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Pioneering Green Pathways: Ethiopia's Leap Forward in Climate-Smart Logistics and Eco-Transportation

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ABSTRACT

The global shift toward electric vehicles (EVs) is rapidly gaining momentum, and Ethiopia is beginning to embrace this transition. Although the narrative around environmental sustainability has been central to the adoption of EVs, it is now clear that the transition to electric mobility is an inevitable progression. In recent years, Ethiopia has made notable strides in advancing its electric transportation sector, with significant efforts from both governmental bodies and private enterprises to increase the accessibility of EVs. Despite this progress, Ethiopia remains one of the countries with the lowest rate of EV adoption globally. Furthermore, there is limited comprehensive information to identify the key challenges that must be addressed to facilitate the decarbonization of passenger vehicle transport in Ethiopia. This study explores the feasibility of implementing green transportation strategies within Ethiopia's logistics industry, aiming to align with broader sustainable development goals. The paper presents findings from a quantitative SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis of the Ethiopian electric vehicle market, which highlights the critical dynamics of the sector. The analysis is based on data collected from a carefully selected panel of 15 experts in the Ethiopian transportation and energy sectors. The analysis reveals that while Ethiopia's EV market has significant strengths, such as increasing awareness and potential for innovation, several barriers hinder the widespread adoption of EVs. Among the most prominent challenges are the lack of well-defined policies and regulatory frameworks that establish clear EV targets, the high upfront costs of EVs, inadequate electricity infrastructure, and a scarcity of public e-charging stations. These factors collectively impede the transition to electric mobility. The study proposes that offering financial incentives, such as subsidies for EVs, could facilitate the acquisition of modern EV fleets by companies, encouraging investment in proprietary charging infrastructure. These measures could improve energy efficiency and raise environmental awareness while fostering the development of a green public transportation system. This transition could ultimately contribute to broader environmental protection efforts and sustainable urban development in Ethiopia.

1. Introduction

The energy sector currently contributes approximately 75% of global greenhouse gas (GHG) emissions(Akpan and Olanrewaju, 2023; Gicha et al., 2022; Lux and Pfluger, 2020), making it a critical focus in efforts to mitigate climate change. To achieve the goal of limiting global warming to 1.5°C, the energy sector must reach net-zero carbon emissions by around the mid-21st century(Barrett et al., 2022; Szinai et al., 2020). However, the escalating global demand for energy, which has predominantly been met by fossil fuels and has grown at an average annual rate of 1.9% since 2000, presents a significant challenge to emissions reduction efforts(Gicha et al., 2021b, 2021a; Molla et al., 2023; Tufa et al., 2021). Even with ongoing reductions in the carbon intensity of the global energy system, it would require approximately 150 years to fully eliminate carbon dioxide emissions at the current rate of decarbonization.

In 2022, atmospheric carbon dioxide concentrations reached a historical peak of 417.2 parts per million, with energy-related emissions constituting the majority of anthropogenic GHG emissions(Koutsodendris et al., 2023). The continued rise in these heat-trapping gases, including a record surge in methane concentrations, is accelerating planetary warming and raising profound ecological concerns. In response to the alarming increase in GHG concentrations and global temperatures, the Paris Agreement was introduced in 2015, aiming to cap the rise in global temperature to 2°C by 2100(Mesjasz-Lech and Michelberger, 2019). Several nations have since committed to carbon neutrality, pledging to achieve net-zero emissions by 2050 or 2060. To meet the targets outlined in the Paris Agreement and support sustainable development, rapid decarbonization of the energy sector, with a particular focus on scaling up renewable energy and enhancing energy efficiency especially in the transport sector has become imperative. Within these strategic plans, the transition to electric vehicles (EVs) is recognized as a critical component in reducing the environmental footprint of the transportation industry and curbing GHG emissions as shown Figure 1 below(Spash, 2016).

As an evolving technology introduced post-Industrial Revolution, electric vehicles (EVs) have been in existence for over a century. The first functional EVs were developed by Thomas Parker in 1884. Despite fluctuations in interest throughout the 20th century, recent decades have seen a significant surge in EV adoption. In 2021, global sales of EVs reached 6.75 million units, with China leading the market, accounting for 50.31% of total sales, followed by Germany (10.22%), the United States (9.89%), and the United Kingdom (4.83%)(Asensio et al., 2021; Ullah et al., 2024). This surge indicates a rapid expansion of the global EV fleet, which is expected to continue accelerating in the coming years. Forecasts suggest that by 2040, EVs will comprise 57% of total passenger vehicle sales and over 30% of the global passenger vehicle fleet. Sub-Saharan Africa (SSA), despite its current dependence on imported used vehicles, is not exempt from this transition, as EVs offer potential benefits in terms of reducing emissions and improving air quality. The EV market in SSA was valued at USD 11.94 billion in 2021 and is projected to grow to USD 21.39 billion by 2027(Ali Aden et al., 2022a; Collett et al., 2021). Despite the region's enthusiasm for adopting EV technology, it currently holds the smallest share of EVs in operation worldwide (Table 1).

