (IOCA, 2007) report approximates the motor vehicles across the world to be growing at about 4 million vehicles per year with an estimated current global fleet of about 815 million.

In 2009, a research done by the International Transport Union (IRU, 2009) revealed that there are more than one million taxis in Europe alone, accounting for about 5% of the European local public transport. The Australian Taxi Industry Board Strategic Plan, (ATIB, 2008) noted the growth of the taxi industry in the metropolitan area to be growing at a rate of 11.4% and forecasted it to shoot up given the projected increase in the taxi demand from 12.0% in 2010 to 18% in 2025.

It is difficult to establish and compare how each kind of automobile is growing against each other globally. It is further not clear what use each automobile is put into once purchased. However it is clear that the manufacture of small cars has tripled more than any other automobile produced. (IRU, 2009) Some countries like Australia, United States, and Netherlands have real-time monitory systems of automobile manufacture and use information. This allows for computation of factual information on what percentage of a type of automobile e.g. trucks used for cargo transport, vans used for tour services, cars are used as taxis, or as private.

Omwenga (2005) estimated the total automobiles in Kenya to be at 749, 680 units in 2005 of which 320,068 were small cars. There is no accurate and readily available data on motor car ownership in Nairobi yet, not even car use information. In his work, he was unable to indicate what percentage of 320,068 cars were private cars, what percentage are taxi and even how many of these are still on the road or are written off. He however concluded that Nairobi County represents approximately 30% of the total cars in Kenya.

Records from the Kenya National Bureau of Standards Motor Vehicle Register (2012) show that motor cars only in Kenya have increased from 211,916 in 1997 to 499,679 in 2009 (KNBS, 2010). Comparing these against - 1,221,083 - the total number of vehicles registered in 2009, (KNBS, 2010). It is evident that the motor cars represent approximately one third of the total cars in Kenya. This statistics equally fail to classify what percentage of these total cars operates in Nairobi, Kisumu, Mombasa and other urban and/or rural areas. The statistics equally fail to present what use are the cars or other motor vehicles put into. It is unlikely that we can establish what percentage of 499,679 motor cars registered in 2009 are used as taxi, car hire, company cars or are used privately in Kenya or even in the city of Nairobi alone. The Table 1 presents statistics of registered cars from the KNBS website. *(http://www.knbs.or.ke/registered%20vehicles.php)* as accessed on 12th June 2013.

Registered Vehicles Between 2001 to 2009

YEAR / VEHICLE TYPE	2001	2002	2003	2004	2005	2006	2007	2008	2009
Motor Cars	255,379	269,925	286,281	307,772	329,068	372,530	410,812	450,137	499,679
Utilities, Panels Vans, Pick-ups, etc	162,603	166,811	172,571	179,613	184,125	195,153	202,671	209,628	219,901
Lorries, Trucks and Heavy Vans	58,501	59,835	61,538	63,999	66,472	69,716	75,347	81,285	91,431
Buses and Mini-buses	42,629	46,606	50,428	55,705	60,109	50,242	55,997	61,886	84,844
Motor and Auto cycles	46,004	47,451	49,257	53,508	57,465	63,321	78,981	130,307	252,960
Trailers	13,897	14,261	14,994	16,106	17,296	40,010	41,803	43,485	27,039
Other motor vehicles**	32,255	32,724	33,439	34,439	35,145	28,472	30,961	32,710	45,229
Total	611,268	637,613	668,508	711,142	749,680	819,444	896,572	1,009,438	1,221,083

Table 1: Vehicle Registration ***(Source: KNBS Website: http://www.knbs.or.ke/registered%20vehicles.ph) accessed on 12 June 2013***

It is important to note that not only are the automobile numbers increasing but also the miles traveled by each user. Stephen Glaister (2011), associates this increase to the rapid changing lifestyles which necessitates the need for rapid mobility. He argues that motor vehicle distance traveled per capita (expressed as vehicle kilometers or miles traveled per person), has peaked in at least eight major developed countries and continues to grow rapidly in urban areas and cities. He strongly disagrees with the hypothesis that car use would eventually reach a saturation level and stop growing, further put forward in 1930s and advanced by Puentes, R. and Tomer, A. (2009).

2.2 Urban Air Pollution

Blacksmith Institute Report (2007), notes that common air pollutants include carbon monoxide, nitrogen oxide, sulphur dioxide, lead and Total Suspended Particulates (TSP), the latter being the most widespread and the most serious for human health. The potential for serious consequences of exposure to high levels of ambient air pollution was made clear in the mid-20th century, when cities in Europe and the United States experienced episodes of air pollution, such as the infamous London Fog of 1952 and Donora Smog of 1948, which resulted in large numbers of excess deaths and hospital admissions. Subsequent clean air legislation and other regulatory actions led to the reduction of ambient air pollution in many regions of the world, and particularly in the wealthy developed countries of North America and Europe. New epidemiological studies, conducted over the last decade, using sensitive designs and methods of analysis, have identified adverse health effects caused by combustion-derived air pollution even at the low ambient concentrations that now generally prevail in cities in Africa and Asia (Health Effects Institute 2001). At the same time, the populations of the rapidly expanding mega-cities of Asia, Africa and Latin America are increasingly exposed to levels of ambient combustion-related pollution that rival and often exceed the levels experienced in developed countries in the first half of the 20th century. Current scientific evidence, derived largely from studies in North America and western Europe, indicates that urban air pollution causes a spectrum of effects on health, ranging from eye irritation to death (Brunekreef 1997). Recent assessments suggest that the impacts on public health may be considerable (Cite 2001).

Quantifying the magnitude of the impact of air pollution in cities, especially in Africa presents considerable challenges owing to the limited availability of information on both effects on health and on exposures to air pollution. Measurements of urban air pollution even when available are largely for a non-representative sample of urban areas and are static. Brasseur et al (2001), in his work advances that the major sources of air pollutants are man's industrial manufacturing and motor vehicle operation activities, both of which are concentrated in urban areas, where also the bulk of the world's population lives. UNEP, (2007), further estimates that more than 90% of urban air pollution in rapidly growing cities of developing countries is attributable to motor vehicle emissions. In a survey completed by the Economist Intelligence Unit (EUI, 2012), Nairobi city is projected to be among the forty (40) fastest-growing cities in the world by 2016. Currently it takes the 115th position with a steady growing rate of 5.2%. This makes it even more qualifying for this statistics and the related impacts.

2.3 Pollutants Emitted By Taxi Industry

Taxi vehicles are an integral part of our society and everyone is exposed to their emissions. They emit into the atmosphere significant quantities of pollutants which are largely categorized as Toxic Air Pollutants (TAPs), or Hazardous Air Pollutants (HAPs). The U.S. Environmental Protection Agency (U.S EPA) classifies these pollutants based on their potential cancer risk due to inhalation as possible, probable, or known human carcinogens. Motor vehicle exhaust contains numerous HAPs, such as benzene, formaldehyde, 1,3-butadiene, and diesel particulate matter. Some additional HAPs emitted by motor vehicles include acrolein, cadmium, chromium and lead.

TAP pollutants include carbon monoxide (CO), hydrocarbons (CxHx), nitrogen oxides (NOx), fine particles, sulphur dioxide (SO_2), and accelerated formation of ozone (O_3). Nitrogen oxides are highly reactive gases, toxic and irritate the lungs. Their formation is favoured by high temperatures and excess oxygen. Hydrocarbons are emitted mainly from gasoline engines. Hydrocarbon pollution results when unburned or partially burned fuel is emitted from the engine as exhaust, and also when fuel evaporates directly into the atmosphere. They contain toxic compounds and cause cancer. The fine particles in suspension come mainly from the smoke of the diesel engines and worsen the respiratory diseases.

Sulphur dioxide is a colorless and non-flammable gas produced by the combustion of sulphur residual in the fuels. Lead comes mainly from the combustion of the additives to lead contained in the gasoline. It is the origin of neurological, hematological and renal disturbances. Ozone is formed by the action of the solar radiation and heat on nitrogen oxides and hydrocarbons. It is irritating for the respiratory system and the mucous ocular membranes.

Carbon monoxide is a colorless, odorless and insipid gas produced by the incomplete combustion of hydrocarbons. CO penetrates into the blood through the lungs, combines with hemoglobin 200 times more easily than oxygen and thus deteriorates the transport of oxygen to the body. CO is a product of incomplete combustion of hydrocarbon based fuels. WHO European Guidelines for Air Quality (2002), acceptable universal limits for each of these pollutant are fixed by the WHO, WHO (2002).

2.4 Taxi Industry Carbon Emission

Most air quality studies show that motor vehicle traffic is a major source of harmful emissions. UN HABITAT (2010), notes that cities of the developing world, where economic growth, coupled with a lack of effective transport and land use planning are consequently resulting into increased vehicle ownership and traffic congestion. These factors combine results to high carbon hotspots especially in areas near and along busy slow roads and at roundabouts.

As urban populations continue to increase, the health and safety impacts of cities to the urban population becomes an issue of concern. Lack of real time air quality monitoring stations makes it even very difficult to assess the environmental health and safety impacts of the carbon emission on the urban environment and urban dwellers health. (Gatari et al. 2005; Maina et al., 2010; Kinney, 2007). This data gap hinders informed planning and formulation of effective policies in relation to air quality and health.

Gatari (2005), observes that Nairobi, is in many ways typical of most growing cities of developing countries that are at the risk of deteriorated air quality. One projection estimated that the number of vehicle trips between 2004 and 2025 in the Nairobi Metropolitan Area will increase by 148% and that the average speed of trips will decrease from 35km/hr. to 11km/hr. as congestion increases (Ministry of Nairobi Metropolitan Development, 2011).This makes it reasonable to assume that if nothing is done, urban air quality will worsen. Undertaking adequate studies and modeling on the situation and using them to inform policy formulation and planning then becomes very vital to warrant control over automotive emissions.

2.5 Effects of Carbon Oxides

Oxides of carbon exist in two important forms when they mix with oxygen: carbon monoxide (CO) and carbon dioxide (CO_2). Carbon oxides are important components of the atmosphere, and are parts of the carbon cycle. Carbon dioxide is naturally produced by respiration and metabolism, and consumed by plants through photosynthesis. It is a colorless, odorless, non-flammable gas that is a product of cellular respiration and burning of fossil fuels. It has a molecular weight of 44.01g/mol (NIOSH 1976). Although it is typically present as a gas, carbon dioxide also can be a solid form as dry ice and liquefied, depending on temperature and pressure (Nelson 2000). This gas is utilized by many types of industries including breweries, mining ore, and manufacturing of carbonated drinks, drugs, disinfectants, pottery, and baking powder (NIOSH 1976). It is also a primary gas associated with volcanic eruptions (Farrar et al. 1999; IVHHN 2005). CO_2 acts to displace oxygen, making compressed CO_2 the main ingredient in fire extinguishers (MDPH 2005). Occupations that are most at risk from

CO_2 exposure include miners, brewers, carbonated beverage workers, and grain elevator workers (CCOHS 2005; Nelson 2000). CO_2 is present in the atmosphere at 0.035% (Aerias 2005; CCOHS 2005). In terms of worker safety, Occupational Safety and Health Administration (OSHA) has set a permissible exposure limit (PEL) for CO_2 of 5,000 parts per million (ppm) over an 8-hour work day. This is equivalent to 0.5% by volume of air. Similarly, the American Conference of Governmental Industrial Hygienists (ACGIH) TLV (threshold limit value) is 5,000 ppm for an 8-hour workday, with a ceiling exposure limit of 30,000 ppm for a 10-minute period based on acute inhalation data (MDPH 2005; NIOSH 1976). A value of 40,000 ppm is considered immediately dangerous to life and health based on the fact that a 30-minute exposure to 50,000 ppm produces intoxication, and concentrations greater than that (7-10%) produce unconsciousness (NIOSH 1996; Tox. Review 2005) due to increased industrialization and human activities. XRT Research Lab (2008), observes that levels of oxides of carbon oxides have gone high posing potential environmental, health and safety challenges and impacts.

2.5.1 Health Impacts

Carboxyhaemoglobin: When carbon monoxide enters the bloodstream through the lungs, it binds to hemoglobin, the substance in blood that carries oxygen to cells to form carboxyhaemoglobin. This impedes oxygen transport to body's tissues and organs, especially the heart and brain, as well as its central nervous system potentially leading to suffocation of cells and death.

Cardiovascular Effects: The health threat from lower levels of CO is most serious for those who suffer from heart disease, like angina, clogged arteries, or congestive heart failure. For a person with heart disease, a single exposure to CO at low levels may cause chest pain and reduce that person's ability to exercise. Repeated exposures may contribute to other cardiovascular effects leading to heart failure and death.

Central Nervous System Effects: High levels of CO can affect even healthy people. People who breathe high levels of CO can develop vision problems, reduced ability to work or learn, reduced manual dexterity, and difficulty performing complex tasks. At extremely high levels, CO is poisonous and can cause death.

Smog: CO contributes to the formation of smog, ground-level ozone, which can trigger serious respiratory problems.

Paolo et al (2010) agrees that typical CO levels currently encountered in most indoor and outdoor environments especially in urban areas have a potential for negative environmental, health and safety impacts. These impacts would be adverse to individuals who are physiologically stressed, either by exercise or by medical conditions that can make them more susceptible to high levels of CO.

