

The present and the future potential effect on urban air quality of the use of electric vehicles:

A case study of Lahti and Lagos

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Abstract

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Title of Publication The present and the future potential effect on urban air quality of the use of electric vehicles: A case study of Lahti and Lagos		
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<p>More than ever before, there is now need for cleaner air, and safer environment and for societies to be more environmental-conscious. The quest for better and healthier living in an environment that is free from avoidable toxin and avertable pollution are currently driving innovativeness, in all sectors, especially the automobile sectors. This study investigated the environmental consciousness of two cities (Lahti City in Finland and Lagos city in Nigeria.) as it relates to the present and future effect on urban air quality of the use of electric vehicles (EVs). EV has the potential to reduce air pollution and greenhouse gas emissions. Although EV adoption is increasing, much about their mitigation potential remains unknown, including ideal vehicle type prioritization, power generation contingencies, the effects of clean air legislation, and EVs' ability to mitigate acute impacts occurrences of poor air quality.</p> <p>Furthermore, this study used the pragmatism research philosophy, inductive research approach and narrative research design. Secondary data collection and qualitative data analysis method were also employed. Finally, Thematic analysis was used to analysis the data collected.</p> <p>In conclusion, the use of electric vehicles currently has and will have a positive impact on the urban air quality of Lahti and Lagos.</p>		
Urban air quality, Air Pollution, Electric Vehicles, Sustainability.		

Contents

1 Introduction..... 1

 1.1 Thesis Focus 2

2 Thesis Structure..... 3

 2.1 Aims and Objectives 3

 2.1.1 Research Question 3

 2.1.2 Thesis Outline..... 4

 2.1.3 Thesis Overview 4

 2.1.4 Description of Study Area. 4

3 Literature Review..... 5

 3.1 Vehicle Effect on Air Quality 5

 3.1.1 Vehicle emission in Europe and Africa..... 7

 3.1.2 Adoption of Electric Vehicles in Lahti and Lagos cities.....11

 3.1.3 Integrating Electric Vehicles into Sustainable Transportation Planning in Lahti and Lagos12

 3.1.4 Evolution of Lahti and Lagos to Smart Cities.....14

4 Methodology18

 3.1 Research Design.....18

 4.1.1 Sampling20

 4.1.2 Data Collection21

 4.1.3 Data Analysis.....22

 4.1.4 Ethical Consideration.....23

5 Results24

 5.1 Reflection and Discussion35

6 Conclusion.....40

References42

Appendices

Appendix 1. Interview Protocol for Qualitative Research.

Brief Description of Concepts

Air Pollution

(Seinfeld & Pandis 2008.) "The presence in the air of one or more compounds at a concentration or for a period above their natural values, with the potential to create a negative effect," is how the definition of air pollution is put. It can also mean the introduction of any chemical, physical, or biological factor that affects the natural properties of the atmosphere into indoor (household) and outdoor (ambient) habitats. (Roberts 2021, 92.) Nevertheless, in many nations, like China, car emissions are considered a significant contributor to air pollution. (Wang et al. 2019, 1.)

Air Quality

This is a measure of how clean or polluted the air is in a particular place, and basically refers to the condition of air in any environment (Marinello et al. 2020, 1.) It evaluates the extent to which the air is clean and free from pollutants such as smoke, smog and other gaseous impurities (Guwe et al. 2021.)

Charging Infrastructure

This means the network of charging facilities for Electric Vehicles, including the charging station or any piece of device that supplies power to Electric Vehicles (Bayram et al. 2013, 2.)

Electric Vehicles

These are cars or vans which use rechargeable batteries as a replacement or addition to petrol or diesel internal-combustion engine (ICE). Hence, they are considered beneficial to the environment as the carbon emissions with electricity are usually lower than those of petrol or diesel. Battery Electric Vehicles (BEVs), which use large rechargeable battery packs, are one of the four categories of electric vehicles. Plug-in hybrid electric vehicles (PHEVs), which are similar to HEVs but have the option of using an external source of electricity, are hybrid electric vehicles (HEVs), which contain both ICE and electric motors but cannot be hooked into any charger.; and Range-extended Electric Vehicles (REVs) which can run exclusively from an electric motor but possess on-board generator to re-charge the battery, if required.

Plan for Urban Sustainable Mobility

This is a systematic, all-encompassing plan that will bring together important stakeholders and cost-effective solutions to address mobility issues. It improves upon current planning techniques and gives proper thought to integration, involvement, and evaluation. – thus, ensuring adequate quality of life for residents (Abdel Wahed Ahmed & Abd El Monem, 2020, 3; Candia et al. 2019, 1.)

Urban Air Quality

This generally refers to the degree of air cleanliness in any city with a high population density and activity level (Borck & Schrauth 2021, 1.) The rapid expansion of industries, infrastructure, and economic development has been blamed for the poor condition of urban air quality, particularly in megacities. This has also been linked to the widespread use of fossil fuels in the manufacturing, household, industrial, and transportation sectors. (Angelevska et al. 2021, 2.)

1 Introduction

The UN General Assembly remarked that transportation would be expected to be the main driving force behind a growing global need for energy during the 1992 United Nations (UN) Earth Summit, which marked the first recognition of the significance of transportation in sustainable development. (Johnson, 1993.) Several anchor points for sustainable transportation were put forth at the UN World Summit on Sustainable Development in 2002, including infrastructure, public transportation systems, goods delivery networks, and transportation convenience, as well as bettering urban air quality and health and lowering greenhouse gas emissions. (Von Frantzius 2004, 469). Global emphasis has recently been focused on the idea that sustainable transportation can boost economic development and increase accessibility as it may relate to urban resilience, urban-rural links, and the productivity of rural areas. (Baffoe et al. 2021,1358).

Air pollution is the major threat to environmental health in the modern era. It kills an estimated 7 million people every year (Roberts 2021, 92). Cook stoves and kerosene lamps, as well as coal-fired power plants, vehicle emissions, industrial furnaces, wildfires, and sand and dust storms, all contribute to pollution. (UNEP, 2022). Rapid increase of the world population which has led to its globalization and urbanization has also caused an increment in the number of motor vehicles on the road. However, increased motorization was frequently accompanied by a general decrease in air quality (Cai & Xie 2007, 1.) Until recent invention and adoption of electric vehicles, all the vehicles were powered using the fossil fuel. The transportation industry alone accounts for 24% of total world GHG emissions, with passenger car combustion accounting for 60% of that (Planète Energies, 2021.) Furthermore, the need for commercial transportation vehicles is expected to increase. This will further decrease the air quality if non-environmentally friendly vehicles are still in use. The use of electric vehicles is stated to reduce carbon emission; the emergence of it has received an adoption and worldwide acceptance, making all automobile companies to strategize their plans towards the production of electric vehicles. According to a recent study by (Yale School of Environment, 2021.) showed that electric vehicles have a considerable pollution advantage over conventional automobiles. As urban population is projected to grow which will also increase the number of vehicles purchased, it is imperative to understand clearly the vehicle emissions and the consequences to our environment.

1.1 Thesis Focus

The purpose of this study is to determine where better air quality is needed and highlight perception of electric cars users in Lahti and Lagos about adoption of Electric Vehicles to combat air pollution. To achieve these aims, available data are analysed using thematic analysis methodology. The research method is to demonstrate the importance of users' perception of improvement of air quality, thus providing insight into the behaviour and attitudes of electric cars users in the study area.

2 Thesis Structure

The dissertation's structure and the arrangement of the remaining sections are covered in this section. Consequently, the dissertation's layout was as follows:

Literature Review: The Literature Review discusses earlier studies in this area that are connected. It covers existing materials and data on vehicle emissions in Europe and Africa, effects of electric cars on air quality, and possible evolution of Lagos and Lahti to smart cities, with increased adoption of Electric Vehicles. The evaluation of previous research publications revealed the scope of earlier studies and highlighted knowledge gaps that still exist.

Methodology: Explains the technical technique employed for data analysis in order to accomplish the project's objective. It summarizes the detailed procedures and outlines the datasets and methodology framework that were employed.

Result: Presents findings of the data analysed in the form of tables. Additionally, it highlights similarities and differences between these findings and those of earlier research studies that have been published.

Conclusion, Discussion, Recommendation and direction for Future work: The dissertation is concluded by summarizing the findings in order to resolve the research uncertainties. It also includes some recommendations and ideas for future work.

2.1 Aims and Objectives

This study's main objective is to investigate how and to what degree conventional vehicles affect air quality, especially in urban areas – such as Lagos and Lahti. Also, this knowledge will help scholars looking at urban environmental challenges. In summary, this will help with forecasting car emission inventories. inventories.

2.1.1 Research Question

The research is based on the three questions outlined below:

- I. Does the increased use of Conventional Vehicles in cities have any influence on air pollution?
- II. Will the adoption of electric vehicles improve urban air quality

- III. How well can we implement adoption of electric vehicles as a feasible strategy for improved air quality in cities

2.1.2 Thesis Outline

This part summarizes the goals of the project goals, describes the study area and outlines the research questions. This study aims to reflect on literature from a variety of fields to serve as a basis for understanding the impact of electric vehicles on urban air quality, using the cities of Lahti and Lagos as case studies, and proposing workable ways to promote the adoption of electric vehicles in the study areas, paying careful attention to the differences between the policies and features available in Europe and Africa.

2.1.3 Thesis Overview

This project involves an integrated analysis approach involving qualitative analysis of vehicle emissions and the perception of users.

2.1.4 Description of Study Area.

This study will attempt to find out the present and the future potential effect on urban air quality of the use of electric vehicles between two different cities of the world, in separate continent (Lahti city in Finland and Lagos city in Nigeria). The study area is chosen due to familiarity with those places. Also, Lahti is Finland's ninth-largest city, having a total area of 517.63 KM², and population of over 120,000 inhabitants. Lahti city is in a first world country which has started using electric vehicles into their transport system, but emits hundreds of tonnes of gases into the atmosphere (EGCA). However, Lagos, Nigeria's largest metropolis and a seaside area, with population of over 21,000,000 and total area of 1171.28 KM². According to (LCAP 2021.) Lagos emitted over 26,000,000 CO₂ in 2015. From the two reports, emission from transportation contributes a lot to the total emission in the two cities. Predicting the effect electric cars would have on the emission present and future of the cities is what this paper will understudy.