In affluent nations, the primary motivation for EV adoption is the potential to mitigate greenhouse gas (GHG) emissions in the transportation sector. However, the factors driving EV uptake in SSA are likely more complex. Countries such as Ethiopia, Nigeria, and Uganda, which still have significant marginalized populations, must prioritize socio-economic development alongside environmental concerns. Furthermore, the region's heavy reliance on imported petroleum hampers economic growth, particularly by limiting access to affordable transportation(Ayetor et al., 2023; Obrecht et al., 2020). Ethiopia has experienced considerable urbanization in recent years, primarily driven by rural-to-urban migration in search of better economic opportunities. This trend, along with the increased use of automobiles, has resulted in a surge in economic activities(Eticha and Emagnu, 2023). However, it has also magnified transportation-related concerns, such as air pollution, traffic accidents, and congestion, which negatively impact the overall quality of urban life. Furthermore, during daytime, emissions like CO_2, NO_x, HC, CO, and particulate matter undergo chemical reactions, leading to the formation of ground-level ozone (O_3) and harmful aerosol particles that are detrimental to respiratory health. In 2015, vehicle exhaust emissions caused approximately 380,000 premature deaths globally. Addis Ababa, Ethiopia's capital, is committed to constructing a resilient, eco-friendly, and secure urban environment. The city is integrating climate change and air quality policies into its urban planning to continuously meet national air quality standards and achieve a 64% reduction in greenhouse gas emissions by 2030. Encouraging the adoption of environmentally friendly transportation modes will foster the development of sustainable urban communities with improved public health outcomes. A transportation system facilitates the movement of people or goods between locations, consisting of inputs, processes, outputs, and feedback(Ali Aden et al., 2022b; Eticha and Emagnu, 2023).

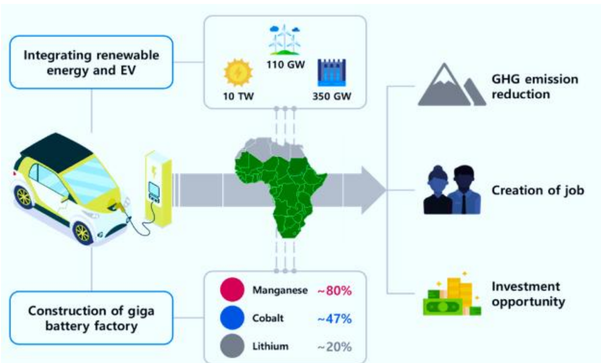

Figure 1. Advantages and Prospects of Electric Vehicle Transition in Sub-Saharan Africa(Spash, 2016)

On the other hand, electric vehicles (EVs) are powered by electric motors, utilizing collector systems, extravehicular electricity, or batteries (often charged by solar panels or fuel cells). EVs, along with emerging technologies such as connected vehicles, autonomous driving, and shared mobility, represent a future mobility concept known as linked, shared, autonomous, and electric (CASE) mobility. In addition to reducing emissions, another reason to discourage the use of outdated internal combustion engine (ICE) vehicles is the sharp increase in fuel prices. To address this issue, the Ethiopian government has implemented several measures. EVs are exempt from VAT, excise, and surtaxes, and reduced import taxes have been announced by the Ministry of Finance. The new regulations lower the tax rate on fully imported electric vehicles to 15% and to 5% on semi-assembled vehicles, aiming to encourage investment in electric vehicle assembly and importation, ultimately benefiting consumers. According to the previous research, a significant portion of vehicles exported to developing nations, including more than half to Africa, fail to meet minimum safety and environmental standards. Between 2015 and 2018, approximately 14 million substandard cars were supplied to developing countries, exacerbating air pollution and traffic accidents(Abiye, 2020).

The Ministry of Transport reports that over 1.2 million vehicles are registered nationwide, with around 630,440 in Addis Ababa. The most pressing issue of the twenty-first century is the continued dependence on fossil fuels, which emit CO2 and other greenhouse gases, contributing to global warming. Climate scientists advocate for updating outdated emission regulations to reduce atmospheric CO2 levels. Transitioning to renewable energy sources is a feasible option to mitigate CO2 emissions. Shifting towards an electric vehicle (EV)-based transportation strategy seems beneficial due to EVs emitting zero emissions compared to traditional combustion vehicles(“Global EV Outlook 2021 – Analysis,” 2021; “Global Trade Data Statistics Supplier,” n.d.). Additionally, with decreasing fuel reserves and rising global gasoline prices, the Ethiopian government has reduced fuel subsidies, resulting in increased financial burdens for users. By reallocating funds previously dedicated to fuel subsidies, the government can address other pressing priorities, as demonstrated by the significant reduction in subsidies and the subsequent savings.

