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

JAMES CHACHA MAROA

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’s 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 establish the growth rate of the cooperate taxi industry in Nairobi County and further quantify the cooperate 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 and 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's evident from findings that there is a consistent growth in the cooperate 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 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 targeting regulatory controls like Fuel Economy Standards to encourage reduced transport related fuel demand through vehicle fuel efficiency improvements among other controls recommended. The study recommends areas of further research work for instance the need to research on the emission streams from varied industries into Nairobi carbon foot print ie construction, agriculture, manufacturing, transport etc. The research hopes this study will create awareness and build on past works on urban air pollution in Africa and trigger further research in the area of automotive emissions.
Introduction

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 km² 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 cooperate taxi industry and further quantifying their contribution to the Nairobi carbon emission.

Statement of the Problem

One of the pressing challenges facing cities in both the developed and developing world is reducing 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 setups 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 vehicle contribute the highest proportion on carbon monoxide/dioxide and other Toxic Air Pollutants (TAPs) such as such as benzene, formaldehyde, 1,3-butadiene etc that have the potential to cause serious adverse health effects in humans like neurological related problems, cardiovascular, 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 medium city that dominantly depends of 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). Compounded by the fact that efficient tools and regulatory policies for comprehensive strategic management that are directly useful to city automotive administrations are lacking worsens the challenges.

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 key in forecasting emission scenarios into ambient air quality. Knowing 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 cooperate taxi industry, this study investigated the growth rate of the cooperate taxi industry in Nairobi City, the challenges they face and their contribution to the Nairobi carbon foot print. It further presents potential solutions available in ameliorating this challenge.

Research Objectives

The study was guided by the following objectives:

(i) To establish the growth rate of the cooperate taxi industry in Nairobi city since 1990.
(ii) To quantify the cooperate taxi industry carbon emission contribution to Nairobi City.

LITERATURE REVIEW

Global Growth of Motor Vehicles

The growth in the production of motor vehicles since the end of world war two has been quite dramatic. Raising 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 1950’s to Europe thought 1960’s and currently the Asian region led by Japan.(MacKenzie,1992), Africa however poised to grow substantially in future decades for it present an 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 approximately 74% of the total motor vehicle annual produced in the world. The remaining 26% are made up by 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 world meter 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’s further not clear what use each automobile is put in once purchased, however it’s clear that the manufacture of small cars has tripled than any other automobile produced. (IRU, 2009) Some countries like Australia, United States, 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 eg trucks used for cargo transport, vans used for tour services, cars are used as taxis, or as private.

Omwenga (2005) estimated the total automobile in Kenya to be at749, 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 city represents approximately 30% of the total cars in Kenya.

**Urban Air Pollution**

Blacksmith Institute Report, 2007 defines air pollution as 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. He 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 that 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, however, 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 (Cifuentes 2001);

Quantifying the magnitude of the impact of air pollution in cities especially in Africa however, 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 available 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

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). HAPs are those pollutants that have the potential to cause serious adverse health effects in humans for example, neurological, cardiovascular, liver, kidney, and respiratory effects or effects on the immune and reproductive systems. 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 (C\text{x}H\text{x}), nitrogen oxides (NO\text{x}), fine particles, sulfur dioxide (SO\text{\textsubscript{2}}), and accelerated formation of ozone (O\text{\textsubscript{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 at the origin of neurological, hematomatological 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.

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 together results to high carbon hotspots especially in areas near and along busy slow roads and at round abouts.
As urban populations continue to increase, the health and safety impacts of cities to the urban population become a matter of concern. Lack of real-time air quality monitoring stations makes it even more difficult to assess the environmental health and safety impacts of carbon emissions 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) notes that Nairobi, Kenya is in many ways typical to most growing cities of developing countries that are at risk of deteriorated air quality. One projection estimated that the number of vehicle trips between 2004 and 2025 in the Nairobi Metropolitan Area would increase by 148% and that the average speed of trips will decrease from 35 km/hr to 11 km/hr as congestion increases (Ministry of Nairobi Metropolitan Development, 2011) which 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 becomes very vital to warrant control over automotive emissions.