3 Literature Review

3.1 Vehicle Effect on Air Quality

In cities around the world, urban air pollution has been observed to have significant influence on public health, as cities are considered important contributors to climate change (Lin & Zhu 2018, 313.) The United Nations predict that by 2025, 66% of the world's population will reside in urban areas (United Nations 2014, 14.) In the same line, transport is considered the fastest-growing source of fossil fuel carbon dioxide emissions in the world and this is responsible for 24% of direct carbon dioxide (CO₂) emissions (International Energy Agency, 2020). Report indicates that between 1995 and 2019, emissions from passenger car transportation increased by 28% globally, as opposed to the expected decrease of 2.5 metric tons of emissions from light-duty vehicles (International Energy Agency, 2019). Therefore, the advent of smart networks powered by renewable energy sources is evidence that the energy and engineering industries must make strategic decisions for the construction and growth of smart cities, leading to energy changes in energy production, usage and distribution (Parag and Sovacool 2016, 4.) This is also demonstrated in the study trend affirming increased adoption of Electric Vehicles in smart cities, as they reduce carbon dioxide (CO₂) emissions and facilitate deployment of business architectural strategies to sustainable mobility (Anthony 2020, 832.)

Industrialization and urbanization have also played significant role in the steady increase of motor vehicles and this has unquestionably led to an overall decline in air quality (Coker et al. 2020, 625). This has also led to increased presence of carbon monoxide (CO), nitrogen oxides (NO_x) and particulate matter (PM) in major cities (Kwakwa & Alhassan 2018, 309; Zaman & Abd-el-Moemen 2017, 1126). Urban air quality has substantially deteriorated, thus necessitating the construction of an urban transportation system that can be complemented with collaborative and intelligent transportation systems (Turon & Kubik 2020, 1). Buildings and transportation systems are considered as primary sources of energy consumption in towns, as the simultaneous study of carbon emissions aid urban legislators and officers to circumvent unintended results of biased policies to lessen carbon dioxide ("CO₂") emissions (Ji et al. 2022, 2). Furthermore, vehicle emissions have also been found to take the place of industrial waste gas as a primary source of pollutants in some major and medium-sized cities in China (Zhang et al. 2020, 1).

Particles and gases in the ambient environment are constituents of air quality and the deteriorating condition of the air in cities has been linked to the rising levels of industrial and traffic emissions (Kumar & Maharana 2020, 194). This is regarded as an adverse issue in the society, with vehicular emission as a core factor that impacts air quality; as major source

of emissions is from on-the-road motor vehicles, which include cars, bikes and trucks (Kumar et al. 2021, 6317). Also, the primary sources of Particulate Matter (PM) emissions are power production and road transport (Ayeter et al. 2021, 2.) Furthermore, diverse studies have linked emission of Particulate Matter (PM) to a number of health conditions leading to early death as a result of heart or lung illness or worsened asthma (Wang et al. 2020, 102244). According to reports, air pollution causes high number of deaths worldwide, with poorer countries accounting for 85% of these deaths (Lelieveld et al 2019, 15). This study aims to assess the potential of Electric Vehicle adoption on air pollution reduction in Lahti, Finland and Lagos, Nigeria – as Electric Vehicles consume more power, thus requiring the Researcher to consider potential impact on air quality when reducing vehicle emission while increasing emissions from power plants (Collett et al. 2021, 3).

Urban Sustainability literatures include diverse studies aimed at understanding recent and projected trends in the frequency and intensity of climate-induced events in cities (Sharifi and Yamagata, 2022; Arabadzhyan et al. 2021, 2). However, limited researches have been conducted to investigate the current and future effects of widespread use of Electric Vehicles in cities (Ewert et al. 2020, 8098; Honey et al. 2014, 143). In addition, there is limited monitoring of air pollution in African countries, including Nigeria, thus posing a hindrance to designing effective measures to address air pollution (Mir Alvarez et al. 2020, 51.)

Consequently, this study will examine potential of Electric Vehicles to reduce emission in cities, thus laying a basis for the formulation of relevant policies on vehicle emission reduction. Despite the fact that when powered by batteries, Electric Vehicles have no tail-pipe emissions as the power source may still emit emissions (Verma et al. 2021, 219). Hence, in geographic areas where low-polluting energy sources are available for the production of electricity, Electric Vehicles have minimal emissions than comparable Conventional Vehicles powered by petrol or diesel (Rosero et al. 2021, 94). However, Electric Vehicles do not indicate any significant reduction in well-to-wheel emissions in areas that significantly rely on coal for energy generation (Hsieh et al. 2022, 68). Well-to-wheel emissions occur from production, processing, distribution and consumption of fuel in the transportation industry (Wang et al. 2020a, 12.)

3.1.1 Vehicle emission in Europe and Africa

Air Pollutants and Greenhouse Gases are two broad categories of Vehicle Emissions. Air Carbon monoxide (CO), non-methane volatile organic compounds (NMVOC), nitrogen oxide (NO_x), sulphur dioxide (SO₂), and particulate matter (PM_{2.5} and PM₁₀) are also examples of air pollutants, often regarded as conventional pollutants. On the other hand, emissions from combustion engine vehicles are considered as the principal sources of Greenhouse Gases, which include carbon dioxide and methane (Shahbazi et al. 2021, 10). Other general pollutants from vehicle emissions include sulfur oxides (Sox), ammonia compounds (NH₃) (Ayeter et al. 2021, 2.) Carbon dioxide is not considered toxic to human health and when emitted in limited dose, it improves plant performances (Arya 2022, 459).

Table 1 gives a summary of the various categories of Vehicle Emissions and their potential sources.

Category	Vehicle Emission	Chemical Symbol	Description (Potential Sources)
Air Pollutant	Carbon monoxide	CO	This is produced from incomplete burning of fuel, especially natural gas, coal or wood (Cesprini et al. 2020, 1.) Major sources are vehicular emissions, fossil-fuel combustion, and biomass burning (Aslam et al. 2021, 6.)
	Non-methane volatile organic compounds	NMVOCs	These are released into the atmosphere from various sources, such as industry operations, solvent use and combustion activities (Mellqvist et al. 2018, 3.)
	Nitrogen oxide	NO _x	This is introduced into the air mainly through automobile exhaust and gas stoves (Yuanxi et al. 2022, 2.)
	Sulfur dioxide	SO ₂	This is created as a by-product of copper extraction and the burning of sul-

			<p>fur-bearing fossil fuels which are naturally emitted volcanic activity (Hung & Ashner 2020, 629.)</p> <p>Major sources are fuel combustion, vehicle emissions, electric utilities, industrial facilities, maritime transport and volcanoes (Matyeni 2021, 19.)</p>
	Particulate matter	PM2.5 and PM10	<p>These are tiny solid or liquid particles suspended in a gas and commonly referred to as Particulates or Fine Particles (Su et al. 2020, 42).</p> <p>Major sources of PM2.5 are fossil-fuel combustion, industrial facilities, biomass burning, waste incineration, cooking and maritime transport (Maciejczyk et al. 2021, 2.) However, forest fires, garbage degradation and road dust from unpaved roads are substantial contributors of PM10. (Gopinath 2018, 12.)</p>
Greenhouse Gases	Carbon dioxide	CO2	This is emitted from burning of carbon-bearing fossil fuels like coal, natural gas and oil (Scogna 2020, 797.)
	Methane	CH4	This is emitted from a variety of human-influenced and natural sources (Naiyer & Abbas 2022, 90.)

Table 1: Composition of vehicle emissions

Statistics reveal that the primary source of pollutants in various cities, including Lagos, has shifted from industrial waste gas to vehicle emissions (Komolafe et al. 2014, 412). Hence, transportation is regarded as the primary cause of unsustainable energy usage as conventional vehicles solely depend on petroleum-based fuels (Singh et al. 2020, 10.). On this basis, original equipment manufacturers have employed diverse technologies, such as exhaust gas recirculation, 3-way catalytic converters, and more, to reduce emissions of carbon dioxide (CO₂) and nitrogen oxide (NO_x) in vehicles (Zhu et al. 2020, 160; Letmathe &

Suares, 2020, 3.) Conventional vehicles with internal combustion engines generally emit direct emissions through the exhaust and fuel system evaporation, whereas Electric Vehicles do not emit direct emissions but may produce from the source of electrical powers (Palaniswamy et. al. 2022, 1.) This is on the basis that majority of electric power plants emit gases which occur through the extraction to distribution phases of the primary energy sources used to produce the electricity, hence energy may be produced using coal or natural gas and contribute carbon pollution or Greenhouse Gases. (Bicer & Dincer 2018, 2). In other words, Electric Vehicles typically have a smaller carbon footprint than petrol-powered cars (Avci et. al. 2015, 779).

Figure 1 presents the framework for the study, as designed by the Researcher, with respect to the adverse effect of vehicle emissions on Air Quality and its resolution via increased adoption of Electric Vehicles into sustainable transportation planning.