The population likely to experience these adverse effects includes:

a. **Individuals with cardiovascular diseases**

COHb levels of 2-6% may impair the delivery of oxygen to the myocardium causing hypoxia and increasing coronary blood flow demand by nearly 30%. When myocardial oxygen demands are increased, as in exercise, the hypoxic effects of CO may exceed the limited coronary reserve producing adverse health effects including earlier onset of myocardial ischaemia, reduced exercise tolerance in persons with stable angina pectoris, increased number and complexity of arrhythmias, and increased hospital admissions for congestive heart failure.

b. **Featuses**

Featuses are more susceptible to CO exposure for several reasons: CO crosses the placenta; fetal Hb has greater affinity for CO than maternal Hb; the half-life of COHb in fetal blood is three times longer than that of maternal blood, and the fetus has high rate of oxygen consumption and lower oxygen tension in the blood than adults. Also, maternal smoking during pregnancy exposes the fetus to greater than normal concentrations of CO leading to a decrease in birth weight.

c. **Children**

They develop acute neurotoxic effects (e.g. headaches, nausea), long-lasting neurotoxic effects (e.g. memory deficits) and impaired ability to escape (i.e.syncopes) at lower [COHb] than adults. Children have greater activity levels and smaller body masses than adults and should therefore experience higher levels of CO uptake than will adults for the same average exposure concentration.

d. **Pregnant women**

Pregnant women have increased alveolar ventilation, increasing the rate of CO uptake from inspired air. Also, a pregnant woman produces nearly twice as much endogenous CO.

e. **Individuals with chronic obstructive pulmonary disease**

These are such as chronic bronchitis, emphysema and chronic obstructive pulmonary disease are more susceptible to CO effects, since their lungs are less efficient at oxygenating the blood.

f. **Individuals with reduced blood hemoglobin concentrations,**

These individuals or those with abnormal haemoglobin, will have reduced O_2 carrying capacity in blood. In addition, disease processes that result in increased destruction of red blood cells (haemolysis) and accelerated breakdown of haemoproteins accelerate endogenous production of CO, resulting in higher COHb concentrations than in normal individuals. For example, patients with haemolytic anemia have COHb concentrations 2 to 3 times those seeming normal individuals.

g. **Certain occupational groups**

These are at risk from ambient CO exposure including those who work on city streets (street repairmen, street cleaners, street vendors, deliverymen, and garage attendants, taxi and bus drivers). Individuals who work in industrial processes including those exposed to other chemical substances (e.g. methylene chloride) that increase endogenous CO formation.

Individuals who have not adapted to high altitude and are exposed to a combination of high altitude and CO. *(http://www.extraordinaryroadtrip.org/research-library/air-pollution/understanding-air-pollution/carbon-monoxide/health.asp XRT Research Lab: accessed on 21st July 2012)*

2.5.2 Environmental Effects of Carbon Monoxide

Carbon monoxide is one of the several pollutants that can interact in the presence of sunlight to produce ground-level ozone or "smog," particularly on hot summer days. Fierro (2001), In addition to posing a health risk, ozone can damage buildings and harm crops. Similarly, wildlife experience impacts in decreased environments of oxygen. Raymond et al (2006).

2.6 Existing Policies, Legislations and Regulatory Structures

2.6.1 The National Environment Management Authority (NEMA)

The National Environment Management Authority (NEMA) is a government agency established to exercise general supervision and co-ordination over all matters relating to the environment. The Authority is the principal instrument of the Kenyan Government in the implementation of all policies relating to the environment. The Authority was established under the Environmental Management and Coordination Act (EMCA) of 1999. Under the act, NEMA has been empowered with 17 statutory functions as stipulated in Section 9(2) of EMCA. Among these functions is to undertake research and formulate environmental regulations and standards. In section 78 of EMCA, NEMA has been empowered to establish the Standards Enforcement and Review Committee (SERC) which has been obligated to recommend to the Authority (NEMA) air quality standards/limits.

2.6.2 TAXI Inspection: The Motor Vehicle Inspection Unit (MVIU)

Housed in the Ministry of Transport and Communication, the Motor Vehicle Inspection Unit (MVIU) is the lead agency on measurement of the vehicular exhaust emissions. MVIU has 17 motor-vehicle testing centres nationally equipped with motor vehicle exhaust emission measurement equipment. However, these facilities cannot meet the biennial exhaust emission requirement for private cars plus the current PSV and commercial vehicles. The proposed draft Air Quality Regulation provides for this Authority in consultation with NEMA to work on a structure and designate private exhaust emission testing garages to support the existing deficit as deemed necessary by the two authorities.

2.6.3 The Draft Air Quality Regulations, 2008

Kenya has no Air Quality Regulations; however, it is still in the process of having its draft "Environmental Management and Coordination (Air Quality) Regulations, 2008" accented in parliament into law. The objective of this regulation is to provide for prevention, control and abatement of air pollution to ensure clean and healthy ambient air. It provides for the establishment of emission standards for various sources such as mobile sources (e.g. motor vehicles) and stationary sources (e.g. industries) as outlined in the Environmental Management and Coordination Act, 1999. It also covers any other air pollution source as may be determined by the Minister in consultation with the Authority. Emission limits for various areas and facilities have also been set in this regulation. The regulations provide the procedure for designating controlled areas and setting up air quality management plans for these areas.

2.6.4 Fossil Fuel Emissions

Even though Kenya has no air quality standards, the Parliament passed internal combustion engine emissions standards in 2006. The EMCA (Fossil Fuel Emissions Control Regulations) aimed at setting standards and monitoring practices for any device or automobile that emits fossil fuel emissions. The standards prohibit the use of an internal combustion engine that emits fossil fuel emissions in excess of standards laid out in the first schedule. The regulations also empower environmental inspectors to without notice inspect and document the emissions of any internal combustion engine in use and fine those who are not in compliance. The standards also limit the use of fuel catalysts, requiring any fuel catalyst to be tested and licensed by NEMA before being used in any internal combustion engine.

2.7 Research Gaps

Literature on motor vehicle carbon emissions, especially its contribution to the carbon footprint in African cities still requires a lot more research to be done. However, developed countries like Japan, China, USA among other countries have made great strides in this area. They have been supported by continued scientific research and real time air quality monitoring data by their emission regulatory authorities e.g. the United States Environmental Protection Agency in USA and the Beijing Municipal Environment Protection Bureau in

China among other countries and cities across Asia, Europe and Middle East. On the contrary, UNEP (2010) acknowledges that none of the twenty one large African cities sampled in its urban pollution study has a real time monitoring station yet. It was thus impossible to accurately assess the air quality. Figures arrived at were either derived or estimated from historic spot measurements.

So much research has been done in developed countries on urban air quality including necessary policy framework and legislation in remediating this challenge. Developing countries especially in Africa need to harmonise what studies have been done and what gaps exist in order to determine how best to fill them. Nairobi, the Kenyan capital city and one of the African's largest cities shares these challenges and still lacks adequate legal, policy and legislative tools to ameliorate the situation, Economist Intelligence Unit (EUI) 2010. Current researchers agree that the transport industry takes the lead in urban carbon emission with the motor vehicle emission on the top of the list. Vehicle ownership has equally increased tremendously. Environmental and health challenges associated with deteriorated air conditions have increased and no adequate research programs and policy framework have been put in place to contain the situation. D.M. Maina (2010) notes that, "…much more that needs to be done to control vehicular emissions in urban cities and the existing policies be reinforced". In the case of Nairobi, D.M. Maina (2010) recomends that, "…there is need to form a national programme on air pollution measurements and to collate all the research on air pollution done so far and use it as the foundation for further studies."

The first Kenyan Motor Vehicle Emissions Control Stakeholders Workshop (MVEC) was held in April 2011, coordinated with the Ministry Of Environment and Mineral Resources and the Office of the Prime Minister in collaboration with Climate Network Africa among other stakeholders. This so far is the first right step towards the right direction. The workshop had the objectives to:

a) Establish current emissions levels in Nairobi against WHO standards.
b) Determine the worst polluters from all sectors giving credence to the selection of motor vehicle emissions as the focus group.
c) Propose methodologies, time frame and facilities that may be required to develop a strategy to give an idea on the scale of resources that may be required.

d) Request interested partners to indicate their willingness to provide facilities and resources for the strategy and confirm the level of support they will provide for publication in the MVEC's workshop report.
e) Determine the process for the legal establishment of the MVEC strategy.
f) Discuss potential benefits and Investment opportunities in implementing proposed MVEC Strategy.

Focusing on the nuclear unit of the motor vehicle sector – Corporate Taxi Industry, this study sought to fulfill objective 2, 3, 4, 5 and 6 of the (April 2011 MVEC). Its output is important in decision making and informing further studies in the sector.

2.8 Theoretical Framework

Combustion of fossil fuel is the greatest source of greenhouse emission, (Kituyi, 2005). These are directly emitted into the atmosphere where they react with different elements in complex chemical processes forming different hazardous gases and compounds. These compounds in one way or another directly and/or indirectly influence the composition of the ambient air quality leading to potential impacts on the environment, health and socio-economic sectors of a society.

MacKenzie (1990); Kituyi (2005) and Maria (2001) agree that efforts towards reducing engine emission would potentially reduce the resultant direct and cumulative impact on the environmental, health and social wellbeing of the society. They further point out increased engine emission has polluted the atmosphere resulting to climate change related impacts. These impacts will influence varied sectors of the economy ranging from agriculture, fisheries, tourism etc. that directly impact on human livelihoods and social welfare. MacKenzie(1990); Figure 1 elaborates his thoughts on the interrelations of emission with with impacts on environmental elements

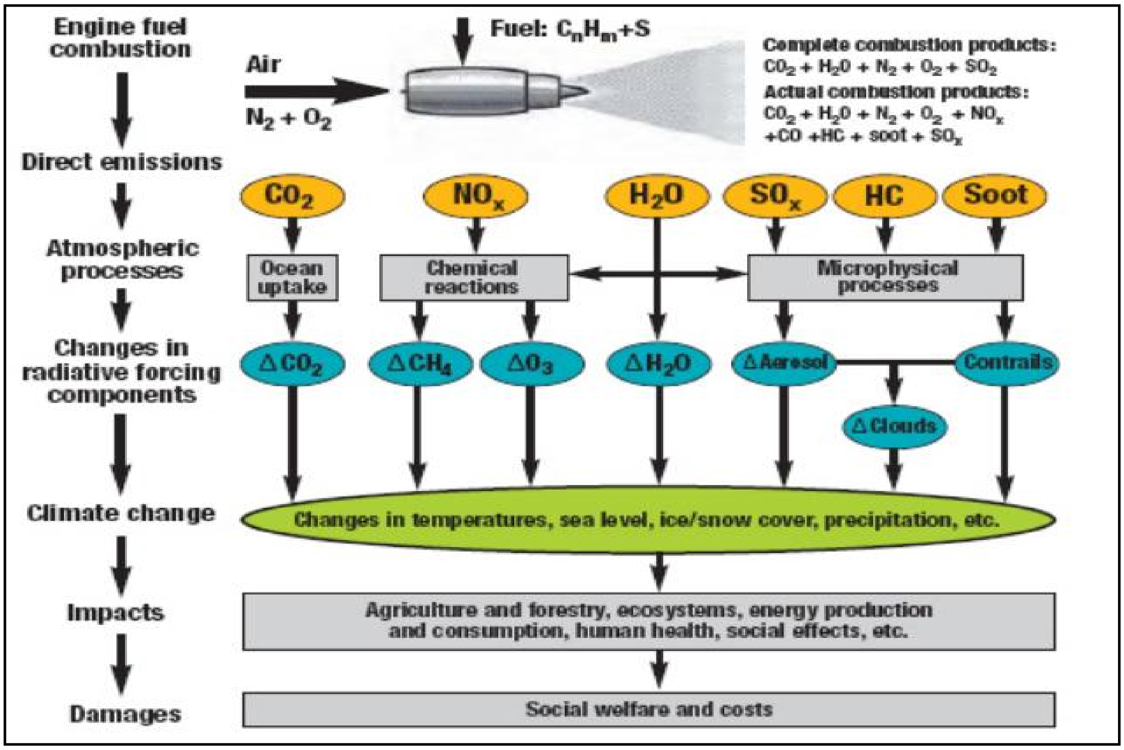

Figure 1: The Theoretical relationship between engine emissions and the resultant impacts on the different sectors of the environment UNEP (2009:259)

Reducing individual streams of engine emission from the varied sources like energy, agriculture, transport will consequently lead to reduced automotive emissions and the resultant environmental, health and safety impacts associated with the emissions.

2.9 Conceptual Framework

Taking the transport sector which is considered the leading source of emission, and specifically the taxi industry; there is great potential of reducing carbon emission and making a significant contribution in improving our environmental, health and social wellbeing. Figure 2 elaborates the linkage between the taxi industry, the existing legislation and administrative controls and the resultant emissions in relation to external influencing factors.