Effects of Carbon Oxides

Oxides of carbon exist in two important forms when they mix oxygen: carbon monoxide, CO, and carbon dioxide, CO₂. 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 in their photosynthesis. It is colorless, odorless, non-flammable gas that is a product of cellular respiration and burning of fossil fuels. It has a molecular weight of 44.01 g/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 industry including breweries, mining ore, and manufacturing of carbonated drinks, drugs, disinfectants, pottery, and baking powder (NIOSH 1976). It also is a primary gas associated with volcanic eruptions (Farrar et al. 1999; IVHHN 2005). CO₂ acts to displace oxygen, making compressed CO₂ the main ingredient in fire extinguishers (MDPH 2005). Occupations that are most at risk from CO₂ exposure include miners, brewers, carbonated beverage workers, and grain elevator workers (CCOHS 2005; Nelson 2000). CO₂ 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 CO₂ of 5,000 parts per million (ppm) over an 8-hour work day, which 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.

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 which 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) agree that typical CO levels currently encountered in most indoor and outdoor environments especially in urban area have a potential for negative environmental health and safety impacts. This impact 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 this adverse effects include:

**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.

**Fetuses**

Fetus 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.

**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.

**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.

Individuals with chronic obstructive pulmonary disease 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.

Individuals with reduced blood haemoglobin concentrations, or with abnormal haemoglobin, will have reduced O2 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 seen in normal individuals.

Certain occupational groups 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](http://www.extraordinaryroadtrip.org/research-library/air-pollution/understanding-air-pollution/carbon-monoxide/health.asp) XRT Research Lab: accessed on 21st July 2012

**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. Maria A. Fierro, M.D, Mary Kay O'Rourke, Ph.D., and Jefferey L. Burgess (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)

**Existing Policies, Legislations and Regulatory Structures**

**The National Environment Management Authority (NEMA)**

The National Environment Management Authority (NEMA) is a government parastatal established to exercise general supervision and co-ordination over all matters relating to the environment. The Authority is the principal instrument of 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 this functions is to undertaking research and formulate environmental regulations and standards. In section 78 of EMCA, NEMA has been empowered to establishes the Standards Enforcement and Review Committee (SERC) which has been obligated to recommend to the Authority(NEMA) air quality standards/limits.

**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 the 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.

**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.

**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 emit 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.

**Research Gaps**

Literature on motor vehicle carbon emissions, especially its contribution to the carbon footprint in African cities still requires alot more research to be done. However, developed countries like Japan, China, USA among other countries have made great strides in this area having been supported by continued scientific research and real time air quality monitoring.
data by their emission regulatory authorities eg 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.

While so much research has been done in developed countries on urban air quality including necessary policy framework and legislation in remediating these 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.”

Theoretical Framework
Combustion of fossil fuel is the greatest sources of greenhouse emission, Kituyi (2005). These are directly emitted into the atmosphere where they react with different elements in complex chemical processes forming up different hazardous gases and compounds. These compounds in one way or another directly and/or indirectly influences 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 advance that 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
Reducing individual streams of engine emission from the varied sources like energy, agricultures, transport will consequently lead reduced automotive emissions and the resultant environmental, health and safety impacts associated with the emissions.

**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 2.1 below elaborates the linkage between the taxi industry, the existing legislation and administrative controls and the resultant emissions in relation to external influencing factors.

**Relationship between the taxi industry and the resultant emissions**

Cooperate taxi service providers use normal fossil vehicles to provide cooperate organization 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 travelled, 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 can have a significant reduction on the cumulative amount of carbon emitted by all corporate taxi
companies. This cumulatively translate to thousands of tones of carbon. Other secondary factors 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 cooperate taxi industry and modelling the potential in influencing the primary variables. It will also seek to investigate the needed legal and institutional framework needed to support the needed supporting environment.

**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.

**Study Area**

Nairobi is the most industrialized county in Kenya and host the highest number of Taxi operation. It has the most developed road network and by far has the heights number of taxi services users. With plural economic activities and a population of over three million, makes it potentially the most affected city by vehicular emissions. This study thus confined itself to investigate only Cooperate Taxi Companies operating within the boundaries of Nairobi

Boundary of the study area: Nairobi County
Administrative boundary of Nairobi County (Source: Nairobi County, 2014)

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 or so 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).

Mixed Methods Research Design

Mixed methodological research designs are principally for “better understanding” (Cook, 1986); mixed methods purposes of complementarity (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. A summary of these mixed method research typologies are contained in the Table 3.1 adapted from (Creswell, et al., 2003).