Poor air quality is the second leading cause of disability and death in Ethiopia, according to the latest Global Burden of Disease study, and is projected to account for 21% of non-accidental deaths in 2017. Without intervention, the number is expected to rise to 32% by 2025. The current transportation system primarily relies on outdated internal combustion engine vehicles that consume more energy, have higher operational costs, and emit greater amounts of pollutants. To address these issues, this study aims to evaluate the transition from conventional gasoline vehicles to an EV-based strategy by conducting a quantitative SWOT analysis with a clearly defined panel of experts(“Global Trade Data Statistics Supplier,” n.d.).

Table 1. Registered Vehicle Numbers, Vehicle Density, and Imported Electric Vehicles in Selected Sub-Saharan African Countries (“Global EV Outlook 2021 – Analysis,” 2021; “Global Trade Data Statistics Supplier,” n.d.).

Country	Total registered vehicles (2021)	Cars per 1000 people	Total EV imported (2017–2021)	Ratio of imported EVs to ICE (2017–2021)
Ethiopia	1,200,300	12	-	0.056
Kenya	4,353,967	73	317	0.083
South Africa	10,339,450	232	1185	0.087
Madagascar	1,302,060	53	-	0.39
Senegal	1,067,523	68	1574	0.74
Cote d'Ivoire	1,554,076	69	886	0.75
Mauritius	580,759	-	1498	0.082
Ghana	1,405,034	47	8197	0.76
Seychelles	29,121	308	-	0.043
Nigeria	13,000,458	275	45482	0.81
Sierra Leone	300,211	42	1463	0.056
Angola	1,145,032	39	1346	0.72

2. LITERATURE REVIEW

In Sub-Saharan Africa (SSA), the rapid population growth, urbanization, and evolving societal dynamics have significantly increased the demand for mobility in both urban and rural areas, leading to a considerable rise and diversification in transportation needs. Globally, the transport sector accounts for nearly a quarter of greenhouse gas (GHG) emissions and is a major contributor to urban air pollution, a pattern observed in many cities across SSA as well. To highlight the scale of this increasing demand, transportation-related emissions in Africa surged by 84% over the past decade. In 2018 alone, the transport sector contributed to 15% of SSA’s total energy consumption (Kessides, 08).

Moreover, SSA has become a destination for second-hand vehicles from industrialized nations, undermining both global and regional efforts to transition towards safer and more sustainable transport systems. Approximately 85% of the vehicle fleet in Africa consists of used vehicles, with Nigeria leading the continent by importing 171,248 used light-duty vehicles in 2019, followed by countries such as Libya, Kenya, Ethiopia, Ghana, Tanzania, Benin, Guinea, and Cameroon. Efforts to mitigate transportation-related emissions are intensifying, driven by evolving regulatory frameworks, including impending bans on the sale of internal combustion engine (ICE) vehicles, shifts in consumer preferences, and advancements in battery and charging technologies("Africa's Automotive Industry: Potential and Challenges," n.d.). A prominent strategy gaining traction is the shift from ICE vehicles to electric vehicles (EVs). It is anticipated that major automotive markets including the United States, European Union, and China will transition to exclusively selling EVs by 2035, with projections suggesting that 80% of global vehicle sales will comprise EVs by 2050. Recent trends have shown a marked increase in EV sales globally, attributed to improvements in driving range, expanded model offerings, and enhanced performance. The timeline of EV introduction into SSA remains uncertain; however, studies suggest that EV adoption is relatively recent in the region. Despite the long-standing presence of major automotive companies such as Toyota, Renault, and Volkswagen in SSA, the emergence of EV manufacturers has been limited. Current production activities are largely confined to small-scale assembly operations using imported kits, with minimal local component sourcing. Nevertheless, a shift is underway as major global players like Japan's Toyota and Germany's Volkswagen are increasingly focusing on entering the African EV market. According to Figure 2, Compared to other regions, SSA is in the nascent stages of the EV revolution, with limited data available that portrays a challenging outlook. For instance, South Africa, which leads SSA in e-mobility infrastructure, had only around 1,000 EVs in circulation in 2022 out of a total vehicle fleet of 12 million(Hull et al., 2024).

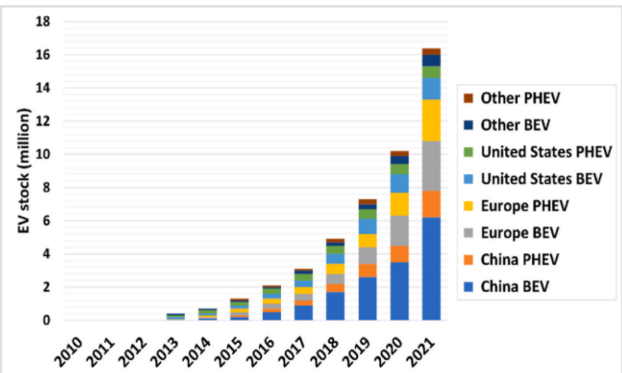

Figure 2. Worldwide EV stock, 2010–2021 ("Global EV Outlook 2021 – Analysis," 2021)

Supply chain management plays a crucial role in achieving sustainability goals. This importance stems from the need for both logistics operations and the supply chain as a whole to adapt and mitigate their environmental impacts. This orientation involves prioritizing resource conservation and environmental stewardship, particularly in transportation methods referred to as "green transport." Green transport is a subset of green logistics and involves managing the movement of goods in a manner that minimizes environmental and energy footprints. It encompasses activities within organizations that consider environmental factors and integrate them into supply chain management practices to improve the environmental performance of suppliers and customers. To address the significant contribution of transportation to greenhouse gas emissions, governments are developing strategies such as the Green Transport Strategy (GTS)(D. et al., 2020; Gaur and Vazquez-Brust, 2019; Grabara et al., 2020; Krynke, 2020).