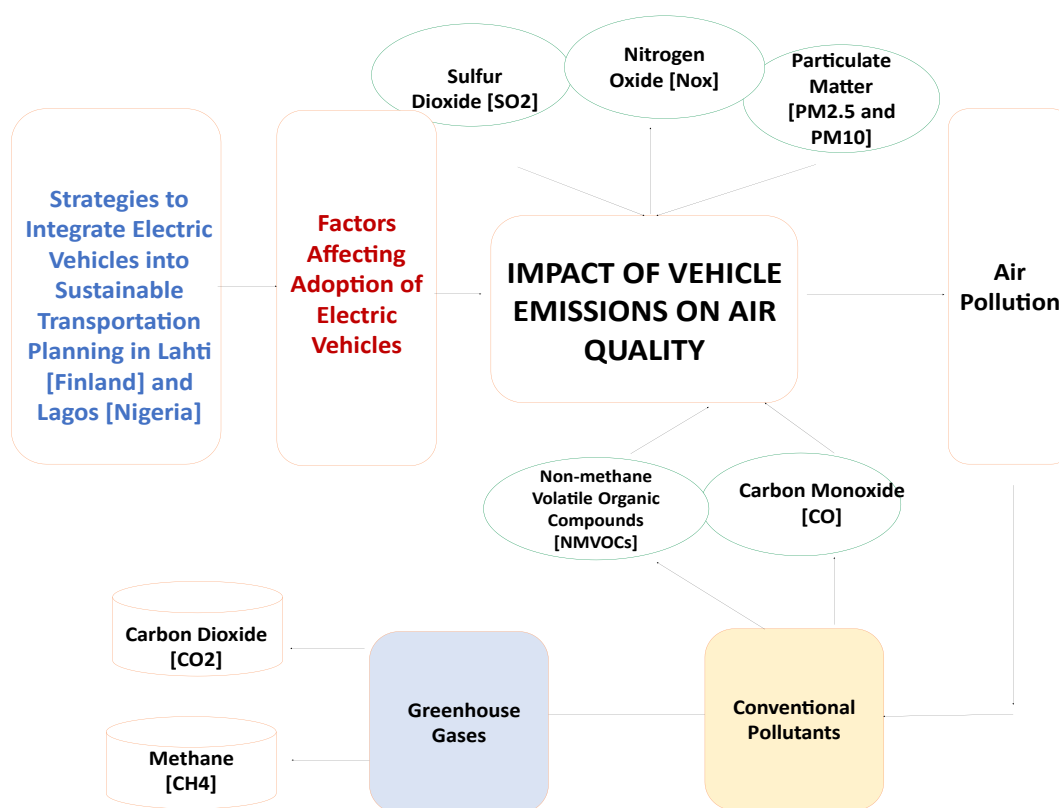


Figure 1: Analytical Framework For Adoption of Electric Vehicles

Figure 2 also shows the average level of Vehicle Emissions (PM_{2.5}) in Africa and Europe, as measured by the World Health Organization in 2020. Though Africa has less motorization rate, its average PM_{2.5} emission is very high, with Nigeria recording 151.52 ug/m³ and classified as the fourth country with Africa's worst ambient air pollution (Awokola et. al. 2020, 72).

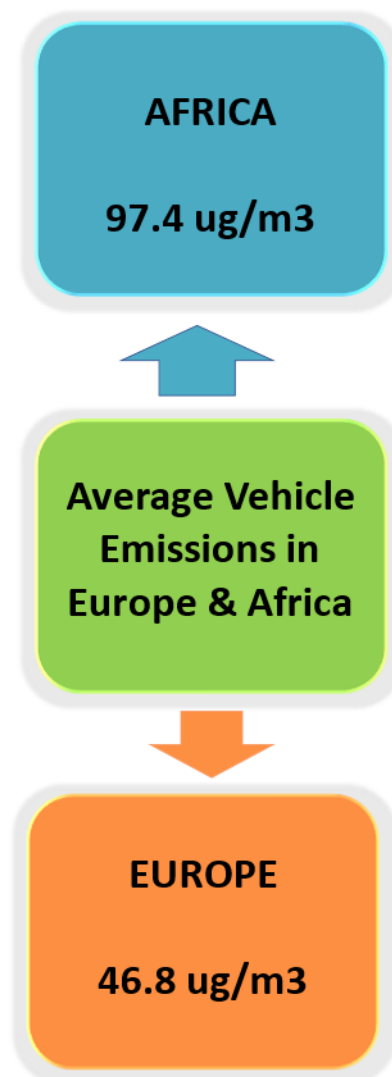


Figure 2: Average Vehicle Emission in Europe and Africa (WHO, 2020)

Europe is reputed as the Leader in adoption of Electric Vehicles, as European countries have demonstrated increased adoption in the Electric Vehicle uptake rate since 2014 as a result of falling production prices and minimal deployment of national charging infrastructure (International Energy Agency, 2019). Vehicle Emission can be estimated using the COPERT model which possess these core components: vehicle population, annual aver-

age vehicle-kilometers traveled and emission factors (Sun et al. 2016, 194.) Electric Vehicles have potential to control decarbonization of transportation (Glitman et al. 2019, 10.) Hence, it is argued that restrictive measures on vehicle purchase and use can minimize vehicle emissions – as Singapore implemented tax measures to restrict the use of vehicle ownership in the late 1960s, thus requiring owners to pay import charges and other costs; but the restrictive measures did not reduce the increased use of personal vehicles (Hu et al. 2021, 2.) On the other, Mexico City implemented a driving restriction program in 1989, which banned drivers from driving one weekday per week; but the restriction on vehicle use intensity only encouraged the growth of vehicle ownership, as each resident subsequently purchased two or more cars (Hao et al. 2011, 1018.) Furthermore, China has explored the development of oil refining technology to address emission limits, as the 2018 Report on Environmental Management of Motor Vehicles in China states that vehicles emitted 10.7% of NO_x, 22.6% of HC, 24.7% of CO and 16.4% of PM (Ministry of Ecology and Environment, 2019).

However, it is regrettable that there are Limited air quality monitoring stations in Lagos, as the available information on air quality is mostly dependent on sporadic and short-term measurements made with air samplers (Croitoru 2020, 753.) Though electric vehicle manufacturer Tesla has two supercharger stations in Morocco, the company is yet to have any active sales location in Africa as most Tesla vehicles in Africa have been privately imported by individuals who frequently combat with issues since Tesla does not support the African market with service centres, supercharger stations, navigation updates, and connectivity (Ayetor et al, 2020, 6). Therefore, this has made it difficult to track the rate of vehicle emissions in Lagos though a number of strategies have been proposed to reduce vehicle emissions in Nigeria, and even Africa (Dioha et al., 2022; Maduekwe et al., 2020).

3.1.2 Adoption of Electric Vehicles in Lahti and Lagos cities

Electric Vehicles have experienced increased awareness in recent years, as support for clean energy transportation have become a pertinent discussion in a number of countries (Muratori et al. 2021, 8.) However, there are obstacles to the widespread use of Electric Vehicles especially range anxiety which is attributed to the limited driving distance of Battery Electric Vehicles (BEVs) against the expected need of users, especially in a country like Finland which is sparsely populated and citizens are known for their tradition of spending weekends and holidays in countryside cottages (Melliger et a. 2018, 112.) Range anxiety is

also considered a barrier to the use of Electric Vehicles in Nigeria, as a Tesla car was recently reported to have 'packed up' on Third Mainland Bridge in Lagos State, owing to the long hours of traffic experienced on Lagos Roads (Linda Ikeji Blog, 2021).

A recent study revealed that the potential of mass adoption of BEVs in Finland is about 85%, based on moderate availability of charging infrastructure relating to home charging and public charging stations (Melliger et al. 2018, 113.) However, this is not the case with Lagos State, where the bulk of vehicles used are owned by households and parked 92% of the time with minimal use of their capacities (MacArthur, 2013). Despite Nigeria's electricity system being dominated by natural gas, the use of Electric Vehicles can aid decarbonization of the transport and energy sectors; though its cost needs to decrease by about 40% in order to be cost-competitive (Dioha et al 2022, 7).

Nigeria is the most populated country in Africa and its automobile fleet makes up about 8.4% of all the vehicles in the continent (Deloitte Africa Automotive, 2018). The metropolitan area of Lagos State is the largest urban area in Nigeria and is regarded as home to the country's largest manufacturing sector which employs over 45% of the skilled labor force in the country (Oderinde, 2016, 6). The present transportation infrastructure in Lagos, which is primarily fueled by fossil-derived petrol and diesel, has continued to be strained by the expanded population and this is incompatible with the air quality in Lagos (Dioha et al. 2019, 2021). The aforementioned has also put a financial strain on the Government, as this body heavily subsidizes transportation fuels and spends twice as much on fuel subsidies as it does on health care (McCulloch et al. 2021, 21). Hence, it has been established that Nigeria is in dire need of transportation alternatives and electricity storage solutions to minimize the over-dependence on fossil fuels and maximize its ample variable renewable energy sources (VRES), thus supporting decarbonization efforts (Dioha et al. 2022, 9.) Nevertheless, it cannot be ascertained that major residents possess the financial capacity to channel adoption of Electric Vehicles into the transportation sector.

3.1.3 Integrating Electric Vehicles into Sustainable Transportation Planning in Lahti and Lagos

Electric Vehicles are powered either partially or completely by onboard electric motors that are charged with plug-in electric outlets (Liu & Wei, 2018). Electric Vehicles are considered as eco-efficient alternatives to conventional vehicles because they do not have tailpipe emissions; hence they can reduce the adverse effects of road transportation, such as air pollution and global climate change (Hu et al, 2021). Though there is a rise in the yearly

adoption of Electric Vehicles, its adoption is still relatively low when compared to the total stock of vehicles (Abergel et al. 2020, 5). This has been attributed to the obstacles related to technology and infrastructural lack of charging stations (Islam et al, 2019). The minor growth in sales of electric vans and trucks in the European Union have also been linked to the absence of infrastructure that would make it possible to recharge Electric Vehicles (Osieczko et al. 2021, 3). However, it is predicted that with the availability of charging stations, many African nations will make substantial investments in the power sector, thus enhancing environmental sustainability and energy access (Ayamolowo et al. 2022; Du et al. 2021).