Examples of Mixed Methods Design Typology

<table>
<thead>
<tr>
<th>Creswell et al. (2003)</th>
<th>Stage of Integration</th>
<th>Implementation</th>
<th>Priority / Status</th>
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<tr>
<td><strong>Sequential designs</strong></td>
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<td>*Sequential explanatory</td>
<td>Interpretation</td>
<td>QUAN→qual</td>
<td>Usually QUAN, can be QUAL or equal</td>
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<td>*Sequential exploratory</td>
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<td>QUAL→quan</td>
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<tr>
<td>*Sequential transformative</td>
<td>Interpretation</td>
<td>QUAL→QUAN QUAN→QUAL</td>
<td>Either dominant or both equal</td>
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<td><strong>Concurrent designs</strong></td>
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<td>*Triangulation</td>
<td>Interpretation or analysis</td>
<td>QUAL + QUAN</td>
<td>Equal</td>
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<td>*Nested/ Embedded</td>
<td>Analysis</td>
<td>qual within QUAN quan within QUAL</td>
<td>Either dominant</td>
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Creswell et al. (2003)

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<th>Stage of Integration</th>
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<tbody>
<tr>
<td>*Transformative</td>
<td>Usually analysis, can be interpretation</td>
<td>QUAL + QUAN</td>
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Adapted from Creswell et al., 2003

**Key for Table 3.1**
* Capital letters signify that methodology is dominant, small letters signify that methodology is less dominant. If both are capitalized, both methodologies have equal weight in the study.
* An arrow (→) signifies sequential implementation. A plus (+) signifies concurrent implementation.

**Target Population**

The study targeted registered cooperate taxi companies operating within Nairobi county eg Kenatco, Jim Cab, Dial a Cab etc. Appendix 4-1 provides a complete register of the cooperate taxis companies that formed the population under study.

**Sampling procedure**

Obtaining information from a sample is normally easier and 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 cooperate taxi companies with the Kenya Taxi Association within Nairobi City. Out of the registered taxi companies, the study sought to focus on only the taxi companies that limit their services to corporate organization. This was to help eliminate potential assumptions that some of the millage 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. 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 15 samples. Considering that the targeted population was homogeneous in nature equally increased the confidence level of the 41 samples being a good representation of the total population of 76 companies.

Working with the first equation ie gives us a sample size of 15 samples:

**Equation 1:**

\[
\text{Sample size (n)} = 20\% \times \text{the total number of registered corporate taxi companies} \\
= 20/100 \times 76 \\
= 15.2
\]

Going with the second equation while factoring sample confidence level, confidence interval and the total population gives a sample of 37 companies.
Equation 2:

\[ \text{Sample size (n)} = \frac{t^2 \times p(1-p)}{m^2} \]

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) = \( \frac{1.655 \times 0.05(1-0.05)}{0.05^2} \)

=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.

The choice of scaling down from the total survey of 76 samples to 41 was informed by the fact that some of the companies did not have complete and consistent data.
Distribution of the Sampled Corporate Taxi Companies Across the Study Area
(Source: Author developed using Google map and GPS data of 2013)

Data Collection

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:

Primary Source

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 4-1 below summarizes the different types of tools that were be used and the nature of data that was collected

<table>
<thead>
<tr>
<th>NO.</th>
<th>TOOLS</th>
<th>NATURE OF DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Summary Notes</td>
<td>Field notes helped capture quantitative information and other observable phenomena. This included information acquired from un official meetings and discussions which cannot be authenticated</td>
</tr>
<tr>
<td>2.</td>
<td>Checklists</td>
<td>This helped in noting and counter truthing key information while in the field eg type of cars used. fuel used etc</td>
</tr>
<tr>
<td>3.</td>
<td>Structured Questionnaires</td>
<td>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. Ref sample questionnaire in Appendix 4-2</td>
</tr>
<tr>
<td>4.</td>
<td>Interview and Minutes</td>
<td>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.</td>
</tr>
<tr>
<td>5.</td>
<td>GPS</td>
<td>The use of a GPS became handy in capturing GPS locations of offices of the taxi companies where the questionnaires were administered. It also help in mapping the distribution and location of the sampled taxi organizations</td>
</tr>
</tbody>
</table>

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.
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

Methods of Data Analysis and Presentation

Data from records and questionnaires was coded for analysis using Microsoft Excel 2007. Each response was analyzed 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 conclusion were then drawn from the analysis based on quantifiable elements like mean, mode, percentages and chi-square test. Other unquantifiable information captured in notes, checklists and observations. Output was presented in tables and graphical form and elaborated in verbatim.