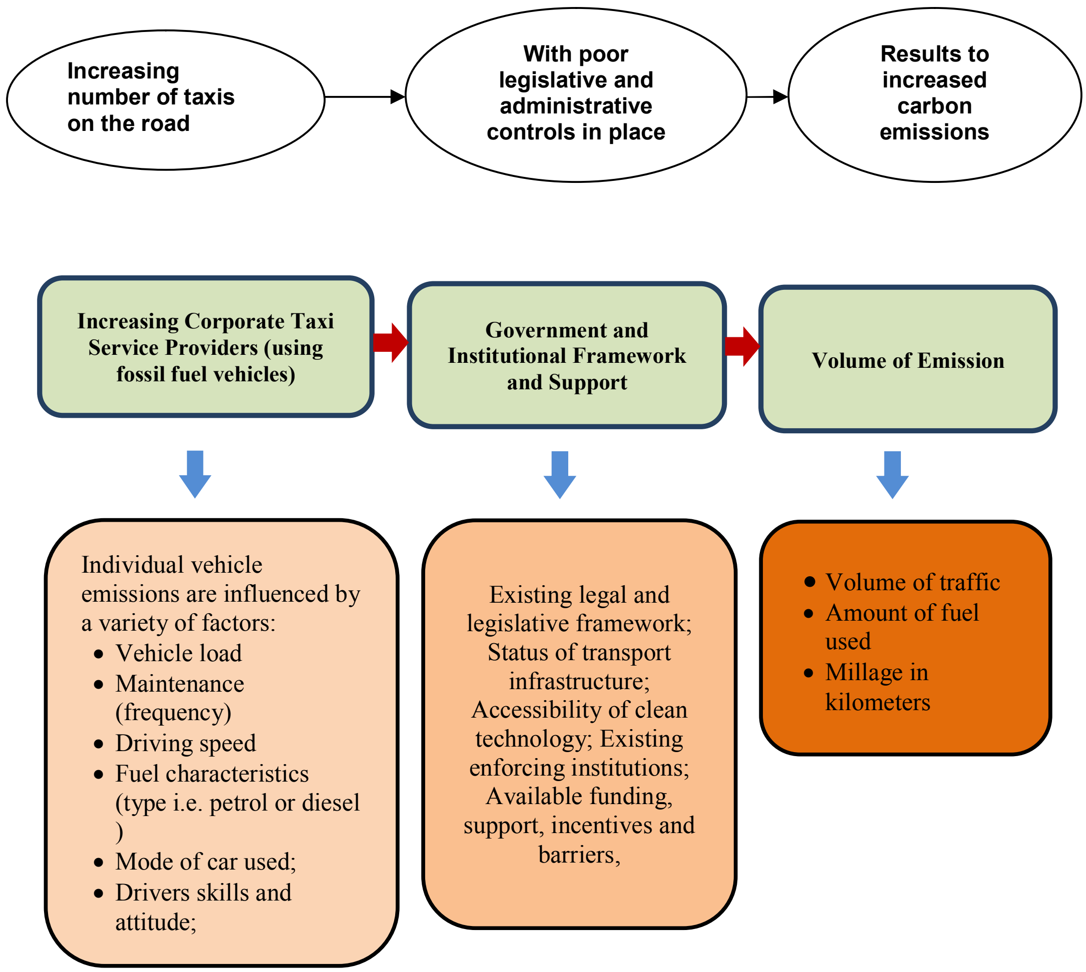

Figure 2: Relationship between the taxi industry and the resultant emissions
Source: Author's perception

Corporate taxi service providers use normal fossil vehicles to provide corporate organizations with transportation services. Depending on the size of the organization and the nature of its activities, daily carbon emission change depending on the size of the organization, mileage travelled, volume and type of fuel consumed, status of vehicle maintenance, model of car used, vehicle load, speed of travel, drivers' skills among other factors.

There is potential to minimize the amount of carbon emitted by influencing these variables. Influencing the nature and the environment in which corporate taxi industries operate can have a significant reduction on the cumulative amount of carbon emitted by all corporate taxi companies. This cumulatively translates to thousands of tonnes of carbon. Other secondary factors are like existing legal and legislative framework; status of transport infrastructure; accessibility of clean technology; existing enforcing institutions; government incentives and barriers among others.

Compounding the primary and secondary variables has the potential of greatly reducing the amount of carbon emitted. This research thus seeks to quantify the volume of carbon emitted by the corporate taxi industry and model the potential in influencing the primary variables. It will also seek to investigate the required legal and institutional framework needed to support the needed supporting environment.

3. CHAPTER THREE: RESEARCH DESIGN AND METHODOLOGY

This chapter seeks to elaborate on the approach that was used in undertaking the study to achieve the desired objectives. It answers the questions of how, what, when, where, by whom and by what means the objectives under study were being investigated.

3.1 Study Area

Nairobi is the most industrialized county in Kenya and hosts the highest number of taxi operation. It has the most developed road network and by far has the highest number of taxi services users. With plural economic activities and a population of over three million, this makes it potentially the most affected county by vehicular emissions. This study thus confined itself to investigate only corporate taxi companies operating within the boundaries of Nairobi County. Figure 3 shows the boundaries of Nairobi County in relation to its neighbouring counties

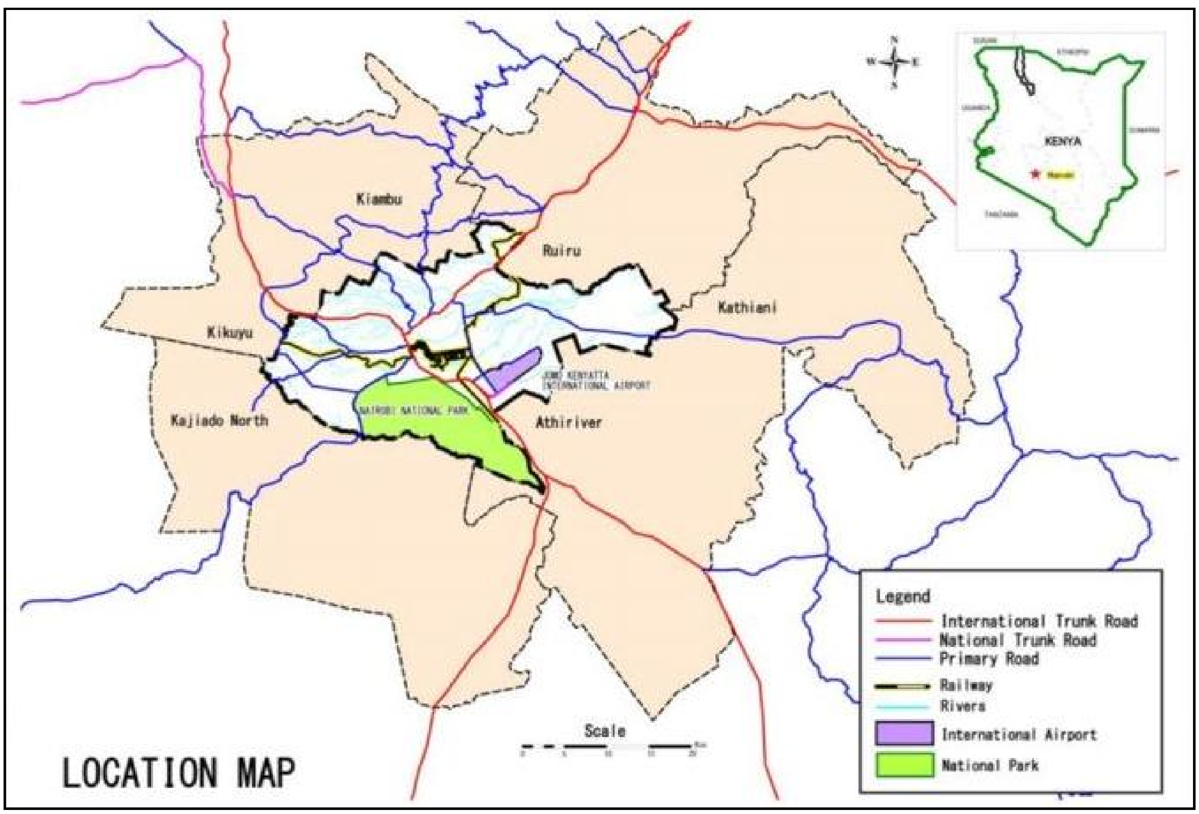

Figure 3: Administrative boundary of Nairobi County (Source: Nairobi County, 2014)

3.2 Research design

Research design is the advance planning of the methods to be embraced for gathering the relevant data and the techniques to be used in their analysis in line with the objective of the research (Kothari, 2009). Mertens (1998) looks at a research design as the strategy and structure of investigation used to obtain evidence to answer research questions (procedures for conducting the study). Research design is therefore intentioned to reduce the obscurity of research evidence as much as possible (Chalmers, 1996). This is because in many cases we can always find evidence consistent with almost any theory. In this study, the research design adopted depicts the plan, strategy and structure of investigation conceptualized to obtain answers to research questions for which the study sought to address.

This study therefore embraced a mixed methodological research design approach whereby both qualitative and quantitative methods were used allowing the study to benefit from the strength of both approaches (Creswell, 2009).

3.2.1 Mixed Methods Research Design

Mixed methodological research designs are principally for "better understanding" (Cook, 1986); mixed methods purposes of complementarily (more complete/comprehensively), triangulation (stronger validity or credibility and less known bias), initiation (insightfully, fresh perspectives, creative concepts and meanings) and understanding with greater consciousness and greater diversity of values, perspectives, and positions.

3.3 Target Population

The study targeted registered corporate taxi companies operating within Nairobi County e.g. Kenatco, Jim Cab, Dial a Cab etc**.** Appendix 1 provides a complete register of the corporate taxi companies that formed the population under study.

3.4 Sampling procedure

Obtaining information from a sample is normally easier and more practical than obtaining the same information from the entire population (Struwig and Stead, 2007). In this study, quota and probability sampling techniques were employed. The sample frame was limited to only registered corporate taxi companies with the Kenya Taxi Association within Nairobi County. Out of the registered taxi companies, the study sought to focus on only the taxi companies that limit their services to corporate organizations. This was to help eliminate potential assumptions that some of the mileage and fuel may have been as a result of private and off-street services and not factored into the emission equation. Out of the whole register, seventy six (76) companies were identified and the research sought to focus on the whole population. See appendix 1, the list of the targeted population. However after the pilot study, the study narrowed down to forty one (41) companies which had complete data. The sample exceeded the minimum representative sample of the population which by use of the sample equation factoring the target population would require a minimum of 38 samples.

Sample Equation 1:

$$\textbf{Sample size (n)} = \frac{t^2 \times p(1-p)}{m^2}$$

Where:

n = required sample size
t = confidence level at 95% (standard value of 1.960)
p = estimated contribution of the industry into the global Nairobi emissions
m = margin of error at 5% (standard value of 0.05)

Thus the minimum **Sample size (n) =** $\{1.655x.05(1\text{-}0.05)\}/0.05^2$

=**38 taxi companies**

Working at a confidence level of 95% and a confidence interval of 5% the minimum sample size is 38 taxi companies however the study sampled 41 companies.

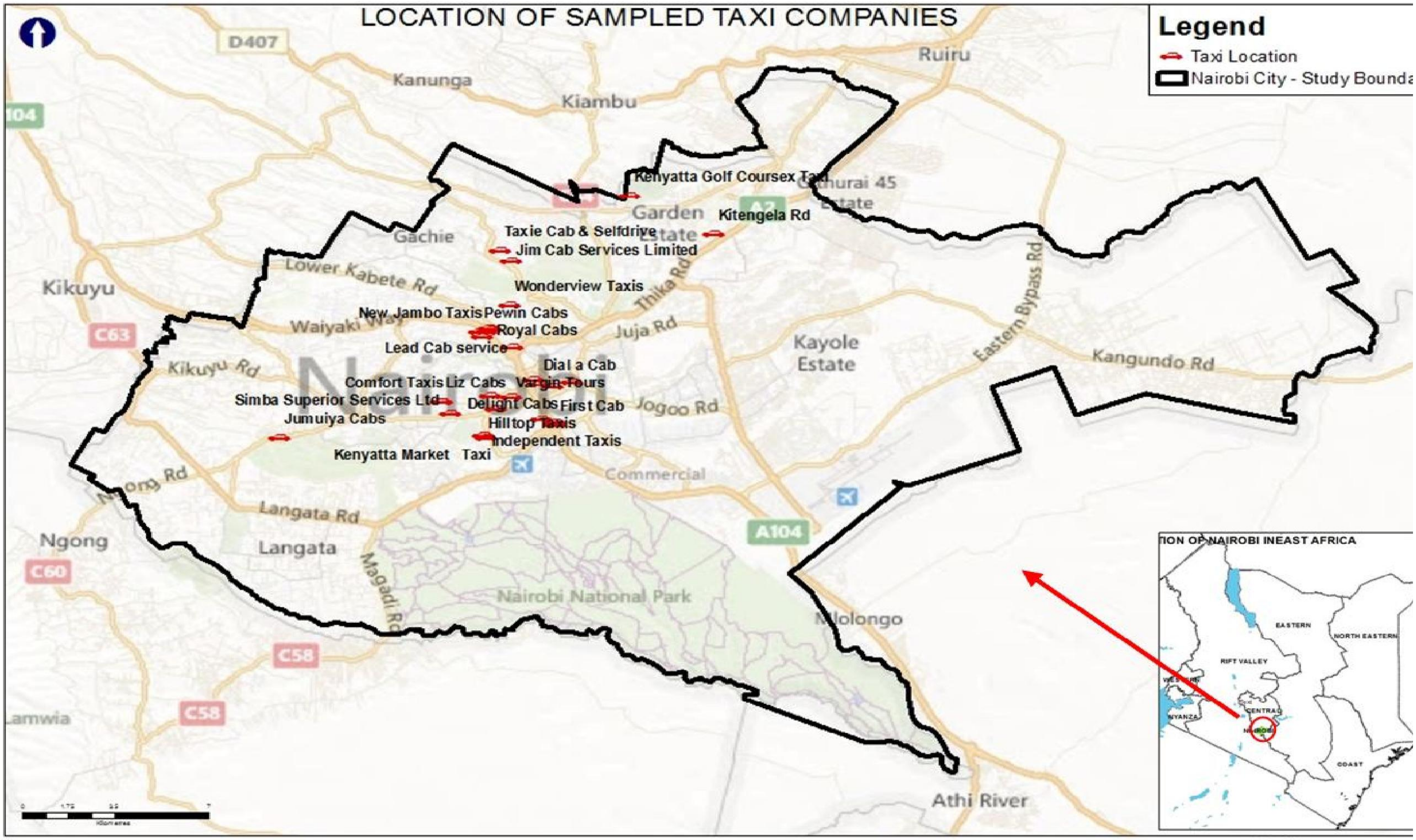

Figure 4: Distribution of the Sampled Corporate Taxi Companies Across the Study Area
(Source: Author developed using Google map and GPS data of 2013)

3.5 Types of Data Collected

In order to meet the research objectives, two types of data were collected: primary data and secondary data. Each of these has been discussed briefly below.