The primary aim of such strategies is to reduce the negative environmental impact of transportation while meeting current and future transport needs. Encouraging the adoption of modern technologies is a key aspect of green transport strategies. This includes promoting the development and implementation of eco-friendly technologies by businesses(Axsen and Kurani, 2012; Dijk and Yarime, 2010). However, integrating sustainable practices, especially in small and medium-sized enterprises (SMEs), presents challenges due to various barriers ranging from organizational and cultural factors to economic constraints. Social resistance is often a major obstacle to implementing changes in sustainable practices. This resistance can delay investments and innovations in industries. It is closely related to mental barriers, which stem from insufficient knowledge about sustainable practices. Overcoming these barriers requires awareness campaigns supported by research to identify the underlying causes of social resistance. Economic barriers pose significant challenges to sustainable development in supply chain management. Limited financial resources can hinder the adoption of innovations and modern technologies(Bartiaux et al., 2016). Transportation currently contributes 10% of Africa's total greenhouse gas (GHG) emissions, a figure projected to increase as the region's vehicle fleet expands. The number of vehicles in operation across six countries South Africa, Kenya, Rwanda, Ethiopia, Nigeria, and others, which collectively represent approximately 70% of annual vehicle transactions and 45% of the Sub-Saharan African (SSA) population is expected to rise from 25 million to 58 million by 2040.

This growth is primarily driven by increasing urbanization and rising income levels. To mitigate the environmental impact, a comprehensive strategy is required, focusing on transitioning to cleaner and more energy-efficient vehicle fleets. Although the electric vehicle (EV) market in SSA remains in its nascent stages, several major industry players are investing in new production facilities and expanding their market presence(Bawakyillenuo et al., 2018; Putri, 2024). However, EV adoption in SSA faces numerous challenges, and sales remain limited due to persistent barriers, preventing EVs from becoming a widespread solution in the region. As more nations adopt electrification, the global electric vehicle (EV) market has experienced notable expansion over the past decade. However, Sub-Saharan Africa (SSA) has lagged behind in this transition compared to other regions(Ayetor, 2022).

A significant barrier impeding EV growth in SSA is the lack of comprehensive policies and regulations that establish clear national EV targets. While governments in developed nations are actively driving the automotive industry towards environmentally sustainable alternatives, SSA governments have shown a relatively passive stance. Empirical evidence underscores the critical role of robust government policies and regulatory frameworks in facilitating the widespread adoption of EVs globally. One of the primary challenges to EV adoption remains the high initial cost, which hinders accessibility. EVs, on average, are priced 30% higher than their internal combustion engine (ICE) counterparts, a disparity that is expected to persist until 2050. This substantial price difference diminishes consumer willingness to pay a premium for EVs. A 2011 survey involving consumers from 21 major U.S. cities highlighted the purchase price as the most significant disadvantage of EVs, with approximately 55% of respondents concurring. Similarly, a study in the United Kingdom, involving 40 hybrid electric vehicle (HEV) drivers who tested EVs for one week, revealed a reluctance to pay the additional upfront cost associated with EVs. The situation in SSA mirrors global trends, where economic, environmental, and social improvements could be realized by capitalizing on the burgeoning EV industry(Lieven, 2015). However, the prohibitive cost of EVs presents a major obstacle for many consumers in the region, with EVs being over 70% more expensive than conventional vehicles. Despite advancements in battery technology and increased investments in EV startups, the upfront cost remains beyond the financial reach of the average SSA consumer. For instance, the average cost of a new EV stands at approximately US$55,600, which far exceeds the purchasing capacity of the average resident in Lagos, Nigeria. In South Africa, survey data indicate that over 70% of respondents would consider transitioning to EVs if models were available at prices below US$30,000. However, the current market is dominated by high-end brands, with entry-level models exceeding US$100,000. The price gap between ICE vehicles (US$25,000) and EVs (US$111,000) in South Africa averages around US$86,000. Additionally, there is a stark deficiency of locally produced EV models, particularly in the mid-range and lower-market segments, with the majority of available vehicles catering to premium and specialized sectors(Contestabile et al., 2017; Dioha et al., 2022; Khan et al., n.d.; Sovacool et al., 2022).