Validity and reliability

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 determines 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 ensures there is even distribution of the samples from each strata and that each category has an equal opportunity thus guaranteeing more and equal representation of the population

Reliability

Joppe (2000) defines reliability as the extent to which results are consistent over time, and accurate representation of the total population under study is referred to as reliability, and 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.

Chi-square test and Null hypothesis testing

A chi-squared test, also referred to as chi-square test or x2 test is a statistical hypothesis test in which the sampling distribution is a chi-squared distribution when the null hypothesis is
true. 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.

**CO2 Emissions Equation**

The CO₂ 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, CO₂ emissions can be determined directly. (TRC General Reporting Protocol, 2008). Often, however, this information may not be readily available for a particular fuel. The CO₂ 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. (WorldResourcesInstitute, 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 CO₂ emissions from Mobile Combustion Sources:

a) Direct measurement and
b) Calculation based method.

Direct measurement of CO₂ 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 4-2 illustrates the methodology for each approach.
Carbon Emission Methodology, (Source: TRC General Reporting Protocol, 2008)

This is an overview of the two possible methods that would have been used. In this study, the Calculation based method was preferred to calculate emissions from the carbon content per unit of energy. Emissions were calculated by applying a carbon content and fraction of carbon oxidized factor to the total fuel consumption for Petrol. Figure 4-3 presents the equation used which has further been discussed in subsequent sections below.

**Equation 2: Carbon Content per Unit of Energy Approach for Estimating CO₂ Emissions**

\[
\text{Emissions} = \sum_{i=1}^{n} \text{Fuel}_i \times \text{HC}_i \times C_1 \times \text{FO}_1 \times \frac{\text{CO}_2 \text{ (m.w.)}}{C \text{ (m.w.)}}
\]

where:

- \(\text{Fuel}_i\) = Volume of Fuel Type \(i\) Combed
- \(\text{HC}_i\) = Heat Content of Fuel Type \(i\) \(\left(\frac{\text{energy}}{\text{volume of fuel}}\right)\)
- \(C_1\) = Carbon Content Coefficient of Fuel Type \(i\) \(\left(\frac{\text{mass C}}{\text{energy}}\right)\)
- \(\text{FO}_1\) = Fraction Oxidized of Fuel Type \(i\)
- \(\text{CO}_2 \text{ (m.w.)}\) = Molecular weight of \(\text{CO}_2\)
- \(C \text{ (m.w.)}\) = Molecular Weight of Carbon

**Step 1: Determine the amount of fuel combusted.**
This was determined from records of fuel receipts, purchase records kept by the TAXI companies. Its the estimate of the fuel consumed in litres.

**Step2: 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)

**Step3: Estimate carbon content of fuels consumed.** To estimate the carbon content, multiply energy content the fuel used by fuel-specific carbon content coefficients (massC/energy) which is 19.36 petrol for Petrol, (US Environmental Protection Agency, 2004)

**Step4: Estimate carbon emitted.** When Petrol is burned, most of the carbon is eventually oxidized to CO2 and emitted to the atmosphere. When all variables are integrated into the equation, the amount of carbon emitted can be accurately derived.

In a 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 $\frac{24}{26} \times 800 = 738$ grams of carbon. Since 1 carbon atom combines with 2 oxygen atoms each $12 \text{ gm}$ carbon combines with $32 \text{ gm}$ oxygen to make $45 \text{ gm}$ 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 CO2 for every one litre of petrol combusted.

**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 in wanting to complete the questionnaires in the capacity of their position. Some were even hesitant to share the millage 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 shared.

Some companies equally didn't have consistent data. Even though reputed and big in terms of fleet capacity, they genuinely did not have records of millage 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 which was overcome by engaging four research assistants to help in data collection and questionnaire coding.
RESULTS AND DISCUSSION

Growth of corporate taxi companies

Corporate taxi industry has continued to grow steadily at a doubling rate. Study findings indicate that since 1990 to 2009, registered corporate taxi companies have been doubling up in their numbers after an interval of every four years. From figure 7-1 below, it evident that between 1990 to 1994 and 1995 to 1999 the numbers 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.