3.5.1 Primary Data

Primary data sources included qualitative information like (name of the taxi company, type and model of cars operated, date of purchase etc.) and quantitative information like (size of the fleet owned, number of kilometres run, number of litres of fuel consumed etc.) collected in their raw form from the sampled population. Table 2 summarizes the different types of tools that were be used and the nature of data that was collected.

Table 2: Data Collection Tools

NO.	TOOLS	NATURE OF DATA
1.	**Summary Notes**	– Field notes helped capture qualitatie information and other observable phenomena. This included information acquired from un-official meetings and discussions which cannot be authenticated.
2.	**Checklists**	– This helped in noting down and counter-checking key information while in the field e.g. type of cars used, fuel used etc.
3.	**Structured Questionnaires**	– A sampled population was selected by use of different methods of sampling that have been discussed in this chapter. Structured questionnaires were then administered to collect the needed information with the help of four research assistants. Before embarking to collect the data, the research assistants were trained on the research tool. Refer to sample questionnaire in Appendix 2.
4.	**Interview**	– This was employed especially when collecting information from key relevant government ministries, regulatory authorities, key informants and opinion leaders. A predetermined interview guide was prepared and the feedback captured in minutes.
5.	**GPS**	– The use of a GPS became handy in capturing GPS locations of offices of the taxi companies where the questionnaires were administered. It also helps in mapping the distribution and location of the sampled taxi organizations.

3.5.2 Secondary Data

Sources of secondary information include: past studies undertaken (both published and un-published work); government legislation (both in draft and in operation); and regulatory authority regulations and standards. This was referenced from the University of Nairobi and UNEP libraries and the internet.

3.6 Methods of Data Collection

The research employed qualitative methods of data collection which included review of secondary recorded data; semi-structured and oral interviews; administration of stakeholder specific questionnaires and photographic recording.

3.7 Methods of Data Analysis and Presentation

Both descriptive and inferential statistic methods were used. Data from records and questionnaires was coded for analysis using Microsoft Excel 2007. Each response was analysed and different graphical outputs generated for each question. Questions that enlisted non-numeric responses were tallied and an assumed opinion reached based on the frequency of the response. General and specific conclusions were then drawn from the analysis based on quantifiable elements like mean, mode, frequencies and percentages. Paired sample t-test method was used to test the hypothesis. Other unquantifiable information was captured in notes, checklists and observations. Output was presented in tables and graphical form and elaborated in verbatim. Refer to collated and analysed data in appendix 3.

3.8 Validity and reliability

3.8.1 Validity

Validity in quantitative research concerns itself with the extent to which the research truly measures that which it was intended to measure or how truthful the research results are. Wainer (1988) and Mertens (1998), argue that validity is about the initial concept and questions that determine which data is to be gathered and how it is to be gathered; the credibility or trustworthiness of the approaches and tools used in the study. In order to increase the validity of the data the following considerations were made during the study:

a) The use of judgemental sampling technique to ensure the homogeneity of the selected sample through blocking of some of the possible intervening or extraneous variables, for instance selecting taxi companies that had complete data and ignoring those that had incomplete data.
b) The use of stratified random sampling technique ensured there was even distribution of the samples from each stratum and that each category had an equal opportunity thus guaranteeing more and equal representation of the population.

1.10.1 Reliability

Joppe (2000) defines reliability as the extent to which results are consistent over time. Accurate representation of the total population under study is also referred to as reliability. If the results of a study can be reproduced under a similar methodology, then the research instrument is considered reliable. It is mostly connected with accuracy and consistency of the methods and tools embraced to measure research variables (Kirk and Miller, 1986). In this study, the use of a regulated interview protocol for all respondents and the documented secondary case studies subject to this study augmented the reliability of the information gathered, findings and the conclusions drawn.

1.10.2 Paired Sample T Test

A paired sample t-test is used to determine whether there is a significant difference between the average values of the same measurement made under two different conditions. Both measurements are made on each unit in a sample, and the test is based on the paired differences between these two values. The usual null hypothesis is that the difference in the mean values is zero. It has a role in inferential statistics to determine probability distributions. The null hypothesis on the flip side is usually a general statement; for example there is no relationship between two sets of phenomena. The null hypothesis can never be proved; only the hypothesis can be either accepted or rejected. The analysis works by collecting data and measuring how likely the particular set of data is, assuming the null hypothesis is true. If the data-set is very unlikely, defined as being part of a class of sets of data that only rarely will be observed, the experimenter rejects the null hypothesis concluding it (probably) is false. This class of data-sets is usually specified via a test statistic which is designed to measure the extent of apparent departure from the null hypothesis. The procedure works by assessing whether the observed departure measured by the test statistic is larger than a value defined so that the probability of occurrence of a more extreme value is small under the null hypothesis (usually less than either 5% or 1% of similar data-sets in which the null hypothesis does hold). If the data does not contradict the null hypothesis, then only a weak conclusion can be made; namely that the observed data set provides no strong evidence against the null hypothesis. As the null hypothesis could be true or false, in this case, in some contexts this is interpreted as meaning that the data gave insufficient evidence to make any conclusion, on others it means that there is no evidence to support changing from a currently useful regime to a different one.

3.8.2 CO_2 Emissions Equation

The CO_2 emissions associated with fuel combustion are a function of the volume of fuel combusted, the density of the fuel, the carbon content of the fuel, and the fraction of carbon that is oxidized to CO. When the fuel density and carbon content by mass are known, CO_2 emissions can be determined directly (TRC General Reporting Protocol, 2008). Often, this information may not be readily available for a particular fuel. The CO_2 emissions can then be estimated from the heat content of the fuel and the carbon content per unit of energy. Carbon content factors per energy unit are often used because they are less variable than published carbon content factors per physical unit. Either of these methods is an acceptable approach by Climate Leaders, Partners and Researchers to use. (World Resources Institute, 2005)

CO emissions are calculated directly with the carbon content of the fuel, the fuel density, and the fraction of carbon oxidized for each fuel type. There are two basic approaches for estimating direct CO_2 emissions from Mobile Combustion Sources:

a) Direct measurement and
b) Calculation based method.

Direct measurement of CO_2 emissions are performed through the use of a Continuous

Emissions Monitoring System (CEMS). Calculation based method is a mass balance approach where the carbon content and carbon oxidation factors are applied to the fuel input levels to determine emissions. Figure 5 illustrates the methodology for each approach.

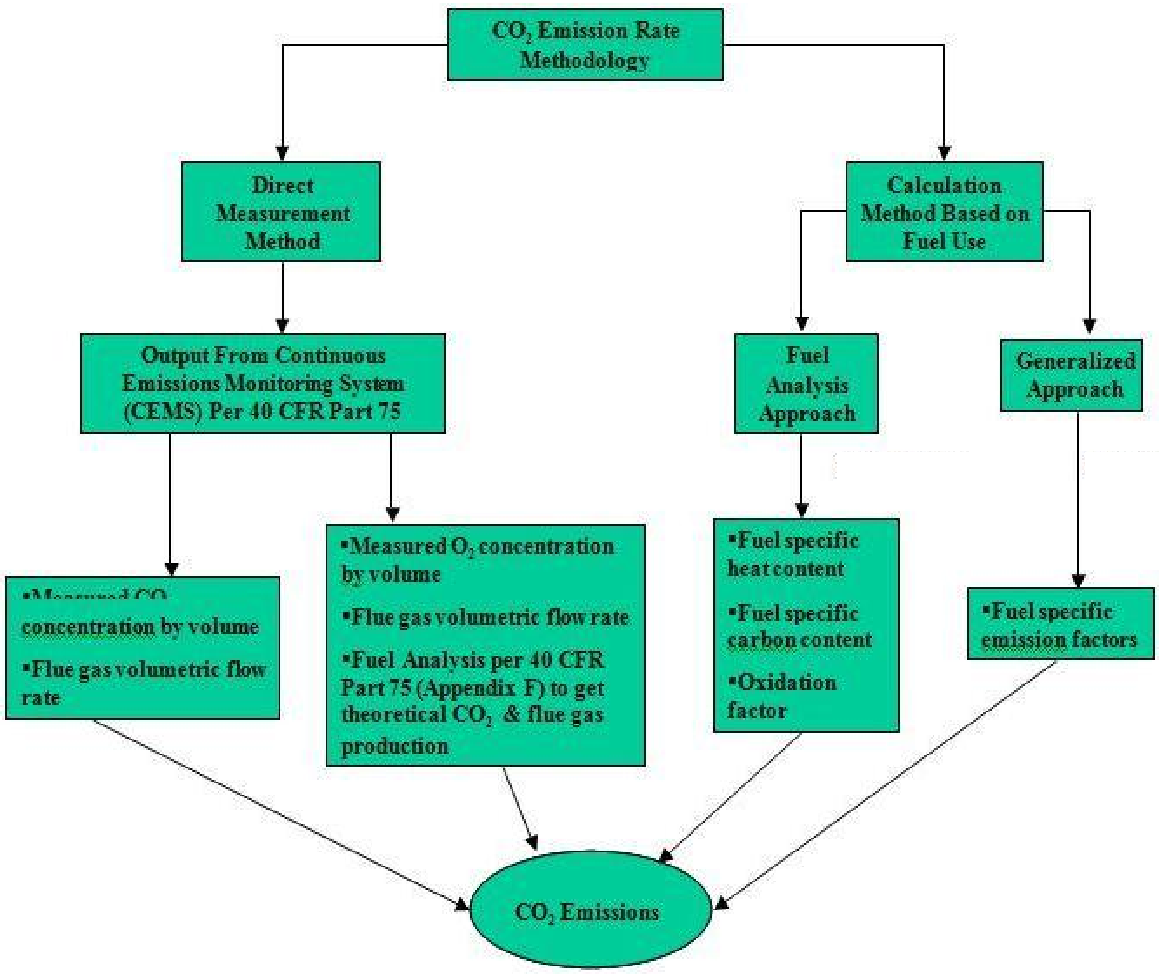

Figure 5: Carbon Emission Methodology, (Source: TRC General Reporting Protocol, 2008)

Carbon Content per Unit of Energy Approach for Estimating CO_2 Emission

$$\text{Emissions} = \sum_{i=1}^{n} \text{Fuel}_1 \text{ x } \text{HC}_1 \text{ x } \text{C}_1 \text{ x } \text{FO}_1 \text{ x } \frac{\text{CO}_{1(\text{m.w})}}{\text{C}_{(\text{m.w})}}$$

Where:

$Fuel_i$	=	Volume of Fuel Type i Combusted
HC_i	=	Heat Content for Fuel Type i
C_i	=	Carbon content coefficient of Fuel Type i
FO_i	=	Fraction Oxidized of Fuel Type i
$CO_{2(m.w)}$	=	Molecular weight of CO_2
$C_{(m.w)}$	=	Molecular weight of carbon

Equation 1 (Source: TRC General Reporting Protocol, 2008)

Step 1: Determine the amount of fuel combusted.

This was determined from records of fuel receipts, purchase records kept by the taxi companies. It is the estimate of the fuel consumed in litres.

Step 2: Convert the amount of fuel combusted into energy units.

The amount of fuel combusted is typically measured in terms of physical units The volume consumed was then converted into energy units by multiplying the volume by the known heating value for petrol which is 45MJ/kg (World Nuclear Association, 2013).

Step 3: Estimate carbon content of fuels consumed.

To estimate the carbon content, multiply energy content the fuel used by fuel-specific carbon content coefficients (mass C/energy) which is 19.36 for petrol according to US Environmental Protection Agency (2004).

Step 4: Estimate carbon emitted.

When Petrol is burned, most of the carbon is eventually oxidized to CO_2 and emitted to the atmosphere. When all variables are integrated into the equation, the amount of carbon emitted can be accurately derived.

In very simple non mathematical and scientific terms, one litre of petrol weighs about 800 grams. It is composed principally of carbon and hydrogen with a ratio of 2 carbon per 2 (and a bit) hydrogen or 24 units of mass carbon per 2 units of mass hydrogen. This means that for every 800 gm (one litre) of petrol combusted fuel you have (24/26)x800 = 738 grams of carbon. Since 1 carbon atom combines with 2 oxygen atoms each 12 gm carbon combines with 32 gm oxygen to make 45 gm carbon dioxide. So for every litre of petrol (which weighs 800gm) you have 738 gm carbon and require 1969 grams of oxygen to combust it. This produces 738+1969= 2707 grams of CO_2 for every one litre of petrol combusted.

3.9 Study Limitations

Creswell (2007) acknowledges that researchers however practical and detailed their approach is, they often face varied limitations in the field when gathering data. In the course of this study a number of imitations were encountered. The most difficult one was resistance in some of the companies and managers to complete the questionnaires in the capacity of their position. Some were even hesitant to share the mileage and fuel data on grounds of confidentiality or on the excuse that they needed clearance from their directors.

To overcome this challenge, the study was patient with them and tried to follow the right approval process to have the information needed to be shared.

Some companies equally did not have consistent data. Even though reputed and big in terms of fleet capacity, they genuinely did not have records of mileage or volume of fuel used. Where available data was manually kept and disorganized. However, the study collected the little information available and tried to collate the missing information with the fuelling station which kept a copy of the records for the purpose of raising invoices. This helped solve most cases of missing data. Manual and disorganised data was collected and sorted with the help of research assistants to help make meaningful interpretation.

Other challenges were limited resources and time to cover the targeted population. This was overcame by engaging four research assistants to help in data collection and questionnaire coding.

4. CHAPTER FOUR: RESULTS AND DISCUSSION

This chapter presents the summarised results of the study in relation to the study objectives in a systematic order. It discusses findings of each question and presents the results in form of graphs, charts, tables and makes comparison against other comparable variables in defence of the hypothesis.