It is important to mention that based on the engine used in vehicles, they are categorized into Internal Combustion Engine Vehicles (ICEVs), Fully Electric Vehicles (FEVs) and Hybrid Electric Vehicles (HEVs) (Yildirim et al. 2014, 6). However, classification of Electric Vehicles on the basis of their power sources are Battery Electric Vehicles (BEVs), Hybrid Electric Vehicles (HEVs) and Plug-in Hybrid Electric Vehicles (PHEVs) (Ajanovic, 2015). ICEVs are typically regarded as Conventional Vehicles which are powered by petrol and hydrogen fuel, while FEVs possess electric motors in place of internal combustion engines and are fuelled by massive battery packs that must be plugged into a wall outlet or other charging equipment (Poullikkas 2015, 1280.) On the other hand, HEVs use both electrical and mechanical energy because they have internal combustion engines and electric motors that draw power from batteries. However, HEVs cannot be plugged in to wall outlets to charge their batteries because they are charged with their internal combustion engines and regenerative braking. (Harshavarthini et al. 2021, 15).

Factors affecting adoption of Electric Vehicles can be categorized into economic and psychological factors, as consumers generally make purchase decisions by making trade-offs between attributes (Liao et al. 2017, 262.) The integration of Electric Vehicles into the society offers substantial benefits for economy's transition away from petroleum, thus ensuring reduced emission of carbon dioxide (CO₂) from the transportation sector. The use of Electric Vehicles also guarantees immense environmental benefits, including significant reduction of noise levels and air pollution. In addition, Electric Vehicles are considered important assets for attaining a sustainable energy future, as the batteries are considered as untapped opportunities for accumulation of electricity from renewable energy sources. However, achieving sustainable energy planning in urban areas requires international strategies based on social incl, financial viability and ecological preservation (Pardo-Bosch et al. 2019, 229.) While widespread adoption of Electric Vehicles may contribute to alleviation of environmental pollution, global warming and oil dependency, the current market penetration of Electric Vehicles is relatively low

3.1.4 Evolution of Lahti and Lagos to Smart Cities

The development of smart cities is dated back to the 1990s, when the term was proposed to highlight urban development toward innovation, technology and globalization (Bokolo & Peterson 2019, 5.) A smart city is considered as an advanced city where residents can securely gather, manage and disseminate data that relates to all areas of their daily lives in a sustainable and universal manner (Anthony 2020, 835; Khatoun & Zeadally 2016, 51.) In smart cities, services are facilitated by information and communication technologies, which are employed in resourceful manner, to improve the quality of life and operational efficiency (Nathali Silva et al. 2017, 112). Smart grids are considered as the backbone of smart cities, as smart grids manage two-way power flows, maintain energy consumption interactions between consumers and producers, and offer flexibility for the consumption and production of energy (Judge et al. 2022, 7).

Due to the proliferation of big data, smart cities are posed to deploy architectures toward managing energy for Electric Vehicles, as they orchestrate the production, consumption and distribution of energy from renewable sources, such as solar and wind. Hence, the integration of Electric Vehicles is expected to pave the way to green mobility with zero carbon emissions (Karpenko et al. 2018, 7.) Electric Vehicles also bring diverse sustainability and cost-saving benefits to consumers, though the deployment of Electric Vehicles will depend on various factors, including performance and costs of batteries, access to the distribution grid and its efficiency, the type of business model implemented to supply the consumer with reliable batteries and electricity, the acceptance of new vehicle types by consumers, and possible implied driving habits (Perujo et al. 2011, 4).

Though Electric Vehicles are regarded as a technology to reduce dependence on fossil fuels, which result to Greenhouse Gas emissions, there are several barriers impeding adoption of Electric Vehicles in different cities (Singh et al. 2020, 8.) These barriers include resistance of consumer to alien technology tools; varying technological knowledge across gender, age and education groups; and high cost of purchasing and maintaining Electric Vehicles (Egbue & Long 2012, 719). In addition, there is an inexistent regulatory framework for scaling adoption of Electric Vehicles in large markets, as most countries are yet to implement policies offering users of Electric Vehicles benefits over purchasers of conventional vehicles (Haddadian et al. 2015, 60.)

Figure 3 enumerates the factors affecting adoption of Electric Vehicles, as it relates to financial, technical and infrastructure attributes designed by the researcher.

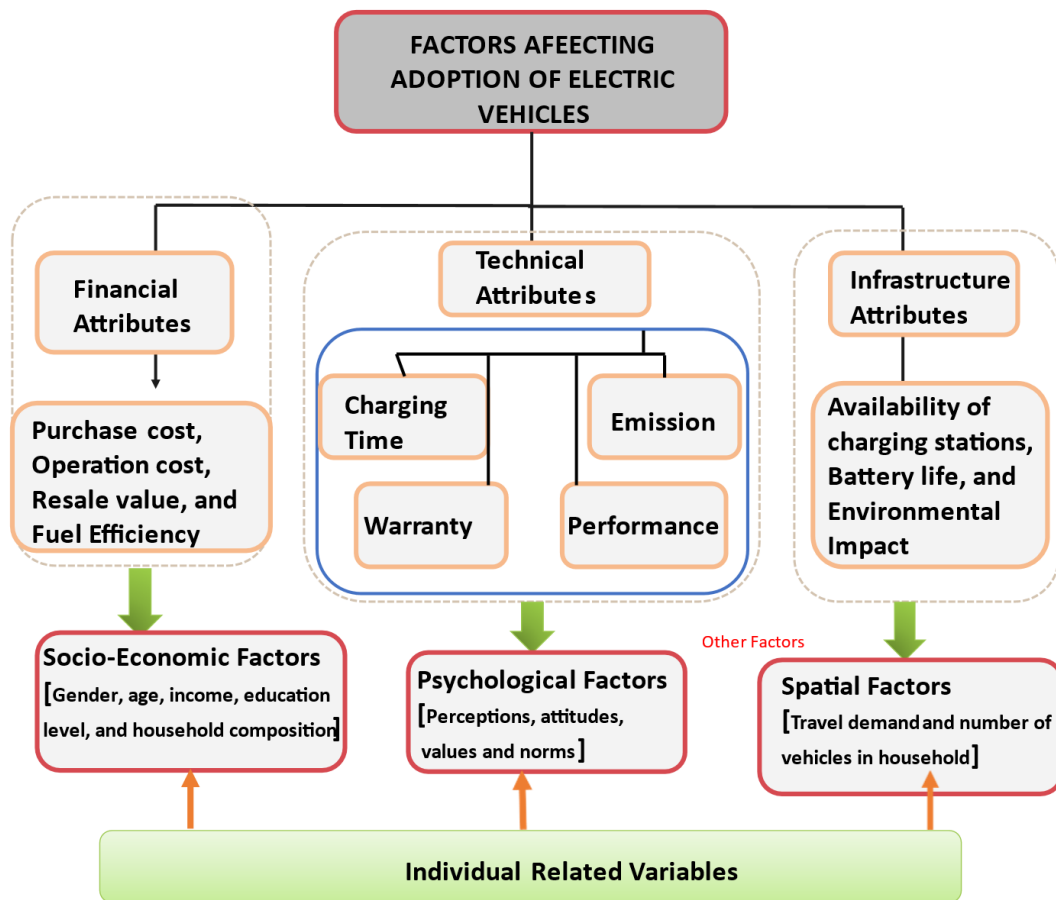


Figure 3: Factors affecting the adoption of Electric Vehicles.

Furthermore, current mobility trends indicate that the popularity of privately-owned cars will decrease in the near future, based on the diffusion of mobility services such as sharing of cars or bikes, or mobility-as-a-service (MaaS) bundles which illustrate the possibilities of being mobile without owning a car (Brezovec & Hampl 2021, 1088.) Hence, car sharing as an alternative to car ownership, may be considered a feasible strategy to adoption of Electric Vehicles in megacities, including Lahti and Lagos; as mobility-as-a-service (MaaS) offerings could potentially provide green and non-ownership alternatives to meet future customers' estimated mobility needs (Brezovec & Hampl 2021, 1088; Ambrosino et al. 2016, 180.) Therefore, to reduce air pollution through adoption of Electric Vehicles, the Government needs to adopt policies designed to increase sale of Electric Vehicles, increase percentage of renewable energy, and implement practices to prevent air pollution caused from manufacturing of required batteries (Vidhi & Shrivastava 2018, 483) Consequently, there is need to implement effective strategies

to integrate adoption of Electric Vehicles into any sustainable urban mobility plan that may be designed for Lahti in Finland and Lagos in Nigeria.

Figure 4 highlights 4 strategies for sustainable urban mobility planning and these strategies include design of energy network, execution of institutional framework and policies, adherence to monitoring and evaluation measures, and compliance with infrastructure maintenance.



Figure 4: Strategies for Sustainable Urban Mobility Planning

The Norwegian capital of Oslo is well known for its success in adopting Electric Vehicles with a combination of local and national measures, as the goal of Oslo is to reduce Greenhouse Gas emissions by 95% in 2020, compared to 1990. These measures include exemption of Electric Vehicles from tolls and parking fees; higher taxation of conventional cars and fossil fuels; implementation of measures to make shared transport solutions more attractive; design of 'green mobility houses' to enable users of Electric Vehicles easily find charging spaces (Schulz & Rode 2022, 11; Rautiainen et al. 2021, 73; Fearnley et al. 2020, 5; Wangsness et al. 2020, 2). Hence, Norway currently has the highest rate of Electric Vehicle

ownership in the world, as 59% of new cars sold in Oslo are either Battery Electric Vehicles or plug-in hybrid Electric Vehicles (Jensen et al., 2022; Ng, 2021).

4 Methodology

The research methodology describes the procedures and instruments used to gather and process the related data. It highlights the philosophy, approach, research design and ethical consideration of the study. The researcher primarily used the pragmatic research philosophy, inductive research approach and narrative research design to carry out this study, which is based on the evaluation of Vehicle Emissions and adoption of Electric Vehicles to enhance urban air quality. Furthermore, the Researcher mostly uses the qualitative data analysis approach and secondary data collection method majorly from industry discussions and observations (Dzwigol, 2018, 429) The Researcher also used topic analysis and material from other blogs, journals and papers as sourced from Google Scholar and Academia.