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 cooperate taxi industry shooting from 76 registered corporate taxi companies now to about 304 in 2024.
Projected growth by 2024 (Source: Field Data 2013)

<table>
<thead>
<tr>
<th>Year Of Incorporation Of The Company</th>
<th>No. Of Companies</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1900 -1994</td>
<td>2</td>
<td>Actual</td>
</tr>
<tr>
<td>1995-1999</td>
<td>4</td>
<td>Actual</td>
</tr>
<tr>
<td>2000-2004</td>
<td>8</td>
<td>Actual</td>
</tr>
<tr>
<td>2005-2009</td>
<td>13</td>
<td>Actual</td>
</tr>
<tr>
<td>2010-2014</td>
<td>76</td>
<td>Actual</td>
</tr>
<tr>
<td>2015 - 2019</td>
<td>152</td>
<td>Projected</td>
</tr>
<tr>
<td>2020 - 2024</td>
<td>304</td>
<td>Projected</td>
</tr>
</tbody>
</table>

Projected growth by 2024(Source: Field Data 2013)

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. The largest growth being between 2005 to 2009 where the industry experienced an increase in fleet from 298 cars to 736.

<table>
<thead>
<tr>
<th>YEAR OF INCORPORATION OF THE COMPANY</th>
<th>NO. OF TAXIS ON THE ROAD</th>
<th>AVERAGE FLEET SIZE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1900 -1994</td>
<td>24</td>
<td>12</td>
</tr>
<tr>
<td>1995-1999</td>
<td>104</td>
<td>26</td>
</tr>
<tr>
<td>2000-2004</td>
<td>298</td>
<td>37</td>
</tr>
<tr>
<td>2005-2009</td>
<td>736</td>
<td>57</td>
</tr>
<tr>
<td>2010-2014</td>
<td>7717</td>
<td>102</td>
</tr>
</tbody>
</table>

Average fleet size (Source: Field Data 2013)

It can be observed that not only has 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. Projecting the same growth rate in a linear graph gives us an average of 293 cars per company by 2024 and an estimated 17,362 taxi cars on the road.
Ownership of cars

Majority of the cars are rented by the companies from individual citizen who then receive a fixed agreed amount on a monthly basis. This arrangement represents approximately 60% of the taxi vehicles on the road. Figure below shows the distribution of ownership of the corporate taxi industry as at August 2012.
Ownership of taxi vehicles (Source: Field Data 2013)

Contribution of the Cooperate Taxi Industry to the Nairobi County Carbon Emission Footprint

Vehicles Used

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

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

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 litter 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
s市区和郊外的出租车服务，服务站和车辆的可销售性。这包括了车辆的内外部状况、耐用性以及车辆的品牌，这些因素对他们的考虑占到了10%。其他影响因素包括车辆的年龄、行驶里程、客户偏好、初始资本成本和颜色。图7-7下面突出了出租车经营者在选择车辆时考虑的因素。

### Factors Influencing Choice of Car for Taxi Services

<table>
<thead>
<tr>
<th>Factors</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumption</td>
<td>22%</td>
</tr>
<tr>
<td>Serviceability</td>
<td>17%</td>
</tr>
<tr>
<td>Age of vehicle</td>
<td>6%</td>
</tr>
<tr>
<td>Vehicle condition</td>
<td>13%</td>
</tr>
<tr>
<td>Customer Preference</td>
<td>3%</td>
</tr>
<tr>
<td>Comfort</td>
<td>10%</td>
</tr>
<tr>
<td>Capital Cost</td>
<td>3%</td>
</tr>
<tr>
<td>Durability</td>
<td>10%</td>
</tr>
<tr>
<td>Brand/make</td>
<td>10%</td>
</tr>
<tr>
<td>Colour</td>
<td>6%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

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

### 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 biofuel. The chart below depicts the proposition of fuel used by the taxi operator.
51% of the respondents service their vehicle on a monthly basis. 44% of the operator’s service them as and when required. Most often as indicated on the service tag; usually 5000km or 3000km. There being no response on servicing ‘when they break’ and higher response on ‘monthly’ the study deduce that the corporate taxi vehicles are well serviced and maintained.