4.1 Growth of corporate taxi companies

Corporate taxi industry has continued to grow steadily at a doubling rate. Study findings indicate that between 1990-2009, registered corporate taxi companies have been doubling up in their numbers after an interval of every four years. From Figure 6, it evident that between 1990 to 1994 and 1995 to 1999 the number of companies increase almost by half from 5% to 9%, then from 9% to 19% between 2000 to 2004 and up to 31% between 2005 to 2009.

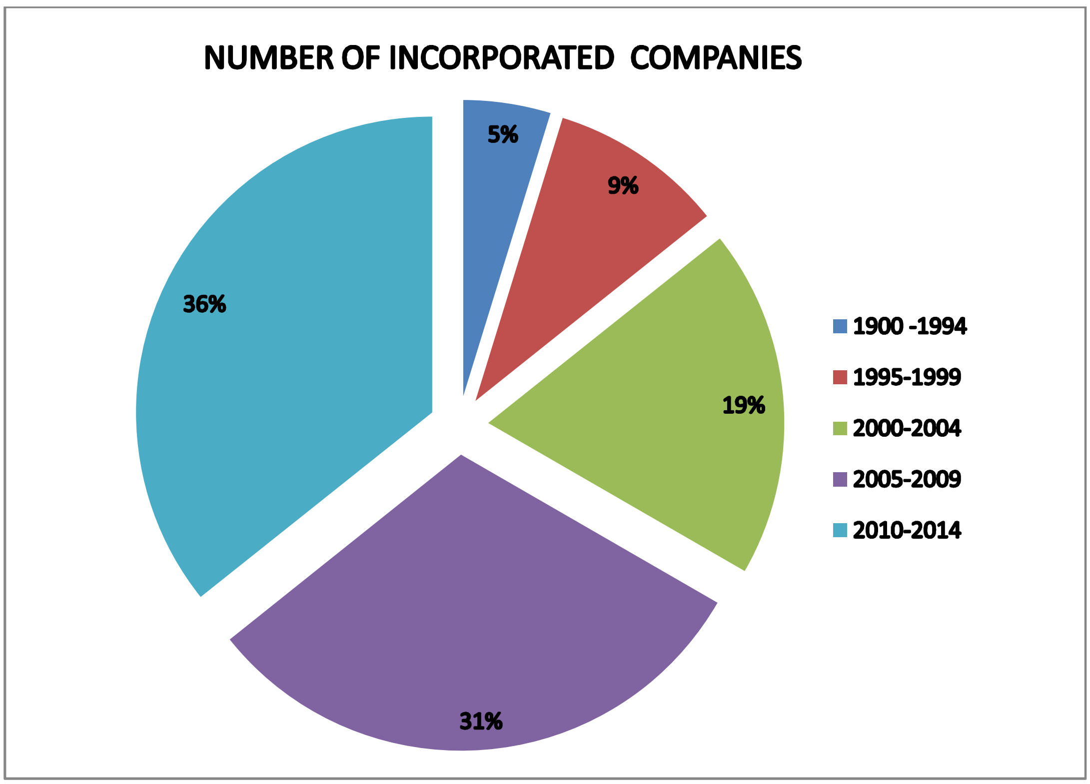

Figure 6: Incorporated corporate taxi industries (Source: Field Data 2013)

This is a rapid exponential growth that infers the potential of the taxi industry continuing to grow to meet the diversifying need for mobility in the corporate industry. Projecting this growth rate assuming that all other necessitating and hindrance factors remain constant, we may see the registered corporate taxi industry shooting from 76 registered corporate taxi companies now to about 304 in 2024. Table 3and Figure7 shows the projection of the expected growth in a table and linear graph by 2024.

Year Of Incorporation Of The Company	No. Of Companies	Remarks
1900 -1994	2	Actual
1995-1999	4	Actual
2000-2004	8	Actual
2005-2009	13	Actual
2010-2014	76	Actual
2015 - 2019	**152**	**Projected**
2020 - 2024	**304**	**Projected**

Table 3: Projected growth by 2024 (Source: Field Data 2013)

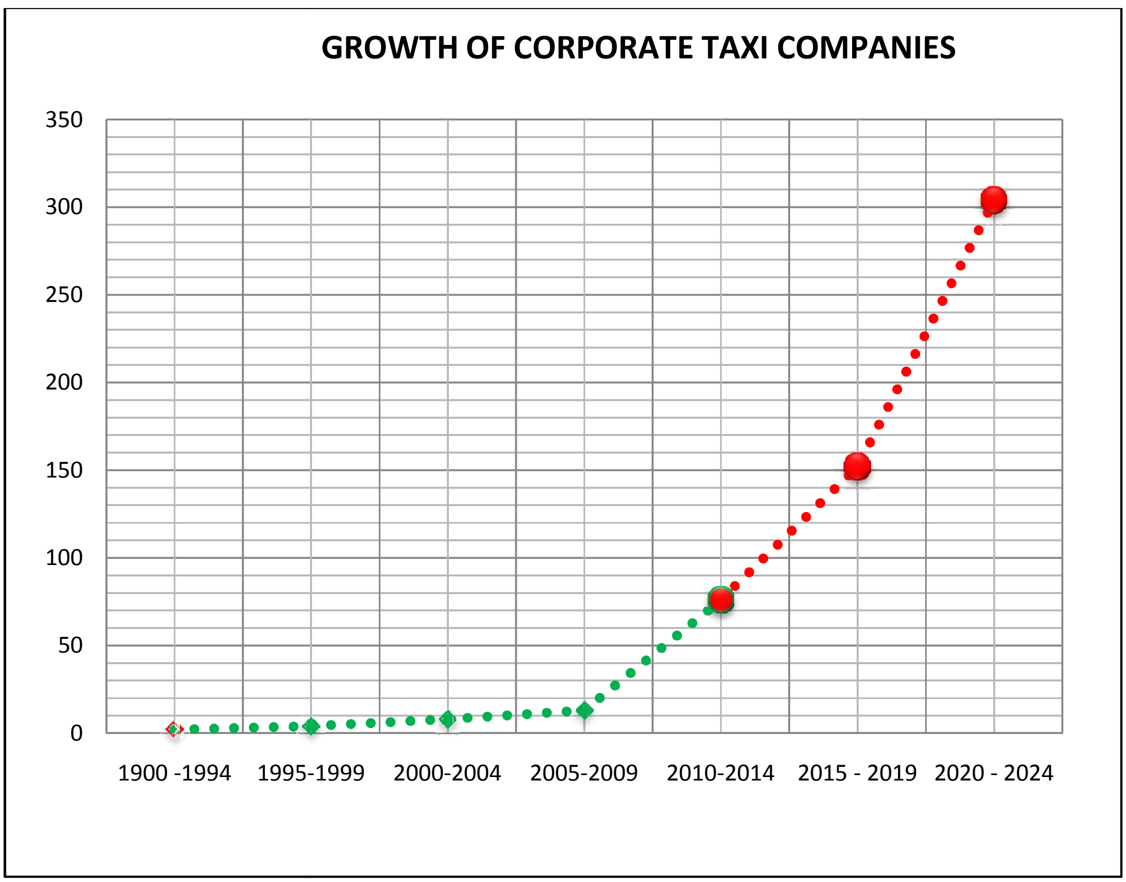

Figure 7: Projected growth by 2024 (Source: Field Data 2013)

4.1.1 Size of taxi fleet

From the collated data, the average fleet size per company equally grew by half after every four years and in some instances it doubled. Field date, Table 4 showed that the largest growth was between 2005 to 2009 where the industry experienced an increase in fleet from 298 cars to 736.

Table 4: Average fleet size (Source: Field Data 2013)

YEAR OF INCORPORATION OF THE COMPANY	NO. OF TAXIS ON THE ROAD	AVERAGE FLEET SIZE
1900 -1994	24	12
1995-1999	104	26
2000-2004	298	37
2005-2009	736	57
2010-2014	7717	102

It can be observed that not only have the taxi companies increased in number but also the size of the fleet they manage. From an average of 12 cars per company in 1990 to an average of 102 cars per company in 2013 in just 23 year is nothing but a big leap. Figures 8 and 9 project the same growth rate in a linear graph presents an average of 293 cars per company by 2024 and an estimated 17,362 taxi cars on the road.

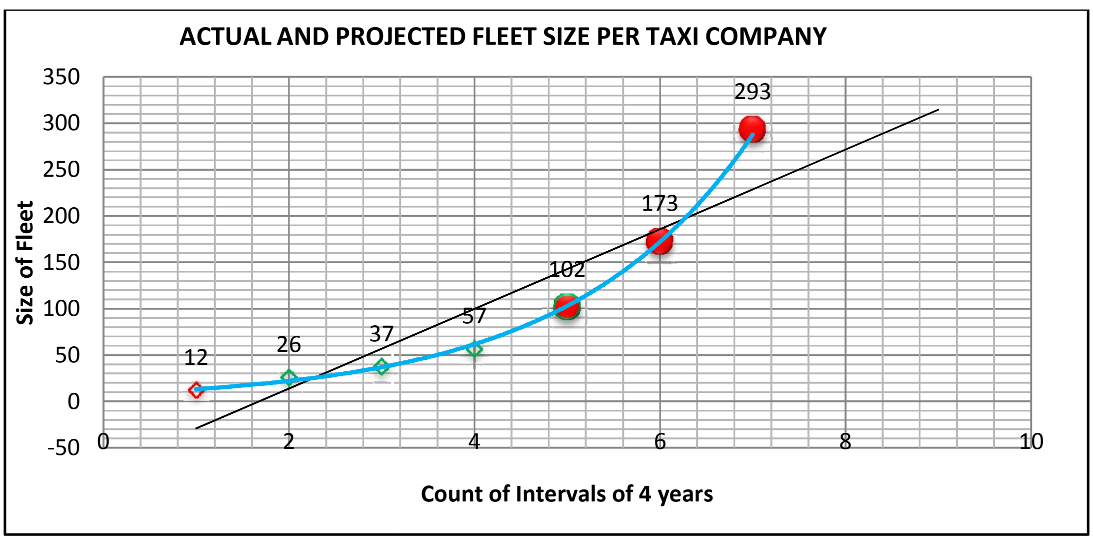

Figure 8: Actual and Projected Fleet Size per Taxi Company (Source: Field Data 2013)

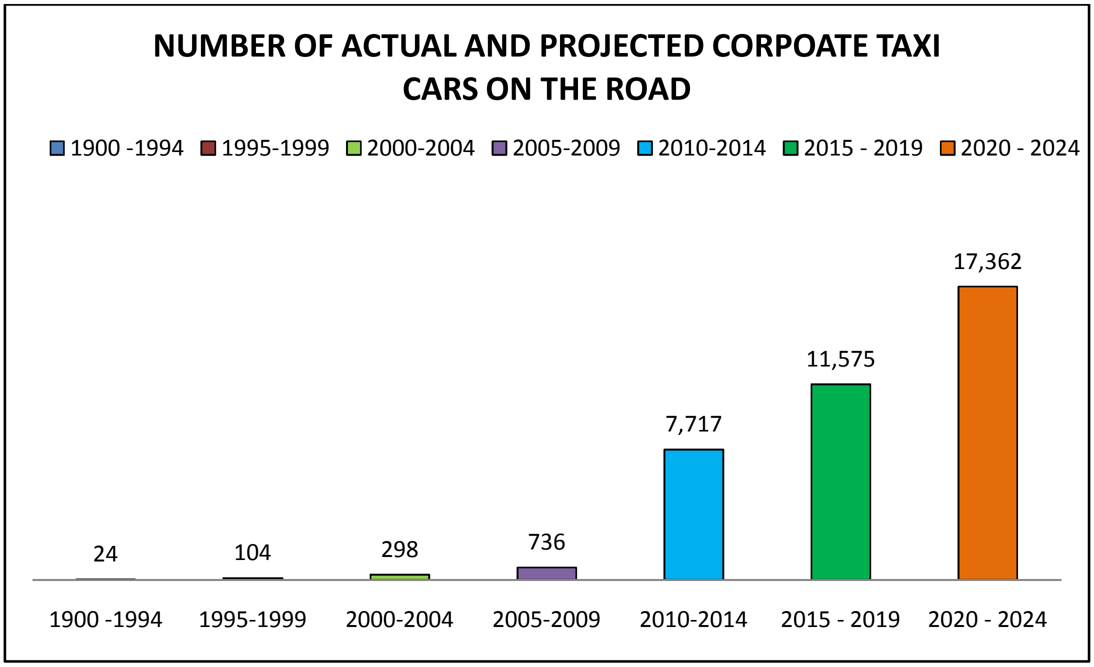

Figure 9: Number of taxis on the road (Source: Field Data 2013)

4.1.2 Ownership of cars

Majority of the cars are rented by the companies from individual citizens who then receive a fixed agreed amount on a monthly basis. This arrangement represents approximately 60% of the taxi vehicles on the road. Figure 10 shows the distribution of ownership of the corporate taxi industry as at August 2012.