3.1 Research Design

This chapter presented the tools and processes adopted to achieve the goal of the project, with respect to the use of Electric Vehicles to improve urban air quality. The researcher adopted (Saunders et al. 2007, 130.) research onion model to design the methodology for this study, thus providing an exhaustive and multidisciplinary description of the stages required to formulate an effective methodology. The research onion consists of 6 layers namely philosophy (foundation of the study), approach (movement trend between theories), strategy (adopt-ed approach based on the research aim), choices (number of selected data types), time horizon (period of data collection), and techniques & procedures (data type and methods of collection, including sampling and data analysis) (Melnikovas 2018, 35.)

The nature of this research is pragmatic as the researcher undertook the research from a practical standpoint where knowledge is constantly questioned and interpreted (Kaushik & Walsh 2019, 4.) The data employed to conduct this study was sourced from diverse sources, as the researcher utilized an inductive approach within the qualitative research. Inductive approach entails strategically combining established theories from previous research measuring the impact of emerging technologies in the workplace and their impact on revenue generation and employee satisfaction (Ramanadhan et al, 2021; Cukurova&Luckin, 2018). Kenneth Hyde 2000) defined it as “a theory-building process, starting with observations of specific instances, and seeking to establish generalization about the phenomenon under investigation” (Ciulli et al., 2020). Online articles and books addressing urban air quality and electric vehicles were duly considered, as their reference lists and citations were examined to find original sources and subsequent articles that opened up novel perspectives that were not earlier considered in the beginning of the literature review

process. Hence, a scientific literature was conducted using keywords in [LAB Primo], the library which belongs to [LAB university of Applied Sciences, Lahti, Finland.] and in Google Scholar, as the keywords included Electric Vehicles, Urban Air Quality, Air Pollution and Vehicle Emission.

According to Michael Patton (2005) qualitative research uses data from open-ended interviews, written materials, and direct fieldwork observations to create detailed narrative descriptions and case studies. (Patrik Aspers & Ugo Corte 2019) also reiterate that qualitative research has a mixed method focus because it adopts an explanatory and realistic approach while employing various materials, such as case studies, personal experiences, and observational or historical data. Therefore, in the data collection strategy adopted in this study, open-ended questions were used in semi-structured interviews with residents in Lahti and Lagos. This made it possible for the researcher to collect information from individuals and undertake thorough evaluation for a detailed study of the effect of automobile emissions on the air quality in these cities. The thematic narrative analysis enabled the researcher to develop understanding of practical issues relating to mitigation of vehicle emissions with adoption of Electric Vehicles. Furthermore, the researcher selected a mono method and solely used qualitative data to analyse participants' views and opinion on urban air quality. The researcher's choice of a mono method was based on the research objectives and practical consideration of viability, with respect to the kind of data that was considered accessible, considering the location of the researcher in Finland and the study areas, namely Lahti in Finland and Lagos in Nigeria. The Researcher also adopts a cross-sectional time horizon, entailing collection of qualitative data for a certain point in time.

Figure 5 highlights the research methodology type which include the research philosophy, the research approach, the research choice, strategy, time horizon and technique and procedures used in achieving the research result.

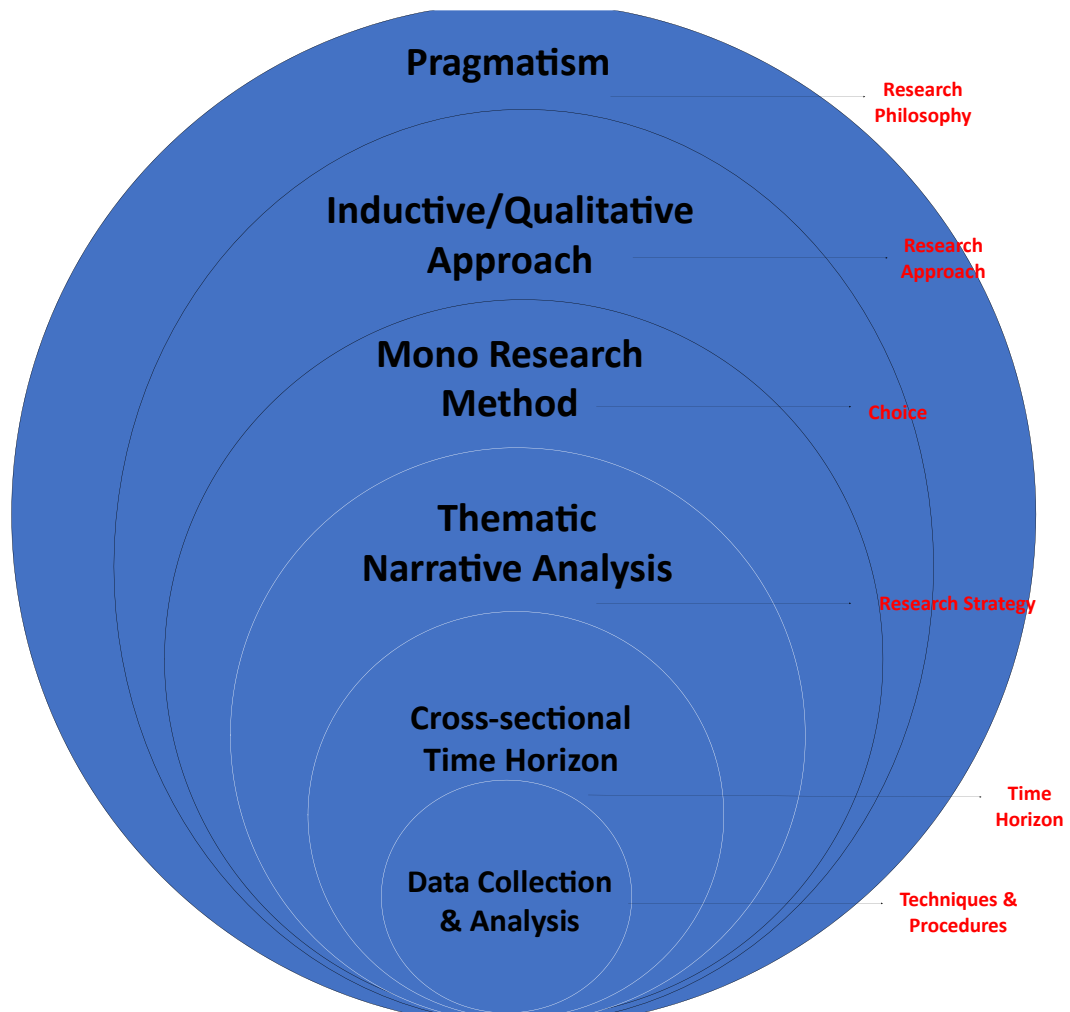


Figure 5: Research Onions (Saunders et al. 2007, 130)

4.1.1 Sampling

The selected population for the research is residents aged 18-45 years in Lahti and Lagos, and purposive sampling was conducted to recruit residents with conventional and electric vehicles as core participants. Purposive sampling is generally referred to as a sampling strategy employed by qualitative researchers to identify individuals who can provide in-depth and thorough information on the topic (Campbell et al, 2020). It has been widely employed in qualitative research to select participants who are considered knowledgeable and experienced with the phenomenon of interest (Cresswell & Miller, 2000).

To gain multiple perspectives on the impact of Electric Vehicles in improving air quality, the researcher adopted the maximum variation sampling (MAXVAR) strategy which is a non-

probability-based sampling that ensures appropriate representation and diversity of selected participants (Suri, 2011; Bradfield et al, 2022). Given that the participants belonged to diverse social classes and the researcher conducted one interview per participants, 16 interviews were conducted. The research instruments were primarily disseminated via email and necessary communication were hosted via WhatsApp calls and chats, thus implying that the sample is restricted to the users of conventional and electric vehicles. However, sampling bias can occur as purposive sampling is commonly referred to as judgmental sampling and the contacts within this range are of a relatively homogenous nature and even discovered to belong to a particular age group, majorly between the ages of 35-60.

The researcher developed an interview instrument containing 8 questions with an estimated response timeline of 20 minutes for each participant. The interview started with questions relating to background of the participant, including the demography and earning potential, in an effort to establish rapport between the researcher and participant. In-person interview sessions were conducted and audio recorded, as they varied between 20-30 minutes

.

4.1.2 Data Collection

In qualitative research, gatekeepers are used to access research participants within social institutions and aid the researcher conduct ethical study on their information and participants (Singh and Wassenaar 2016, 42.) Gatekeepers are regarded as crucial mediators for gaining access to study settings and participants within social research (Andoh-Arthur, 2020) While Electric Vehicles owners may be popular in some European countries, this is not the situation in Africa. This is because the adoption of Electric Vehicles has been slower in Africa countries the probability of encountering 1 Electric Vehicle owner is roughly one in a million (TechPoint Africa, 2021) Hence, in this study, a gatekeeper was engaged to gain access to the selected participants in Lagos, as the researcher contacted a car dealer in Victoria Island, Lagos to aid in establishing a referral-based relationship between the referral and Electric Vehicles owners in Lagos. The gatekeeper and researcher discussed the goals of the study and outlined the characteristics of participants needed for the study. The gatekeeper contacted participants that were fit for the study and made reasonable efforts to confirm their availability to participate in the data collection phase which took form of semi-structured interview. However, the gatekeeper was unable to connect the researcher with electric vehicle owners in Lagos Nigeria.

Prior to the data collection phase, each participant was given a consent form in English Language and requested to deliver the signed copy to the gatekeeper. Each participant was

also informed of the right to anonymity and requested to use a pseudonym for the interview. The researcher interviewed the participants in English Language, which is regarded as a universal language for communication. The interview session with each participant was audio-recorded in separate files and the Researcher took notes during the interview. Additionally, participants were informed that breaks were permitted, if they felt the need to take any break during the interview.