Traffic jam is perceived to be the greatest challenge to the industry at 22% followed by 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 its 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, its 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.
Challenges of the Cooperate Taxi Industry (Source: Field Data 2013)

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's arguable that the area lacks informed policies and regulations to guide and give direction and all measures put forward have been reactive to contain the ever emerging new challenges. This has resulted in systems 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 below depicts respondents rate of possible solutions to the existing challenges.

Possible Solutions (Source: Field Data 2013)
Environmental and Alternative Technology Awareness

More than half the companies sampled demonstrated environmental sensitivity and awareness. This was evident by existence of a signed off environmental policy committing the company to sustainable engagements. See figure below.

![Environmental Awareness Graph](image)

Environmental Awareness (Source: Field Data 2013)

This is further evidenced by the high number of respondent showing knowledge of alternative green taxi solution. From the tally, 80% of the respondent 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 5-13 below shows the knowledge response and the known technologies.

![Knowledge of Alternative Green Taxi Technologies](image)

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

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

From the figure above, the industry players feel the green technology vehicles are not built to endure the harsh and difficult environment and roads present in Kenya. The respondent feels 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

The market awareness on the available alternative greed 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.
Special Client Request and Willingness to Adopt Green Technologies (Source: Field Data 2013)

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 5-14 above present a pie chart depicting willingness to adopt the technologies and the market request for the technology.

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 hindrances of all things. 22% complained about delayed pickups 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. Besides these, unprofessional drivers, road conditions and insecurity stand out as some of the increasing complaints clients raise to their service providers. See figure 5-15 below the major complains raised by clients.
Volume of Fuel Combusted (Source: Field Data 2013)

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 ref figure 5-1 to figure 5-4. Figure 5-16 below shows a consistent growth on an yearly basis.

![Fuel Combursted (Petrol)](image)

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 5-10 above, 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 would 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). Ref appendix 4-3: questionnaire no. 105 and 112 in the fuel sheet

Carbon Emissions

It is evident from the figure below 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 tones of carbon were emitted from the corporate taxi industry, which only represent an insignificant number of the automobiles in Nairobi City.
It is right to argue that the corporate taxi industry only represent a fraction of the taxi industry which in turn represents a fraction in the larger different classes of automobiles eg matatus, trucks, private cars, car hires, shuttles etc. which significantly contributes to the Nairobi carbon foot print.

Hypothesis Testing

$H_0$: The cooperate taxi industry does not contribute significant carbon emission to the Nairobi county carbon foot print.

$H_1$: The cooperate taxi industry contributes significant carbon emission to the Nairobi county carbon foot print.

| Paired Statistics |
|-------------------|-----------|-----------|-----------|
|                   | Mean      | Std. Deviation | Std. Error |
| Pair 1            |           |             | Mean     |
| No. of cars on the road | 100.12    | 1.729      | .125     |
| Carbon Emissions (Tones) | 3396.88   | .475       | .081     |

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

Paired Correlations

<table>
<thead>
<tr>
<th></th>
<th>Correlation</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pair 1</td>
<td>.464</td>
<td>.706</td>
</tr>
</tbody>
</table>

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 (\( \rho \)) is different from 0.

<table>
<thead>
<tr>
<th>Paired Differences</th>
<th>95% Confidence Interval of the Difference</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>Std. Deviation</td>
<td>Std. Error Mean</td>
<td>Lower</td>
<td>Upper</td>
</tr>
<tr>
<td>Pair 1</td>
<td>No. of cars on the road &amp; Carbon Emissions (Tones)</td>
<td>1.794</td>
<td>1.038</td>
<td>.178</td>
</tr>
</tbody>
</table>

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 cooperate taxi industry contributes significant carbon emission to the Nairobi county carbon foot print.

**SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS**

**Summary of Findings**

From the research above, it’s 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. Ref section 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 opens 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 services. 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 provides 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 tones of carbon. If 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.

Conclusion and 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 be 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 need 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 need to rephrase itself and mobilize authority. The government on the other hand need 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 necessary and equally due than now. The need for monitoring and modelling facilities able to collate and present data of the state of the nations 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 this investments and further finance research in this area to inform policies and plans.
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