The region is confronted with substantial infrastructural challenges, particularly in terms of deficient electricity networks, substandard road conditions, and a scarcity of public electric vehicle (EV) charging stations. Sub-Saharan Africa (SSA) has the lowest electricity access rates globally, and even those with access often endure unreliable and low-quality service (Fig. 3a). Persistent and prolonged power outages have profound socio-economic repercussions, further complicating the feasibility of EV charging(Bauer et al., 2020). Addressing the increased electricity demand generated by EV charging will necessitate engagement from independent power producers. Given the current limitations, widespread electrification of vehicle fleets in most SSA nations is presently impractical(Falchetta et al., 2020). However, projections indicate a future increase in electrification rates across SSA, signaling improved electricity access (Fig. 3b), which aligns with the global shift toward sustainable transportation. Nevertheless, inadequate charging infrastructure remains a significant barrier to the broader adoption of EVs, compounded by the lack of suitable EV models in various sectors. A 2012 survey found that 17% of technology enthusiasts identified the insufficiency of charging infrastructure as their main concern regarding EV adoption(Dagnachew et al., 2017; Wang et al., 2023a). By 2021, approximately 1.8 million publicly accessible charging points were available worldwide, with one-third of them being fast chargers(Egbue and Long, 2012). Data suggest that most EV charging occurs at residential or workplace locations. China leads with over half of the world's charging stations (810,000), followed by Europe and the U.S. with 288,000 and 99,000 stations, respectively (Fig. 3 c and d) (Wang et al., 2023b).

In South Africa, public access is available to 142 slow-charging and 163 fast-charging stations. The Plug Share platform lists 500 EV charging stations across Africa, with 61% of these located in South Africa(Calitz and Bansal, 2022). Ghana, Nigeria, and Uganda each have three stations, while Mauritius has six. Comparatively, SSA lags significantly behind other regions in terms of EV charging infrastructure(Pamidimukkala et al., 2023). Expanding the availability of public EV charging facilities is crucial for facilitating long-distance travel and enhancing consumer confidence. Additionally, existing EV owners express dissatisfaction due to the limited number of service facilities and maintenance centers relative to those available for conventional vehicles(Voytenko et al., 2016).

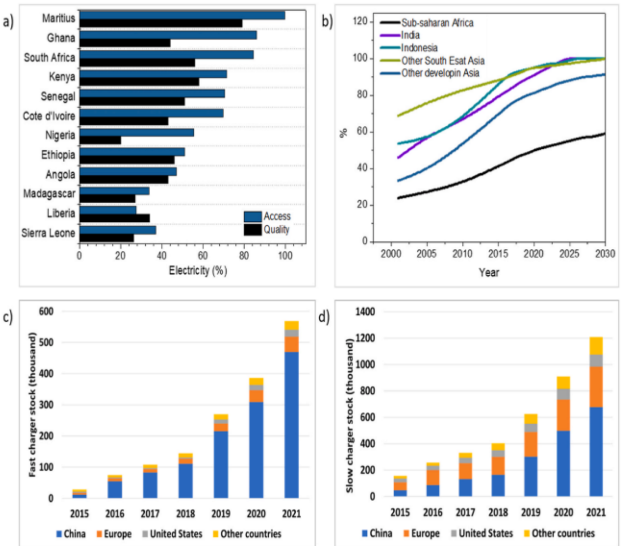

Figure 3. (a) Electricity access and quality for selected SSA countries in 2020 (Ayetor et al., 2023). (b) Electrification rates in selected countries and regions in the New Policies Scenario, 2000–2030. Publicly accessible charging points by power and region, 2015–2021 (c) Fast charger, and (d) slow charger.

Compounding this issue is the scarcity of mechanics in SSA with the requisite skills to repair and maintain EVs, as the technical requirements are often complex(Ayetor et al., 2023). To overcome this barrier, governments and international organizations often provide financial support through subsidies and funding programs. For transportation companies, transitioning to green management involves modernizing their fleets with energy-efficient solutions. This includes retrofitting vehicles with hybrid, electric, or hydrogen-powered engines, as well as adopting vehicle-to-grid (V2G) technology. However, such transitions require substantial investments and commitment from entrepreneurs, as eco-friendly vehicles can be costly.

To facilitate the adoption of green practices, various structural programs and subsidies are introduced, such as the EVAN program in Europe, which supports the purchase of electric delivery vehicles and charging infrastructure(Iodice et al., 2022; Mamo et al., 2024; Sadiq Okoh and Chidi Onuoha, 2024). In summary, this paper aims to identify key areas within Ethiopian logistics companies that are essential for advancing sustainable development, particularly in energy usage.

3. METHODOLOGY

SWOT analysis, initially detailed by Learned et al. (1969) (Puyt et al., 2023), is a prevalent tool for environmental analysis that aids strategic decision-making. Its applications are widespread, including fields such as management sciences (e.g., business and marketing) and social sciences (e.g., mass communications, education, library science, and international relations). Additionally, SWOT analysis is occasionally employed in computer-based AI projects, AI computations, and data analytics.