The reflective journal of the researcher will also be used as a form of data, as the researcher expressed his views in the notebook. This is based on the idea that keeping a reflective journal improves the rigor of qualitative research, as this enables the researcher record thoughts, expectations, observations and biases regarding the research process, thus providing additional data for the analysis (Barrett et al 2020, 11; Collins and Stockton 2018, 29). As of 2019, it was estimated that air pollution ranked among the top leading causes of death, maybe even surpassing HIV/AIDS, and caused high premature deaths yearly (Bauer et al 2019, 132). As a result, the researcher's journal emphasizes the role that air quality plays in the process of urban growth and discusses the link between air pollution and social issues.

4.1.3 Data Analysis

The Researcher transcribed all interviews, observations and field notes with Microsoft Word, before analyzing the data gathered. The transcribed entries were analyzed through thematic analysis, following (Braun & Clarke 2006, 89) 6-framework, which required that the researcher (1) becomes familiar with the collected data, (2) generates initial codes, (3) reads each transcript to become immersed in the data, (4) reviews relevant themes, (5) defines and names themes, and (6) produces the report. Thematic analysis is a method used by social scientists to identify recurrent themes and patterns in a piece of data, and these themes may be essential to understanding the research topic (Vaismoradi et al 2013, 402).

Interviews were conducted between 18 May – 7 June 2022 with virtual tools, majorly WhatsApp communication. The researcher sent requests to 22 intended participants, but received positive responses from only 12 participants (see a breakdown of their characteristics below).

4.1.4 Ethical Consideration

Although there were no identifiable risks at the time of the research, a number of things were considered when dealing with the participants. First, each participant was interviewed individually and expected to talk about their experiences using vehicles and the resultant emissions on the environment. However, there is the possibility that participants may not possess sufficient knowledge to evaluate air pollution and its impact on global environmental factor of ill health. Second, given that the gatekeeper connected the researcher with participants, the participants may have experienced any form of pressure to respond to all of the interview – and such pressure remains unknown to the researcher.

Furthermore, the researcher possesses limited understanding of the impacts of outdoor air pollution in Lagos, Nigeria, due to lack of epidemiological studies along with political and societal reasons (Ahmed et al 2017, 209). These factors will be duly considered throughout the research design process and appropriate precautions will be adopted, to ensure that all participants feel safe, at ease and confirm that they are aware of their right to withdraw from the research at any desired time.

5 Results

This chapter discusses the result from qualitative data obtained from respondents using Electrical Vehicles and Conventional Vehicles. The Researcher interviewed users of Conventional Vehicles and Electrical Vehicles in the study areas – Lahti, Finland and Lagos, Nigeria. Interview questions were designed to assess the lay perceptions of vehicle users to urban air pollution and its attributing factors. To analyze the responses, the researcher utilized thematic analysis to evaluate interview transcripts of 12 respondents. This study aims to identify the opportunities inherent in integration of content analysis into urban research. Thematic analysis has been employed as a qualitative method for data analysis in various disciplines, but has been less applied in the field of urban planning (Rafiei et al. 2020, 5.) This study aims to address the contribution of vehicle emissions to air pollution in cities and adoption of Electric Vehicles to combat air pollution, as the experiences of residents are evaluated to obtain helpful information for professionals and other stakeholders.

In studying the atmospheric pollution, the concentration of air pollutants was quantitatively isolated using meteorological variables. IQAir provided the air quality index and PM2.5 air pollution in Lagos, Nigeria (IQAir, 2022). The air population level was reported to be good with an air quality index of 42 US AQI, as PM2.5 was reported as the main pollutant of the air quality in Lagos.

In conclusion, an effort was made to analyse the current air quality in Lahti and Lagos, based on existing research works. The narrative texts contained a range of potentially useful material which was considerably expanded with latent content, thus affirming qualitative analysis as a flexible tool for integrated research (Zaleckis et al. 2019; Gavora. 2015, 12.)

Demographic Assessment

The target population for this study were residents of Lahti in Finland and Lagos in Nigeria. The interview question was designed to have two sections, with the first section collecting information to measure the demographic characteristics of the respondents and the second section collected data relating to the respondents' perspectives of air pollutants and resultant effects on the environment. The data collected on demographic characteristics of the respondents were analysed using frequency counts and statistics, as presented in the table below.

Table 2 summarizes profile of the respondents that were interviewed for the study.

	NUMBER	PERCENTAGE (%)
GENDER		
Male	11	91.7%
Female	1	8.3%
LOCATION		
Finland	8	66.7%
Nigeria	4	33.3%
AGE		
18-30 years	5	41.7%
31-42 years	1	8.3%
43 years and above	0	0%
Undisclosed	6	50%
VEHICLE TYPE		
Conventional Vehicle	8	66.7%
Electric Vehicle	4	33.3%
TOTAL RESPONDENTS	12	100%

Table 2: Respondents' Profile

Process of Thematic Analysis

Qualitative research analysis generally refers to the assessment of information obtained through interviews and focus groups, and represented in verbal or narrative format (Nyumba et al. 2018, 25.) Interviews are regarded as the cornerstone of qualitative research, especially physical interviews (Sy et al. 2020, 603.). However, virtual qualitative data collection has gained traction, especially with the constraints of social distancing necessitated by COVID-19 (Roberts et al, 2021, 96.) Qualitative data was collected from 12 participants via their choice of interview method – face-to-face, telephone and email were the methods participants preferred for their interviews. Interview data was transcribed verbatim, through interactive sessions, note taking and audio recording. Conclusively, thematic analysis was used to analyze responses and identify recurring themes in the data set.

The foundation of Thematic Analysis is built on the 6-step Braun & Clarke's approach, which comprises data familiarization, coding, theming, theme evaluation, defining and naming themes, and report presentation (Braun & Clarke 2006, 89.) Data familiarization involved conducting interviews, transcribing audio, reading through transcribed notes and analyzing statements in the transcript (Saldaña, 2011). The researcher subsequently designed descriptive codes to symbolically assign features for emphasized passages of the transcript (Saldaña 2016, 37.) Thereafter, the Researcher examined recurring clusters of related codes and identified core themes to prepare the thematic analysis sheet, using the latent approach and perspective approaches to analyze data contained in the transcript

The Description of Interview Result.

The researcher engaged 12 participants in Lagos and Lahti, and over 50% of the participants used conventional vehicles. Majority of the participants however agreed that electric vehicles were essential for improving urban air quality, though noted implementation of feasible strategies for ensuring clean and reliable energy supply, affordability of electric vehicles and continued improvement of air quality.

Presentation of Thematic Analysis.

Table 3 is the thematic development of qualitative analysis from all the Respondents.

Interview Extracts	Description (Latent Approach)	Code Fields
<p>“I see conventional vehicles as all petrol and diesel cars, and electric vehicles as electric cars, electric scooters, and electric bicycles.”</p>	<p>The major difference between electric vehicles and conventional vehicles is the power source, as electric vehicles run on electricity, as opposed to traditional gas-powered and hybrid cars – which affects the urban air quality.</p>	<p>Discrepancy in power source</p>
<p>“I would say conventional vehicles are vehicles powered by petroleum products, such as petrol while electric vehicles are the ones powered by rechargeable batteries.”</p>		
<p>“Electric Vehicles are vehicles that operate without the use of natural gases, as they mostly use electricity to power their engines. Conventional ones are those ones that operate using natural gases like petrol, diesel and gas.”</p>		
<p>“I assume conventional vehicles means vehicles with wheels that run on petrol or some other type of fuel and Electric Vehicle is pretty much the opposite – a car that runs on electricity and electricity only.”</p>		
<p>“Conventional vehicles are vehicles that utilize less of fuel so that the atmospheric concentration of CO₂ that contributes to global warming would be reduced. Electric vehicles are higher performance cars that utilizes the combustion of fuel to power their engines.”</p>		

<p>“Conventional vehicles correspond to vehicles with combustion engine and/or petrol tank but not only cars, also trucks and other means of transportation. This also includes hybrid vehicles. Electric vehicles correspond to vehicles with electric motors and batteries and goes the same way to trains, boats and whatever means of transportation.”</p>		
<p>“In Lahti, we have fully electric buses. They do not work perfectly during the winter yet, but I think we might get there in the next 10 years ... While personal electric vehicles are more expensive, I think we could emphasize public transportation more ...”</p>	<p>Though electric vehicles require low running costs and do not emit harmful gases, the lithium-ion batteries used in electric vehicles do not perform well in cold temperatures and this can lead to further range reductions.</p>	<p>Factors affecting adoption of EVs</p>
<p>“In winter, the consumption level is high and the charging. the charging frequency increases because you have to heat the car, play music and do other things.”</p>		
<p>“The adverse effect I foresee is inconsistency in supply of electricity in my area, which will not allow the vehicle to charge properly.”</p>		
<p>“If you embark on a long-distance trip with a conventional vehicle, you can have a full tank take you for about 500km drive. However, with an electric car, you may have to stop halfway of your journey and recharge before you can get to your destination.”</p>		

<p>"... we do not always charge up electric vehicles in a green way, which kind of destroys the purpose."</p>	<p>Electric cars cannot be regarded as fully eco-friendly, as manufacturing of the batteries is highly dependent on mining activities with polluting processes. Also, renewable or clean energy is required to power electric cars, else the CO2 emission will be higher.</p>	<p>Gas emission from vehicles and power sources</p>
<p>"The adverse effect of Electric Vehicles could be seen as excessive dependence on electricity and the need to recycle the batteries."</p>		
<p>"I would consider the adoption of electric vehicle as an option for combating vehicle emissions and improving urban air quality because Electric Vehicles leave lesser carbon footprint in their environment"</p>		
<p>"The exhaust from fuel-powered cars is the main source of air pollution in Helsinki. ... the exhaust pollution coming from gas-powered cars is all year round and this can be considered the main source of air pollution in Helsinki, besides emissions from factories and power plants."</p>		
<p>"In my own opinion, the air pollution in Lagos is quite large, and if more people use electric cars the quantity of carbon dioxide pumped into the atmosphere would be reduced."</p>		
<p>"The adoption of Electric Vehicle is an option to my understanding that would have a little impact on the environment if it came apparent and usual to drive Electric Vehicles, but also have to note that the making of the electricity is affecting the environment."</p>		