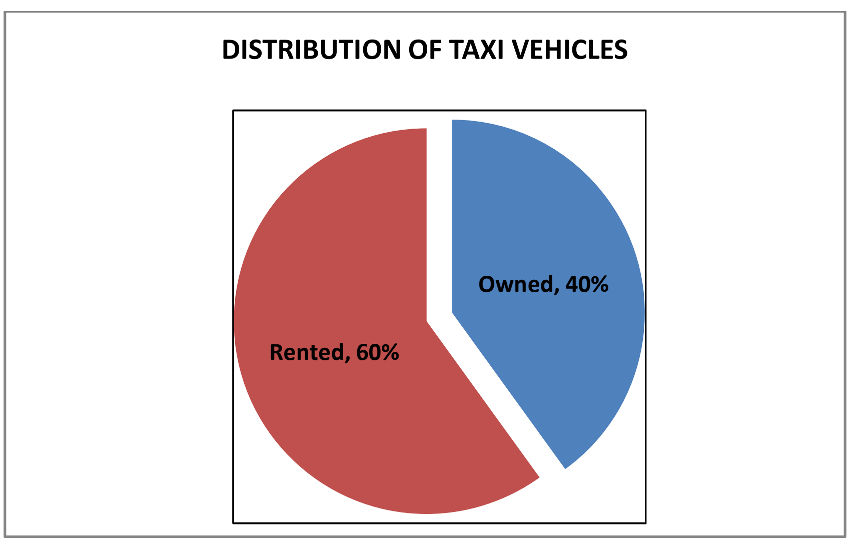

Figure 10: Ownership of taxi vehicles (Source: Field Data 2013)

4.2 Contribution of the Corporate Taxi Industry to the Nairobi County Carbon Emission Footprint

4.2.1 Vehicles Used

Most of the vehicles used to offer taxi services are small cars and majority being the Toyota model. Feedback from the survey, Figure 11 indicated that majority of the companies (26%) prefer Toyota NZE over any brand followed by Toyota Premio (20%) then the Toyota Fielder and Toyota Allion at 17% and 14% respectively. For larger capacity vans, Noah and Voxy model are more preferred over Toyota shuttles.

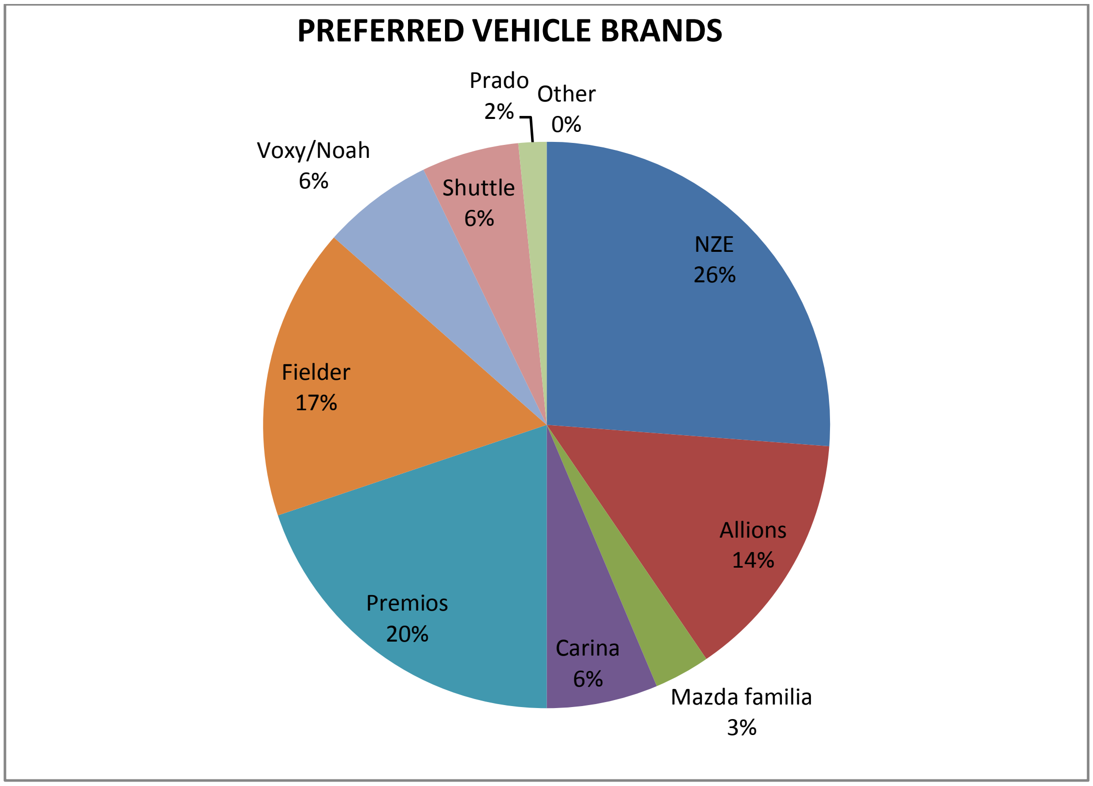

Figure 11: Distribution of vehicle brands in the taxi industry *(Source: Field Data 2013)*

4.2.2 Choice of vehicles used

There are many factors that influence the choice of car for taxi usage. The most important one is the vehicle fuel consumption capacity. 21 % of the respondents always consider a vehicle's consumption capacity first before any other factors. This made NZE the most preferred brand for the taxi service. They are interested to know averagely how many kilometres can the vehicle run with one litre of fuel. Serviceability was considered second at 17%. Operators would also like to know not only at how much but also how available are the spare parts. This includes the existence of good servicing stations and the potential to resale.

The vehicle interior and exterior condition, durability and the brand of the vehicle have an equal consideration of 10%. Other contributing factors included age of the car, mileage covered, customer preference, initial capital cost and colour. Figure 12 highlights the views of respondents on factors they consider most when choosing a car for taxi services.

Factors Influencing Choice of Car for Taxi Services

Factors	Frequency
Consumption	22%
Serviceability	17%
Age of vehicle	6%
Vehicle condition	13%
Customer Preference	3%
Comfort	10%
Captital Cost	3%
Durability	10%
Brand/make	10%
Colour	6%
Total	**100%**

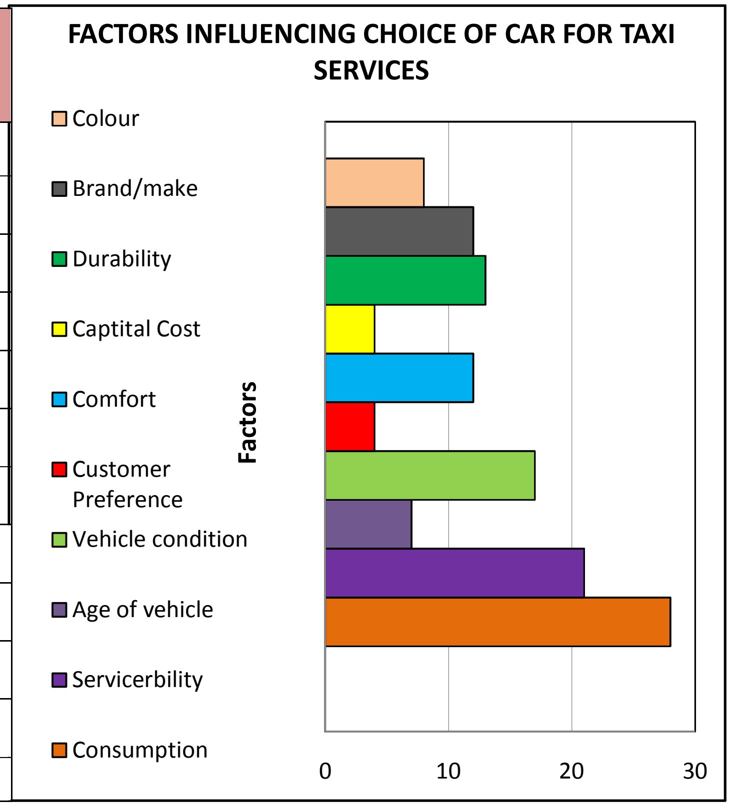

Figure 12: Factors influencing choice of vehicles (Source: Field Data 2013)

4.2.3 Fuel used and Servicing

Majority of taxi vehicles (81%) use petrol as a source of fuel and a few (21%) use diesel. None of the companies sampled uses gas, electricity or bio-fuel. The Figure 13 depicts the proportion of fuel used by the taxi operators.

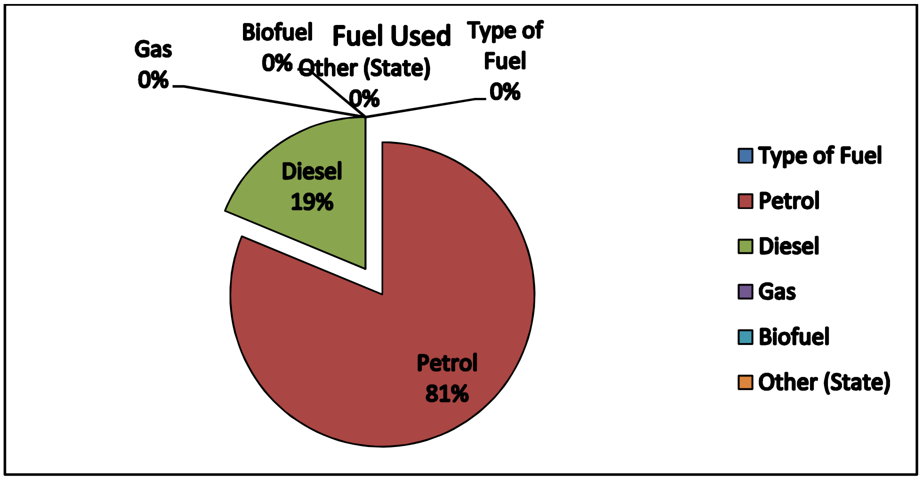

Figure 13: Fuel Used (Source: Field Data 2013)

Majority of the respondents, fifty one percent service their vehicles on a monthly basis. Forty four percent of the operators service them as and when required. Most often as indicated on the service tag; usually 5000km or 3000km mileage. There being no response on servicing 'when they breakdown' and higher response on 'monthly basis', the study deduce that the corporate taxi vehicles are well serviced and maintained. Figure 14 shows the frequency of vehicle servicing by the taxi companies.

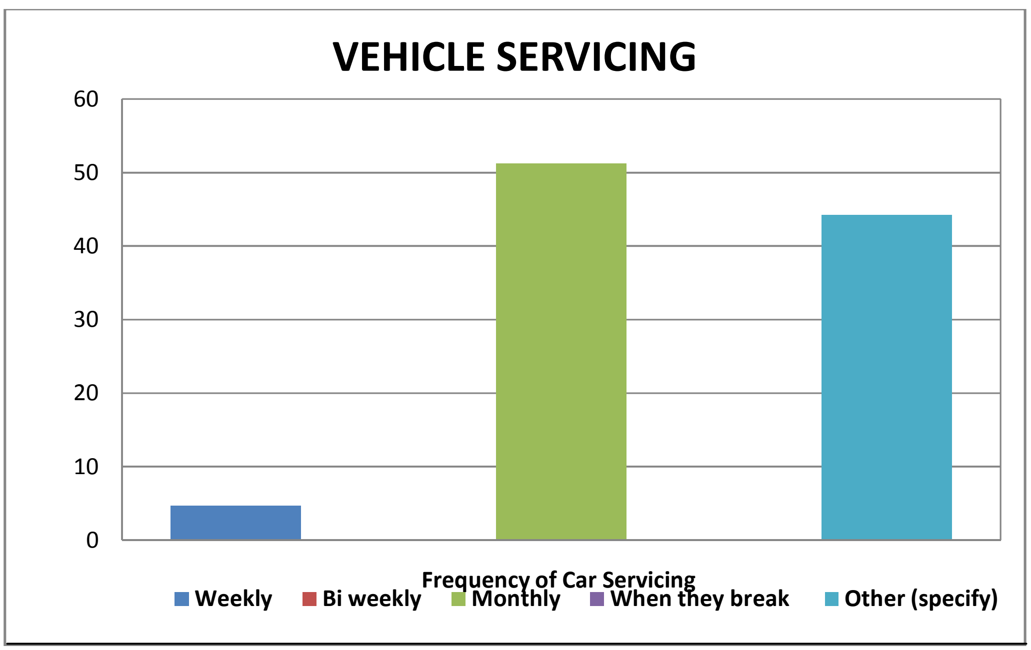

Figure 14 : Vehicle Servicing (Source: Field Data 2013)

4.2.4 Industry Challenges

Traffic jam is perceived to be the greatest challenge to the industry at 22% followed by regulatory-associated nuisance related to NCC and the traffic police. Fluctuating fuel prices and inadequate vehicle parking at 15% and 14% respectively were tallied to affect taxi operation. The operators advance it is now difficult to anticipate and plan for fuel cost as the fuel prices fluctuate as often as twice in a week unlike before. Even though the operators subscribe to the council monthly parking fees, it is impossible to conveniently find parking in most sections of the city to conveniently drop or pick clients. Other challenges on the rise include poor roads, delayed payments, increased accidents, in-experienced drivers, street transaction among others. Figure 15 depicts the sentiments of the respondents of the challenges faced.