Table 1 exemplifies a standard generic template, structured as a matrix, commonly utilized to encapsulate the critical elements of a SWOT analysis. Within this framework, strengths and weaknesses represent internal factors that either facilitate or hinder an organization's ability to achieve specific objectives, while opportunities and threats are external factors. A comprehensive SWOT analysis was carried out to devise a strategy for promoting green vehicles in the Ethiopian market, with a particular emphasis on their incorporation into diverse logistic enterprise fleets. This type of analysis typically assesses an organization's strategic position within its operational scope. However, numerous studies have shown that it can also be used to evaluate progress towards sustainable development goals or to prioritize sustainable urban regeneration in environmentally sensitive areas, revealing its broad utility.

This study employed a quantitative SWOT analysis to evaluate the strategic position of electric vehicles (EVs) within Ethiopia's transportation and logistics sector. To ensure the rigor and objectivity of the analysis, a structured, multi-step data collection and evaluation process was implemented.

3.1. Expert Panel Composition and Selection Criteria

A purposive sampling method was used to select a panel of 15 experts. The sample size was determined to be sufficient for a qualitative weighting and assessment exercise, allowing for in-depth input while maintaining a manageable group for consensus building. The selection criteria required experts to have a minimum of five years of professional experience in fields directly related to Ethiopia's transportation or energy sectors. The final panel (n=15) was composed of the following profiles: Transport Policy Experts (5): Senior officials from the Ethiopian Ministry of Transport and Logistics, involved in policy formulation and regulation. Energy Sector Specialists (4): Engineers and planners from the Ethiopian Electric Utility and the Ministry of Water and Energy, specializing in grid infrastructure and renewable energy integration. Academics and Researchers (3): University faculty members from Addis Ababa University and Adama Science and Technology University, whose research focuses on sustainable transport and supply chain management. Logistics and Fleet Managers (3): Senior managers from private logistics companies in Addis Ababa that are currently operating or considering integrating EVs into their fleets.

3.2. Data Collection Procedure

Data was collected through a two-phase process:

Factor Identification (Literature Review & Preliminary Interviews): An initial list of factors influencing EV adoption was compiled from a comprehensive review of academic literature and industry reports on electric mobility in Sub-Saharan Africa. This list was then refined and validated through semi-structured interviews with three of the experts (one from each category) to ensure its relevance to the Ethiopian context. This process resulted in a final list of factors across the four SWOT categories.

Quantitative Assessment (Survey): A structured questionnaire was administered to all 15 expert panel members. The questionnaire had two parts for each SWOT factor: Weight Assignment: Experts were asked to assign a weight to each factor within its category (Strengths, Weaknesses, Opportunities, Threats) based on its relative importance. The sum of weights for all factors within a single category had to equal 1. This process ensures that the analysis accounts for the differential impact of factors (see Table 2).

Impact Assessment: Experts were asked to rate the impact of each factor on the strategic position of EV adoption on a 5-point Likert scale, where 1 represented a "very low impact" and 5 represented a "very high impact."

3.3. Ensuring Objectivity and Data Analysis

To minimize individual bias and enhance the objectivity of this quantitative SWOT analysis, a two-step aggregation method was employed. After collecting the individual assessments: Step 1: Average Calculation. For each factor, the weights and impact scores provided by all 15 experts were averaged to produce a single, consolidated weight and a single, consolidated assessment score. Step 2: Weighted Score Calculation. The consolidated weight for each factor was then multiplied by its consolidated assessment score to generate a final weighted score for that factor. Step 3: Strategic Positioning. The weighted scores for all factors within each SWOT category were summed. These category totals were then used, as shown in Section 4, to plot the overall strategic position of the EV market on a Cartesian graph, determining the recommended strategic approach. This quantitative approach, using aggregated expert judgment, provides a more objective and robust foundation for strategic recommendations than a purely qualitative SWOT analysis.

Table 2. SWOT Analysis Template

Factors	Internal	External
Positive	Strength	Opportunity
Negative	Weakness	Threat

Source: (Puyt et al., 2023)

4.RESULTS

The quantitative SWOT analysis provides an evaluation of electric vehicles' strategic position in transportation companies. Based on the aggregated expert assessments, the final weighted scores for each SWOT category are presented in Tables 3-6. By using the SWOT analysis, the strategic importance of EVs can be assessed. As shown in Table 7, the suggested strategy's location on the coordinate system indicates its position. To determine the coordinates of the point, the following calculations were performed: The value of Y, which signifies the difference between the absolute values of strengths and weaknesses, can be calculated as follows: $Y = |strengths| - |weaknesses| = 4.4 - 3.5 = 0.9$ (1).