<p>“... people seem to think somehow that if you charge the EV with polluting energy the car itself is somehow polluting. This is a weird way of thinking. Energy used in the EV should be made in clean ways but the car itself is not adding more pollution to the environment. ... Personally, I see that me using an EV is logically and financially even greater than environmentally.”</p>		
<p>“I would say Electric Vehicles do not have any adverse effects on the environment I would say so but then, they run on batteries and if we want more Electric Vehicles, it means there will certainly need to be an increase in battery manufacturing and some of the elements used to manufacture these batteries are taken from countries in Africa like the Democratic Republic of Congo where the means of extraction are not so environmentally friendly.”</p>		
<p>“Air pollution in my city is not the best, based on the fact that everyone runs on Conventional Vehicles because the major fuel we use is petrol. Petrol is very volatile when it is being heated and emits gas, and the gases are toxic to humans. It is harmful, affects the air quality and pollutes the area.”</p>		
<p>“The air quality in Lahti is actually very good, even though I think there are still lots of conventional vehicles being used in Lahti. However, the reason for this high air quality is largely due to the strict yearly car</p>	<p>The Finnish Road Safety Council efficiently enforces the policy relating to yearly car checkup at approved inspection stations, thus improving air</p>	<p>Benefits of effective policies</p>

<p>checkup, which every vehicle must go through ...”</p>	<p>quality and lessening the negative impacts of pollutants</p>	
<p>“Lagos is full of cars that are not of good standard and that has affected the environment negatively. This is as a result of high volume of commercial vehicles being used in transporting individuals from place to place.”</p>		
<p>“The air pollution in Lagos State is really bad and I believe this is because we do not have sustainable policies to combat practices that contribute to air pollution.”</p>		
<p>“For a country like Nigeria where most Conventional Vehicles are imported as used vehicles (popularly referred to as Tokunbo), a primary approach to improving the air quality in Lagos should be directed towards reducing the importation of used Conventional Vehicles. Thereafter, other strategies can be proposed and implemented appropriately.”</p>		
<p>“Considering the high cost of these vehicles, their impact will still not be the same until the adoption is combined with other strategies due to financial incapacity of some of the poor communities”</p>		<p>High costs of manufacturing and purchasing electric vehicles</p>
<p>“Electric cars are for long-term investment. Hence, adoption of Electric Vehicles is considered a good strategy because the vehicle can be used for a long time and most of the charging ports in my</p>		

vicinity are free. Therefore, you are not required to pay to charge your vehicle and you do not need to buy diesel or benzene to run it. Ultimately, you are saving more in the long run than with conventional vehicles.”

“Though Electric Vehicles are expensive, especially when compared to the cost of regular cars, but its cost of maintenance is cheaper.

Therefore, immediately combating air pollution with increased adoption of Electric Vehicles may not be feasible, but it is worth pursuing.”

“I would say enough people can afford using electric cars if our government adopted regulations that would allow individuals to purchase them and spread the cost over 5, 10, or 20 years.”

“Currently, the prices of electric cars are much higher than that of regular cars. I don't believe they will become more common in the near future. But if they do, it will be beneficial for the environment.”

“I don't see cost of Electric Vehicles as high; many makers have cheaper models that would be just fine for many users. The bigger question in my opinion is if it is feasible for the user to change to EV.”

“... adoption of Electric Vehicles is not a primary option to improve the air quality in

<p>Lagos State. This is with respect to the financial implications and inadequate infrastructure for sustained use of Electric Vehicles.”</p>		
<p>“Electric cars should be cheaper before everybody can change their cars to electric cars. However, it is a bad idea because everybody cannot afford an electric car.”</p>		
<p>“Electric Vehicles are quite expensive but also considering the fact that vehicle emissions are the biggest contributors to air pollution, I think the best strategy for improving air quality will be the adoption of more electric vehicles.”</p>		

Table 3: Thematic Development for Qualitative Analysis.

The researcher identified and discussed 5 key themes from the data collected, relating to potential adoption of Electric Vehicles for improved air quality in urban areas. The themes are presented in Table 4 below.

Theme	Sub-theme	Code Field	Description
Power sources	Reliance of CVs on petroleum products	Discrepancy in power source of CVs and EVs	CVs are powered by petroleum products, while EVs are powered by rechargeable batteries which use electricity or other renewable sources of energy.
	Reliance of EVs on electricity		
Efficiency levels	Increased charging time	Factors affecting adoption of EVs	In winter, the cold temperature affects electrochemical reactions and limit the charging rate to avoid damage to the battery, thus increasing the charging time for the battery and decreasing efficiency of the vehicle on the road.
	Exposure to potential road dangers		
	Limited driving range		
Environmental costs	Increased gas emission by vehicles	Gas emission from vehicles and power sources	CVs are not eco-friendly because of over-reliance on fuel products. However, EVs can only be considered eco-friendly if the electricity used for charging electricity comes from renewable energy sources.
	Emission by power sources		
Regulatory policy	Restriction of substandard vehicles	Benefits of effective policies	The air quality in Lahti is good because there are effective legislations guiding purchase and inspection of vehicles. However,

	Adherence to yearly car inspection rules		the air quality in Lagos is bad because there are no policies restricting importation of foreign used cars, nor mandating periodic vehicle inspection.
Financial costs	High production cost of EVs	high costs of manufacturing and purchasing electric vehicles	EVs are quite expensive to manufacture, purchase and maintain – due to limited availability of infrastructure, such as charging stations. However, the adoption of EVs can be combined with other feasible strategies, such as production of cheaper models, introduction of incentives and subsidies, and investment in infrastructures required for maintenance of EVs.

Table 4: Presentation of Thematic Analysis.

5.1 Reflection and Discussion

The International Energy Agency (IEA) Global EV Outlook report states that over 10 million Electric Vehicles were on the road worldwide in 2020, mostly in Europe (Ajanovic et al. 2021, 8.) Findings from the qualitative research were assessed in accordance with perceptions of vehicle users in the study areas. The themes distilled from the qualitative research are discussed below, to assess the results obtained from application of a latent approach to qualitative research. The latent variables included in this research enabled the researcher to consider perceptions and socioeconomic factors which may directly or indirectly affect the research objectives. Consequently, a latent method entails interpreting the subtext and underlying presumptions of the data (Smith 2016, 213).

Theme 1: Power sources for Conventional and Electric Vehicles

Most respondents agreed that Conventional Vehicles are generally fueled by petrol, which have caused growing concerns about the detrimental impacts of global warming and air pollution (De Souza et al. 2018, 449.) However, the primary feature of Electrical Vehicles is their ability to effectively use electrical power to drive electric motors (Chen et al. 2012,4.)

Furthermore, using electrical energy from batteries allows electric vehicles to be more environmentally friendly because they can be charged using power sources with minimal emissions (Goel et al. 2021, 4)

Therefore, electric vehicles offer substitutes that reduces reliance on conventional fuels, such as petrol and lowers dangerous gas emissions (Ghassemi et al. 2022, 6). This is based on the idea that if Electric Vehicles are powered by low-carbon and renewable electricity sources, they would have the potential to reduce exposure to exhaust emissions and greenhouse gas emissions.

The major difference between conventional vehicles and electric vehicles is the power source as electric vehicles run on electricity, as opposed to traditional gas-powered and hybrid cars. However, in the case that the electric vehicles that are charged from the grid, they cannot be regarded as environment-friendly machines, because grid power is produced by burning coal (Singh & Letha 2019.) Electric vehicles can have significant environmental benefits if their additional electricity consumption is covered by power production from renewable energy sources (Luca de Tena & Pregger, 2018, 2677.) Hence, this indicates the need for integration of renewable energy resources in sustainable urban planning, as widespread use of electricity and technologies are key components for achieving sustainability in the energy sectors (Dincer & Rosen 2012, 152.)

Theme 2: Efficiency levels of Conventional and Electric Vehicles

Electric vehicles are immediate solutions to reducing pollutant emissions from the transport sector, but the range prediction is a complex issue as this is dependent on influence factors, such as internal, external, constant and variables (Varga et al. 2019, 946.) The effects of high temperatures on lithium-ion batteries are one significant example, as the batteries may experience thermal runaway, which can result in short circuits, combustion, explosions, and other safety issues (Zhang et al. 2022, 12). This is also due to the difficulties with life cycle evaluation, the need for charging, and the shorter driving range of electric vehicles compared to conventional vehicles (Goel et al. 2021, 5.)

However, difficulties with electric vehicles' efficiency levels need not be viewed as irreparable because science and innovation can offer workable and sustainable solutions, such as the hybrid liquid cooling plate concept, which is a potential thermal management strategy for electric vehicles. (Akbarzadeh et al. 2021, 2). The issue of insufficient charging facilities can potentially be remedied by placing electric vehicle charging stations in the best possible locations, which often considers costs associated with charging station installation, active

power loss, reactive power loss, and voltage deviation. (Chen et al., 2021) To reduce daily active power losses and enhance the system voltage profile, (Injeti & Thunuguntla 2020, 9.) also investigated the best way to integrate distributed generators into radial distribution systems of plug-in hybrid electric vehicles (PHEVs). The findings showed that the suggested approach enhanced the system performance of electric vehicles. Additionally, (Fathy & Abdelaziz 2020) proposed a metaheuristic-based method for locating and sizing parking lots optimally in radial distribution networks, with the goal of increasing network resiliency at the lowest possible cost. It is however necessary to note that improper locating and sizing of Electric Vehicle charging stations have been found to make a negative impact on the traffic network layout (Meng et al., 2020).