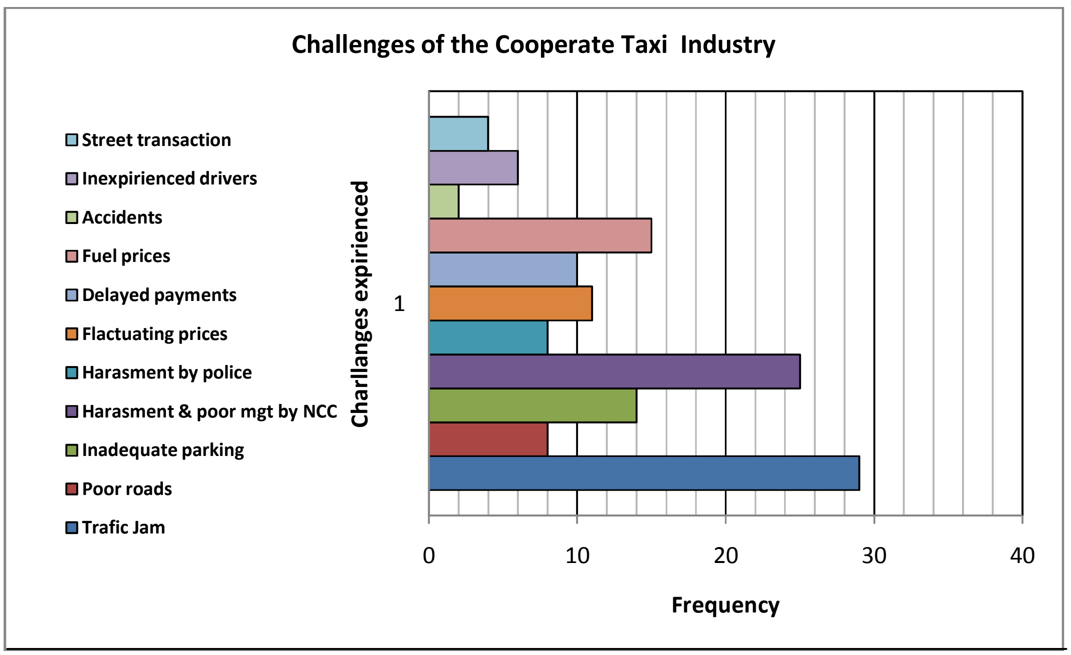

Figure 15: Challenges of the Corporate Taxi Industry (Source: Field Data 2013)

4.2.5 Potential Solutions

The industry feel there is great potential in solving these challenges if the relevant regulatory bodies improve on the management structures and approaches. It is arguable that the area lacks informed policies and regulations to guide and give direction. Further, all measures put forwards have been reactive to contain the ever emerging new challenges. This has resulted to system conflicts and disjointed coordination between involved management authorities

Infrastructure, regulated payments rates and fuel prices and drivers' capacity building are equally seen as areas of great potential in containing the adverse industry challenges. Figure 16 depicts respondents' rate of possible solutions to the existing challenges

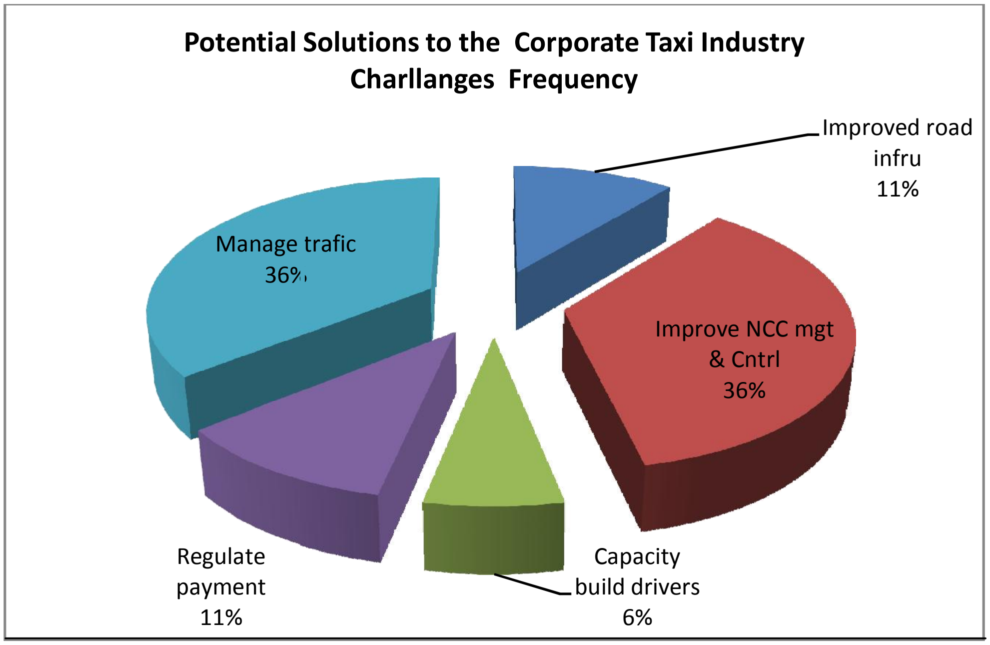

Figure 16: Possible Solutions (Source: Field Data 2013)

4.2.6 Environmental and Alternative Technology Awareness

More than half the companies sampled demonstrated environmental sensitivity and awareness. Figure 17, this was evident by existence of a signed-off environmental policy committing the company to sustainable engagements.

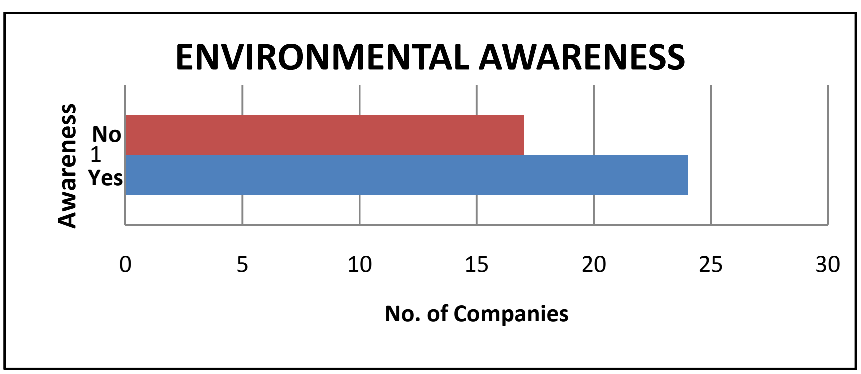

Figure 17: Environmental Awareness (Source: Field Data 2013)

This is further evidenced by the high number of respondents showing knowledge of alternative green taxi solution. From the tally, 80% of the respondents showed knowledge of various alternative green technologies that may be adopted in the taxi industry. Among the known technologies are: battery cars, electric cars, hybrid cars and bio-fuel cars. Figure 18 shows the knowledge response and the known technologies.

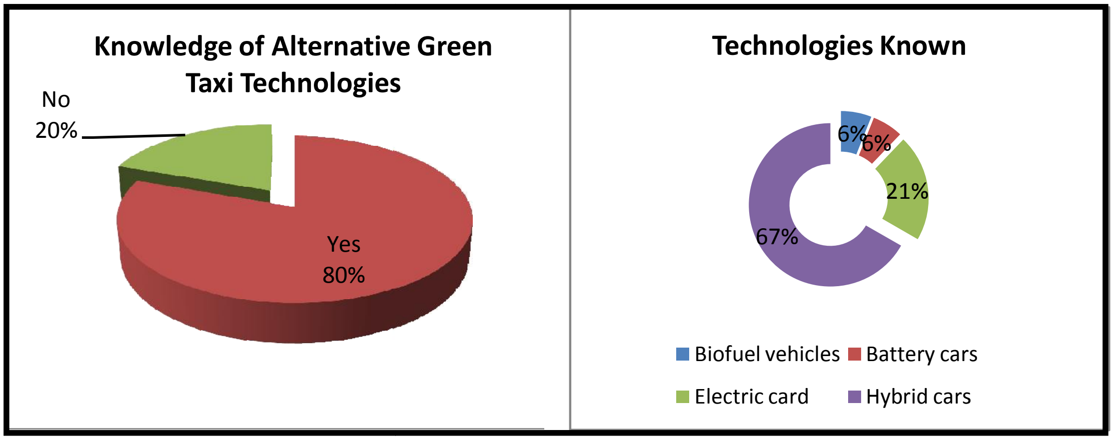

Figure 18 : Knowledge of Alternative Green Taxi Technologies (Source: Field Data 2013)

4.2.7 Perceived Challenges of Green Technologies

While green alternatives look interesting, there are several challenges that discourage industry players from embracing them. Some of these are actual while others are just a perception. Figure 19 presents some of the most perceived challenges by the respondents.
It is evident that the industry players feel the green technology vehicles are not built to endure the harsh and difficult environment and roads present in Kenya. The respondents feel that they will need to maintain a lot of overheads to service the green cars. They are equally very expensive. The cost of one car is equivalent to the cost of three ordinary cars.

The availability of spare parts and technical professional who repair and maintenance services are equally very limited, where available they are very expensive. The general public is equally not aware of the technology. Thus a small problem that does not need a mechanic could ground down a vehicle. Then there is the challenge of charging station and gas station. Kenya as a nation has not yet developed the infrastructure to support the new technologies that are environmentally friendly. These are some of the major challenges hindering the industry from adopting the technologies.

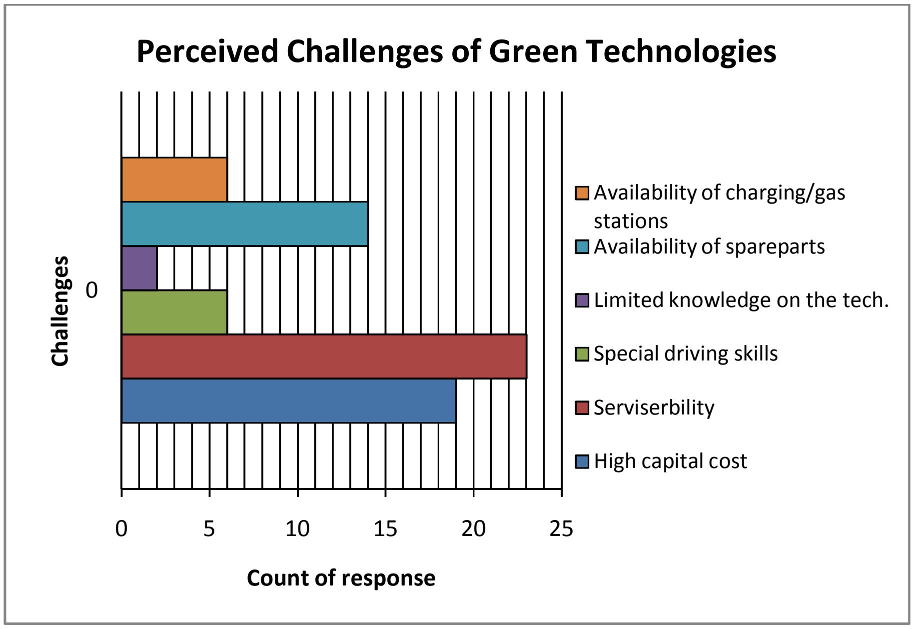

Figure 19: Perceived Challenges of Green Technologies (Source: Field Data 2013)

The market awareness on the available alternative green technologies is equally increasing. In tallied responses, 19 companies indicated that at least one client had made a special request for the company to provide environmentally friendly taxi vehicles. Is represents 46% of the sampled companies. It reflects that even though the taxi industry is reluctant to adopting the technology, very soon the market is going to demand for it and the industry will have no choice. Perhaps continued awareness creation by the government on the existing technologies will expedite this market demand.

The industry is equally very willing to adopt the technology if the necessary supporting infrastructure and facilities are put in place. A question enlisting respondents' willingness yielded 43% very willing followed by 33% willing. Only 24% are not sure considering that the hindering factors are contained. Figure 20 present a pie chart depicting willingness of operators to adopt the technologies and the market request for the technology.

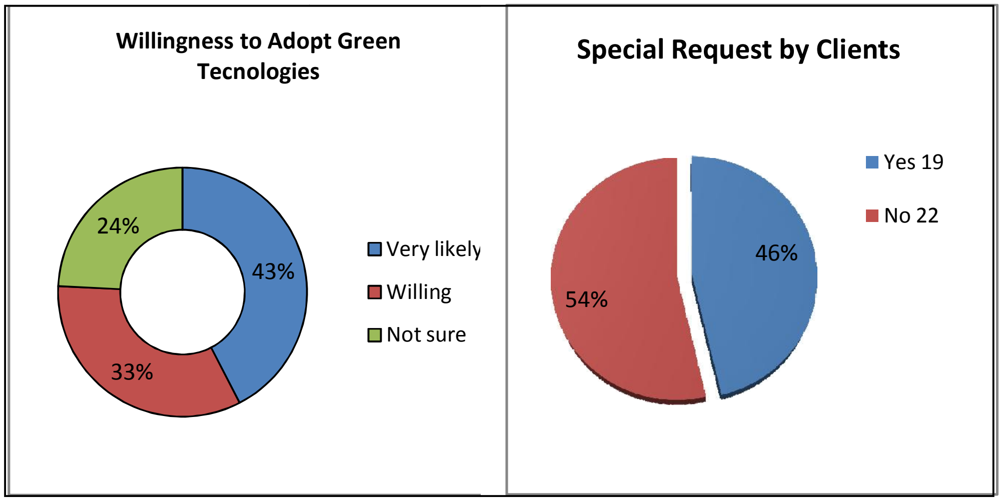

Figure 20: Special Client Request and Willingness to Adopt Green Technologies
(Source: Field Data 2013)

4.2.8 Complains Raised By Clients

Clients on the other hand have a take on the industry operation. 24% of the respondents agreed that traffic jam is the greatest hindrance of all things. 22% complained about delayed pick up time by drivers. 50% of the time the drivers arrive late or barely on time. Some (19%) expressed their dissatisfaction at the state and condition of the vehicles that offer the services including the disparities in rates across the taxi companies. Figure 21. Besides these, unprofessional drivers, road conditions and insecurity stand out as some of the increasing complaints clients raise to their service providers.