The value of X, which represents the difference between the number of opportunities and threats, can be calculated as follows: X = |opportunities| - |threats| = 4.45 - 3.8 = 0.65 (2). According to the analysis of SWOT, the EV industry for transport companies is now favorable, with strengths greater than weaknesses and opportunities greater than threats. This signifies that the EVs' strategic location is in the Cartesian system's first quadrant, suggesting an aggressive (maxi-maxi) approach. This strategy aims to increase the adoption of EVs by taking advantage of strengths. It is important to identify and utilize opportunities that can optimize the utilization of one's best attributes. Several variables influenced the outcomes of the analysis. Despite these global efforts, debates persist regarding the full lifecycle emissions of EVs. For example, a complete transition to Battery Electric Vehicles (BEVs) could lead to an average 54% reduction in CO_2 emissions across the African continent, while Plug-in Hybrid Electric Vehicles (PHEVs) could achieve a 50% reduction [20]. However, as Ayetor et al. [20] demonstrated (Figure 4), this potential varies significantly by country. Ethiopia emerges as the region with the highest emission reduction potential, owing to its fully renewable energy grid, achieving an estimated 90%+ reduction. Conversely, South Africa's heavy reliance on fossil fuels (coal, oil, and natural gas) for 87% of its electricity generation limits its reduction potential to approximately 30%.

Table 3. Grouping of the Key Strengths Factors of Electric Vehicles

Items	Wording	Assessment	Weight	Assessment Weight
S1	Enhanced energy efficiency.	3	0.05	0.15
S2	Enhancement of air cleanliness.	3	0.05	0.15
S3	Lower noise emissions from electric vehicles.	5	0.1	0.5
S4	Eco-friendly transportation options.	5	0.15	0.75
S5	A large choice of electric cars.	4	0.1	0.4
S6	Growth in Corporate Social Responsibility initiatives.	5	0.1	0.5
S7	Superior comfort while driving.	5	0.15	0.75
S8	The feasibility of hydrogen-powered vehicles.	4	0.05	0.2
S9	Increased energy autonomy with a V2G (Vehicle-to-Grid) fleet.	4	0.1	0.4
S10	Lower emission of exhaust gases.	4	0.05	0.2
S11	Advancement in sustainable logistic networks.	4	0.1	0.4
Total			1	4.4

5.DISCUSSION

There is a widespread agreement that electric vehicles (EVs) present significant benefits compared to other transportation modes, particularly in terms of energy efficiency, reduction of emissions, and environmental sustainability. Consequently, many developed countries have implemented strategic plans to promote the advancement of EV technology. For instance, the European Union has proposed a ban on the sale of internal combustion engine (ICE) vehicles, advocating for the full electrification of new vehicle fleets by 2035 [69]. Similarly, the Biden Administration has set an ambitious target, aiming for EVs to represent 50% of the total vehicle market by 2030, while Chinese regulatory bodies have declared an intention to achieve a 20% EV market share by 2025.

Table 4. Grouping of the Key Weaknesses Factors of Electric Vehicles

Items	Wording	Assessment	Weight	Assessment Weight
W1	Buses lacking emission compliance	2	0.1	0.2
W2	Inadequate electric vehicle charging infrastructure	5	0.1	0.5
W3	Green vehicles costing up to four times more	4	0.15	0.6
W4	Elevated operational expenses for hydrogen and electric vehicles	4	0.15	0.6
W5	Rising demand for lithium, affecting costs and mining challenges	3	0.05	0.15
W6	Challenges in recycling lithium-ion batteries	3	0.05	0.15
W7	Electric cars with limited range per charge	4	0.1	0.4
W8	Extended duration required for charging	4	0.1	0.4
W9	Silent operation poses risks to pedestrians	2	0.05	0.1
W10	Lack of collaboration among automotive manufacturers	3	0.05	0.15
W11	Diversity in electric vehicle charging connectors	3	0.05	0.15
W12	Limited availability in the market for certain electric cars and buses	2	0.05	0.1
W13	Extremely low electric vehicle sales in Ethiopia	4	0.1	0.4
Total			1	3.5

Table 5. Grouping of the Key Opportunities Factors of Electric Vehicles

Items	Wording	Assessment	Weight	Assessment Weight
Q1	The potential for offers for green cars	5	0.1	0.5
Q2	Opportunity for novel strategies and innovative technology	4	0.1	0.4
Q3	Harmonization of charging infrastructure	4	0.1	0.4
Q4	Regulatory measures supporting electromobility growth	4	0.1	0.4
Q5	Influence from society	5	0.05	0.25
Q6	Energy strategy of Ethiopia	4	0.05	0.2
Q7	Swift advancements in manufacturing more affordable, larger electric batteries	5	0.1	0.5
Q8	Advancements in green vehicle-based public transportation systems	5	0.1	0.5
Q9	Growing awareness among the public	5	0.05	0.25
Q10	Opportunity to establish personal charging stations with a capacity of up to 22kW	4	0.1	0.4
Q11	Enhanced autonomy through the use of renewable energy sources	4	0.1	0.4
Q12	Boost in Ethiopian companies' reputation through reinforcing environmental commitments	5	0.05	0.25
Total			1	4.45

Table 6. Grouping of the Key Threats Factors of Electric Vehicles

Items	Wording	Assessment	Weight	Assessment Weight
T1	Volatility about prices	3	0.15	0.45
T2	More severe emission regulations	5	0.15	0.75
T3	Lowering the expenses associated with financial aid for electric vehicles	3	0.1	0.3
T4	Significant rise in the cost of electricity	5	0.1	0.5
T5	Adverse regulatory measures	4	0.1	0.4
T6	Unstable infrastructure for refueling stations	4	0.1	0.4
T7	Social resistance to adopting novel technologies	4	0.1	0.4
T8	Complicated procedures for financing and leasing vehicles	3	0.1	0.3
T9	Profitless investments in new green automobiles	2	0.05	0.1
T10	Potential modifications in energy taxes (ambiguous legal terms)	4	0.05	0.2
Total			1	3.8