Theme 3: Environmental costs of Conventional and Electric Vehicles

The replacement of combustion vehicles with Electric Vehicles has been identified as a sustainable and economical way to minimize dependency on fossil fuels and even reliance on foreign countries for oil (Krishnan & Koshy 2021, 9556; Mirzapour et al. 2019, 80.) Especially in terms of easing the oil crisis and lowering urban air pollution, electric vehicles are seen as viable alternatives to conventional vehicles (Li et al., 2020). Additionally, electric mobility is marketed as a future mode of transportation with favorable economic and environmental outcomes as well as a motivator for eco-friendly urban transportation. (Petruskien & coworkers 2021, 957).

Although the batteries that power electric vehicles don't produce any greenhouse gases directly, the electricity needed to recharge the batteries is created by burning fossil fuels (Fernández 2018, 951.) Due to the increased usage of metals, chemicals, and energy for the creation of high voltage batteries and other components, this suggests that while the adoption of electric vehicles may reduce greenhouse gas emissions, it will also increase the degree of human toxicity (Verma et al. 2021, 630.)

Fueled primarily by fossil-derived petrol and diesel, Nigeria's transportation sector has become expensive for Nigerians and even a financial burden for the government (Dioha et al. 2021, 22.) Although Nigeria's electrical grid is dominated by natural gas, new studies show that the use of electric vehicles can support the decarbonization of the transportation and power sectors, though at a somewhat high cost (Dioha et al. 2022, 7). A survey of 400 participants conducted in Ibadan, a cosmopolitan city in Oyo State, Nigeria, revealed that age, income, marital status, education level, and level of awareness are significant factors influencing willingness to pay for renewable electricity in Nigeria. Renewable energy

sources have the potential to increase power supply safety and contribute positively to environmental sustainability (Ayodele et al. 2021, 3.)

Theme 4: Policies regulating Conventional and Electric Vehicles

In order to lessen reliance on imported energy sources, air pollution, and offset negative effects of transportation, it is vital to consider sustainable mobility options. (Goel et al. 2021, 4). Technology, policy, and environmental issues are few of the variables that influence use of Electric Vehicles in various nations (Singh et al. 2020, 102436) The lack of transportation options has led to a rise in the number of automobiles in Lagos. The majority of these vehicles are over 15 years old and consume fuel with a high sulfur content that is 200 times higher than U.S. fuel standards (Kemper & Chaudhuri, 2020). Several countries, including the United States and the European Union, have provided incentives, programs, and initiatives to promote the use of electric vehicles (U.S. Department of Energy, 2011; European Commission, 2010).

The initiatives linked to the use of Electric Vehicles aim to minimize air pollution, though the source of the electricity used to charge the Electric Vehicles still contributes significantly to gas emissions in the atmosphere (Towaju, 2021, 10; Doucette & McCulloch, 2011, 5.) The findings of a case study conducted in a representative Indian town using a questionnaire survey and structural equation modeling to assess the factors influencing purchase intentions showed that factors like perceived barriers, policy attributes and ease of use hinder adoption of Electrical Vehicles but have a positive impact on purchase intentions (Krishnan & Koshy, 2021, 15). West Africa has a reputation for being a second-hand vehicle market, as Benin and Togo are motivated by the profits derived from re-export trade and port operations, with Niger acting as a proxy market for illegal re-export of these vehicles to Nigeria (Ezeoha et al., 2019).

Therefore, to attain increased adopt of Electric Vehicles for improved air quality, attention must be given to present and future vehicle regulations, especially in Nigeria

Theme 5: Financial costs of Conventional and Electric Vehicles

Compared to Conventional Vehicles, Electric Vehicles are environmentally friendly and energy-efficient, in comparison with Conventional Vehicles, but limited availability of charging stations is a barrier to their greater adoption, especially in African nations (Mutarraf et al. 2022, 102177.) The conditions for market penetration of Electrical Vehicles are critical, although shifting from a fleet of fossil-fueled vehicles to eco-friendly vehicle fleet can lead towards a more sustainable future (Karolemeas et al. 2021, 2298.) However, the adoption

of Electric Vehicles to improve air quality requires intervention of the government – as demonstrated by the pilot subsidy scheme launched by the Chinese government to improve market penetration of new energy vehicles and this is a potential strategy to combat urban air pollution (Xie et al. 2021, 142232).

Electric Vehicles are high-end and mass-produced in high-income countries, supported by subsidies that ensure the electricity sector will generate sufficient electricity to meet energy demand; but this is not the case in Sub-Saharan Africa due to limited access to capital and unreliable electricity systems (Collett et al. 2021, 4.) Though Electric Vehicles offer benefits to governments, electricity providers, private car owners, and even paratransit owner-operators, different strategies to encourage their adoption will be applied in Lahti and Lagos, as Lahti is a high-income country. Therefore, promoting public-private partnerships that encompass both the transportation and electricity sectors will be a practical approach for the adoption of Electric Vehicles in Lagos, as demonstrated in the “New-style Urbanization” model implemented in China (Anwar et al., 2021). Indeed, incorporating sustainable practices into infrastructure projects under the auspices of public-private partnerships is crucial for achieving the Sustainable Development Goals of the United Nations (Akomea-Frimpong et al. 2022, 7174.)

6 Conclusion

As this study ends, it has attempted to look at the present and the future effect of electric vehicles on urban air quality of Lahti Finland and Lagos Nigeria using qualitative approach and thematic analysis for evaluation. Although, Lahti and Lagos are different cities with different characteristic, Lahti being in a first world country with major infrastructures and has made visible and clear progress in areas affecting the impact of urban air quality while Lagos on the other hand has not taken enough action towards sustainable air quality.

Air pollution is the major threat to environmental health in the modern era. Transportation industry is among the highest contributor to the air pollution. The study attempted to know the air quality of respondent's location and their perception on electric and conventional Vehicle's effect on the air quality in their area.

A good number of respondents agreed that Conventional Vehicles which are fueled by petrol, hydrous ethanol, have caused growing concerns about the detrimental impacts of global warming and air pollution. They also agreed that Electric Vehicles are immediate solutions to reducing pollutant emissions from the transport sector. Furthermore, the answers gotten were further simplified into 5 different categories (Power sources, Efficiency level, Environmental costs, Regulatory policy, and Finances) to better understand the current progress/ effect and places improvements are needed.

Lahti has made significant progress in the adoption of electric vehicles and its infrastructure which is evidenced in the possibility of being able to interview 4 people with electric vehicles while none was recorded for Lagos.

Lahti has made a good progress with the usage of electric vehicles, exploring more of public and private partnership, more incentives with the purchase of electric vehicles could further aid in increasing the numbers of electric cars on Lahti's road on the other hand, Lagos would need to go through a lot of reform to reduce emissions from Vehicles. Beginning from strict implementation of periodic vehicles inspection, to vehicle regulations by restricting importation of used vehicles and to also exploring of public-private partnership. A little effort has been made, more is needed to create a better urban air quality.

Study Limitation.

On the completion of this study, some issues were encountered which are inaccessibility of people using electric vehicles in Lagos

Unavailability of Transport and emissions data from Lagos

Difficulties getting people for an Audio survey

Future Research

The respondents to interview were random people that stays in either Lahti or Lagos. interviewing professionals or experts in Environment and automobile fields would be a different approach.

The usage of electric vehicles, scooters and different forms of electrical modes have become core research topic, the sustainability and climate friendly advantages are being experienced as the usage increases, determining the exact vehicle type that would fit perfectly for use would be nice to work on in the nearest future.

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APPENDIX

Interview Protocol for Qualitative Research

INFORMED CONSENT FORM

Dear Participant,

You are invited to participate in a research study that will evaluate the present and future potential effect on urban air quality, with respect to the use of electric vehicles in Lahti, Finland and Lagos, Nigeria. Nevertheless, you can decide not to participate.

The information below is provided to help you make an informed decision.

Project Topic: The present and future potential effect on urban air quality of the use of electric vehicles: A case study of Lahti and Lagos

Purpose of the Project: This study will investigate the current and potential impact of vehicle emissions on urban air quality.

Procedures: The Researcher will invite you to a virtual interview for about 20-30 minutes. You will be asked to choose a pseudonym before the interview, to achieve confidentiality. The interview will be audio-recorded, as you will be asked 8 questions designed to allow you to share your experiences.

Risks and/or Discomforts: There are no known risks or discomforts associated with this research.

Benefits: The information gathered from this study may help stakeholders design effective policies to address air pollution.

Confidentiality: During the interview, you will be asked to provide a pseudonym to protect your identity, except you do not choose to use any fictitious name. The audio-recording will be assigned the selected pseudonym, as you will not be asked to write your name on any research document. The information obtained during this study may be published in journals or presented at meetings, but the data will be prepared as aggregated data.

Compensation: You will not receive any type of compensation for participating in this study.

Opportunity to ask questions: You may ask any questions concerning this research, whether before or during the interview. If you have unanswered questions about your rights as a research participant, you may call Mr. Babatomiwa Ajayi via Babatomiwa.Ajayi@student.lab.fi.

Freedom to withdraw: You are free to decline participation in the research or withdraw your consent at any time. Your decision will not also result in any loss of benefits, to which you are otherwise entitled.

I confirm that I possess the legal capacity to give informed consent to participate in this research study. I also affirm that I voluntarily give informed consent to participate in this research study.

Initials of Participant

Date

Signature of Participant

DEMOGRAPHIC FORM

Pseudonym:

Gender:

Location [City and Country]:

Age:

Annual income range:

Highest level of education:

Current type and model of vehicle:

INTERVIEW QUESTIONS

Section A

1. Please introduce yourself.
2. Do you understand the purpose of this study and other information contained in the Informed Consent Form earlier shared with you?

Section B

3. What do you understand by Conventional Vehicles and Electric Vehicles?

4. How would you describe air pollution in your current environment?

5. Do you consider adoption of Electric Vehicle as an option for combatting Vehicle Emissions and improving urban air quality?

6. Considering the high cost of Electric Vehicles, to what extent do you consider it as a feasible strategy for improved air quality in your city?

Section C

7. What are the adverse effects of Electric Vehicles?

8. Please provide any information you would like to add, as it may relate to the effect of vehicle emissions on urban air quality.