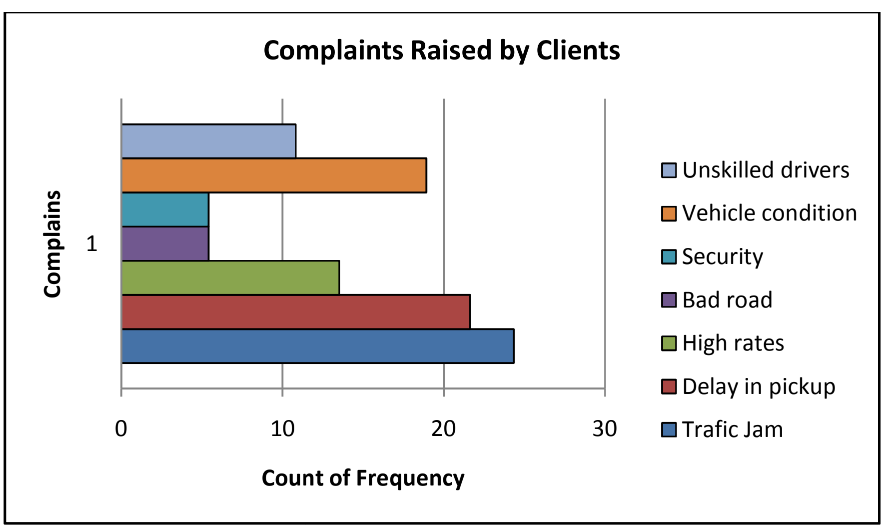

Figure 21: Complaints Raised by Clients (Source: Field Data 2013)

4.2.9 Fuel Combusted

The volume of fuel combusted further coincides with the fact that the industry has been growing steadily as depicted by the increased number of operating companies and the size of fleet Figures 6, Figures 7 and figure 8. It is also evident that there has been a consistent growth on volume of fuel combusted on a yearly basis, Figure 22.

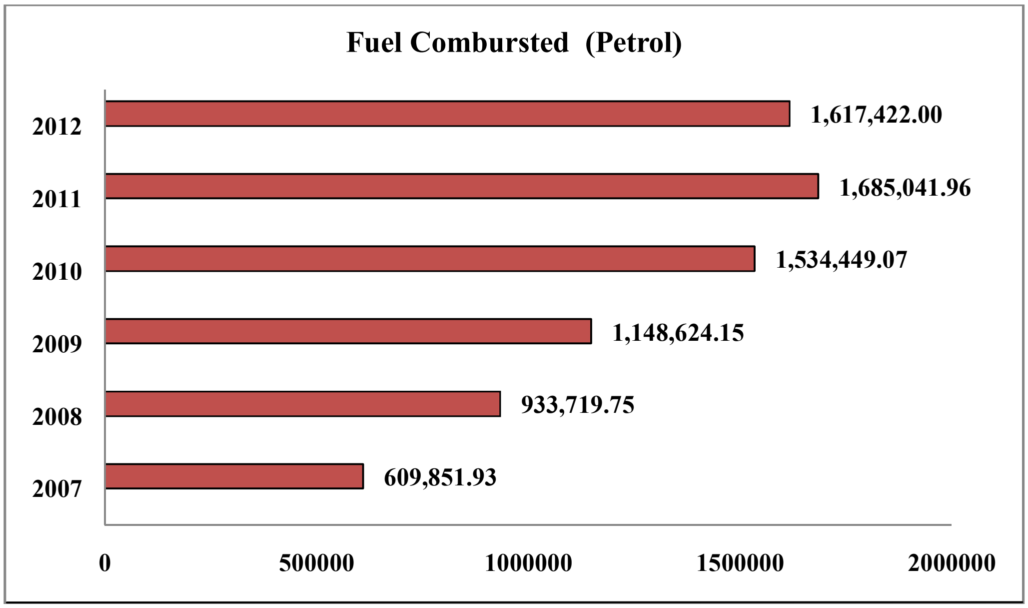

Figure 22: Volume of Fuel Combusted *(Source: Field Data 2013)*

It is possible to deduce that the volume combusted just like the number of registered taxi companies and the number of taxi fleets double after every four years. While referring to Figure 22, volume of litres of fuel combusted in 2007 was 609,851.93 and that combusted in 2011 (four years later) is 1,685,041.96. The same is reflected by the volumes combusted in 2008 and that of 2012.

For the purpose of consistency, only years with complete data across the sampled companies was used to tabulate the fuel consumed. Data prior to 2007 had gaps and was thought to affect the results and thus was not factored in the interpretation of combusted volumes.

There was a slight drop in the volume of fuel combusted in 2012 and this is due to missing data from two respondents for that year (2012). Refer to appendix 3: questionnaire no. 105 and 112 in the fuel sheet.

4.2.10 Carbon Emissions

It is evident from Figure 23 that the amount of carbon emitted into the atmosphere has continued to grow over the years. Since 2007, the yearly average from the corporate taxi industry alone has been in the excess of 3400 tones. In 2012 alone, approximately 4300 tonnes of carbon were emitted from the corporate taxi industry, which only represent an insignificant number of the automobiles in Nairobi City.

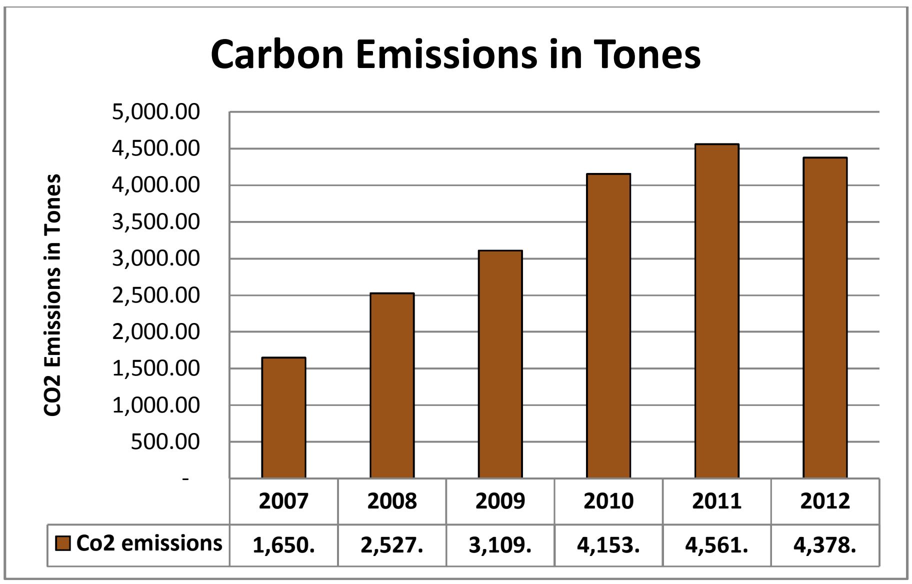

Figure 23: Carbon Emissions (Source: Field Data 2013)

It is right to argue that the corporate taxi industry only represenst a fraction of the taxi industry which in turn represents a fraction in the larger different classes of automobiles e.g. *matatu* (common 14-seater commercial public vehicles used in Kenya), trucks, private cars, car hires, shuttles (52-seater mini-buses) etc. which significantly contributes to the Nairobi carbon footprint.

4.2.11 Hypothesis Testing

H_0 The Corporate taxi industry does not contribute significant carbon emission to the Nairobi county carbon footprint.

H_1 The Corporate taxi industry contributes significant carbon emission to the Nairobi county carbon footprint.

Paired Statistics

		Mean	Std. Deviation	Std. Error Mean
Pair 1	No. of cars on the road	100.12	1.729	.125
	Carbon Emissions (Tonnes)	3396.88	.475	.081

In the above table, on average, 3.24 cars are on the road, with a standard deviation of 1.729 and an average of 3396.88 tonnes of carbon emissions. The last column gives the standard error of the mean for each of the two variables.

Paired Correlations

		Correlation	Sig.
Pair 1	No. of cars on the road & Carbon Emissions (Tones)	.464	.706

The correlation between the two variables is given in the second column. In the above table r = 0.464, this value shows a positive correlation between the number of cars and the amount of carbon emissions implying that an increase in number of cars on the roads increases the level of carbon emissions. The last column gives the p value for the correlation coefficient. Since the p value obtained above is greater than the alpha level (0.05), the null hypothesis is rejected. In this case, p = .706, so we to reject the null hypothesis. That is, there is sufficient evidence to conclude that the population correlation (ρ) is different from 0.

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	No. of cars on the road & Carbon Emissions (Tones)	1.794	1.038	.178	1.432	2.156	10.078	33	.000

The "t" column gives the observed or calculated t value. In the table above, the t value is 0.377 (you can ignore the sign.) The column labelled "df" gives the degrees of freedom associated with the t test. In this case, there are 33 degrees of freedom. The column labelled "Sig. (2-tailed)" gives the two-tailed p value associated with the test. In case, the p value is

0.000. If this had been a one-tailed test, we would need to look up the critical value of t in a table.

Decision: Reject H0: The decision rule is given by: If $p \leq \alpha$, then reject H0. In this hypothesis test, 0.000 which is the p- value is less than 0.05, so we reject H0 and accept H1. This implies that there is sufficient evidence to conclude that the corporate taxi industry contributes significant carbon emission to the Nairobi County carbon footprint.

5. CHAPTER FIVE: SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

This chapter presents a summary of the findings, conclusions and gives recommendations that may be adopted to minimize avoidable emissions from the corporate taxi industry and enhance willing adoption of the alternative green car technologies. These may also be applicable to the general automobile industry. It also presents a management plan that summarizes all the findings, recommendations, actions and key stakeholders who may induce the transformation process.

5.1 Summary of Findings

It was observed that the number of registered corporate taxi companies has continued to increase steadily since 1990 at a doubling rate after every four years. This is also reflected in the total number of fleet operated by the industry and the average number of fleet per company. Refer to sections 5.1 and 5.2. Sixty percent of the cars used by the companies are rented from the private individuals who prefer the Toyota NZE and Premio modes for its resilience, serviceability and low consumptions.

Consumption, serviceability, vehicle condition, comfort and durability are the highly determining factors for taxi industry. The first two open an opportunity for the government and other regulating authorities to capitalize on to invoke the transformation to the new alternative technologies.

Petrol is the most used fuel at 81% and there is good indication that corporate taxi vehicles are well serviced. The three major challenges of the industry are: road traffic, poor management and harassment from NCC and the traffic police, fluctuating fuel prices and inadequate parking.

The industry is confident that improving management structures and regulating policies and further developing plans to contain road traffic will ease the challenges. Both the corporate taxi industry service providers and the consumers themselves showed a high degree of environmental awareness. Findings indicate that they know the existing technologies and are very willing to adopt them if the existing challenges are suppressed and necessary support provided

Overall, corporate taxi industry alone burns approximately 1,617,422.00 litres of fuel every year. This transforms to about 4,300 tonnes of carbon. This is data from just a sample of the corporate taxi industry which represents the smallest fraction of the general taxi industry which consequently is a very smaller representation of the larger automotive industry. Then, it is possible to imagine the tonnage of emissions the general Nairobi county automobile industry is emitting into the environment.

5.2 Conclusion

The corporate taxi industry among other automotive sectors contributes significantly to the Nairobi carbon emission. There is unexploited potential from both the government and the industry stakeholders to reduce the emission to make Nairobi County a healthy environment. The Central and County governments have a great opportunity to institute control measures to regulate the automotive industry and put up necessary structures to support green mobility taking into account the challenges of the automotive industry and the factors influencing the choice of taxi vehicles. The public and the taxi industry are already aware of the available opportunities of green mobility and their advantages and would easily adopt the technology if the supporting infrastructure is put in place together with some awareness programs.

5.3 Recommendations

The government should step in and set up promotive and control policies and regulation to guide the industry towards adopting clean alternative vehicles towards reducing carbon and automotive emissions. This may include control, incentives and public awareness program. Besides the Fossil Fuel Emissions Control Regulations, other specific sector-targeted regulatory controls like Fuel Economy Standards to encourage reduced transport related fuel demand through vehicle fuel efficiency improvements; Fuel Quality Standards etc will steer the nation on the right course. The public on the other hand need to know these technologies exist and the related benefits of safeguarding the nation’s clean and healthy environment for all. The need to support local and external investors to initiate and set up information centres, repairs and mechanic workshop, importation and trade in spare parts of these green vehicular technologies is equally vital as is one of the key determining factors for the willing buyers.

The need for a centralised authority to control the industry and the transformation is also very necessary. Rather than having a disjointed approach from respective ministries, it would be important to have one authority charged with the responsibility of leading this transformation. It would regulate issues of emissions, vehicle conditions; incentives related to the alternative technologies adopted and even in charge of regulating the number and size of fleets each company should have. Again, it will be necessary to limit the number of licences of operating taxi companies on a yearly basis.

The taxi industry on the flip side needs to equally regulate their operations to avoid disparities across companies. KTA seems not to have the needed authority over its members and important issues that touch on the taxi operations. To meet and exceed the expectations of the market, KTA needs to rephrase itself and mobilize authority. The government on the other hand needs to improve on the challenges related to traffic and poor infrastructure. They are not exclusive to the taxi industry alone but the whole automotive industry would be at ease.

A nationwide baseline survey on the air quality has never been more necessary and equally due than now. The need for monitoring and modelling facilities able to collate and present data of the state of the nation's air quality on a real time is equally lacking. Past studies have only focused on Nairobi forgetting other cities and major towns. It would be important for the government to set aside finances to support these investments and further finance research in this area to inform policies and plans.

5.4 Areas for further research

The research revealed several gaps. There is need to research on the emission streams from varied industries into Nairobi carbon footprint i.e. construction, agriculture, manufacturing, transport etc. There is further a gap on the contribution of general automotive industry emissions into each sub-sector of the transport automotive sectors e.g. trains emissions, *matatu* emissions, planes, private cars etc.

Past studies in Nairobi City have been based of air quality and usually only spontaneous reading is taken. The government, regulating authorities and research institutions need to take this to a higher level and establish real time air quality monitoring centres at pre-identified locations or optionally have mobile monitoring centres to capture and record air quality data on a real time basis. This will generate very important information to support informed policy formulation and necessary government controls.

To inform awareness creation and invoke the needed self-will to initiate the country towards adopting alternative clean automotive technologies, detailed research on the existing policy, structural, management and physical challenges across the automobile industry will be necessary to set a good environment for the idea to thrive based of factual information.

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