Table 7. Strategic Position Derived from SWOT Analysis

	Strengths (S1 -S11)	Suggested aggressive strategy
Opportunities (Q1-Q12)	The availability of subsidies for green vehicles (O1) will enable investment in a modern fleet that includes a wide range of electric vehicles (S1) and the potential to use hydrogen vehicles (S2). The ability to establish private charging stations up to 22kW (O10) can lead to improved energy efficiency (S5) and enhanced energy self-sufficiency for the V2G fleet (S9), while also providing a wide selection of electric vehicles (S1). The potential for new technologies and solutions (O2) could impact the adoption of hydrogen vehicles (S2). Social pressure (O5) regarding environmental protection will raise public awareness (O9) and compel businesses to take necessary measures to protect the environment and minimize their impact, thereby improving Corporate Social Responsibility (S11). The expansion of green public transport (O8) and the standardization of charging systems (O3) will encourage the use of electric vehicles, allowing a broader selection of electric vehicles (S1).	Weakness (W1-W13)
	Threats (T1-T10)	

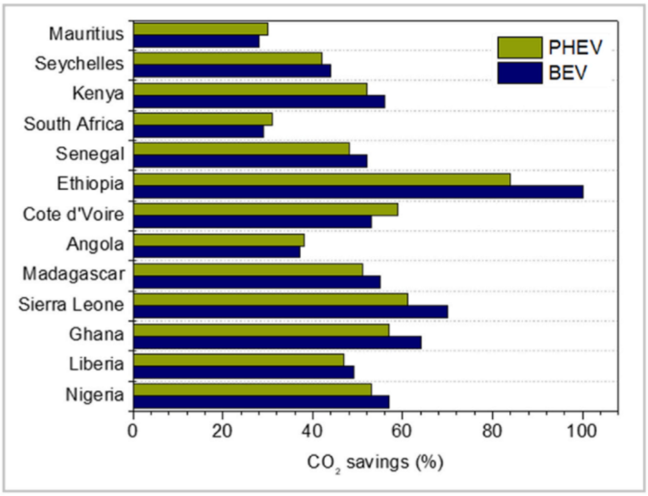

Figure 4. EV CO2 in some SSA countries

The quantitative SWOT analysis conducted in this study provides a structured evaluation of this transition. The results place Ethiopia's EV market in the "aggressive strategy" quadrant of the SWOT matrix, indicating that internal strengths and external opportunities currently outweigh weaknesses and threats. The most significant strengths identified are related to the direct environmental and operational benefits of EVs (S4: Eco-friendly options, score 0.75; S7: Superior driving comfort, score 0.75). Conversely, the principal challenge, and the most significant weakness, is the inadequate infrastructure for electric vehicle charging (W2, score 0.5). This deficiency is a critical vulnerability that requires extensive investment to rectify. Regarding opportunities, the potential for government subsidies (O1, score 0.5) and advancements in battery technology (O7, score 0.5) present the most tangible benefits. These could directly address the weakness of high upfront costs and range anxiety.

However, these opportunities are counterbalanced by significant threats, most notably the potential surge in electricity costs (T4, score 0.5) and the imposition of more stringent future emission standards (T2, score 0.75) which could necessitate costly, unplanned fleet overhauls. This strategic analysis leads to concrete recommendations. The adoption of an aggressive (maxi-maxi) strategy, as delineated in Table 7, seeks to leverage the identified opportunities to accentuate the strengths. This means Ethiopia should:

- Leverage its renewable energy strength (S4) by using the opportunity of growing environmental awareness (O9) to promote EVs as a truly zero-emission solution.
- Use the opportunity of potential government subsidies (O1) to directly combat the weakness of high upfront costs (W3) and encourage the development of private charging infrastructure (W2).
- Mitigate the threat of rising electricity costs (T4) by investing in and promoting the opportunity of renewable energy sources for charging (O11), such as solar-powered charging stations, ensuring that the operational cost advantage of EVs is maintained.

In summary, this analysis constitutes a strategic framework for the future utilization of EVs in Ethiopia. It moves beyond a simple list of factors to provide a weighted, data-driven foundation for policy and investment decisions, aiming to optimize the integration of EVs within the broader ambit of sustainable development.

6.Conclusion and Recommendations

The quantitative SWOT analysis uncovered several insights about implementing environmentally friendly logistics strategies in public transit organizations in Ethiopia. The results indicate a favorable strategic position for EV adoption, provided that key weaknesses and threats are addressed proactively. Monetary assistance for eco-conscious vehicles would enable the acquisition of state-of-the-art fleets, including a diverse range of electric vehicles. Creative solutions such as dedicated refueling stations could boost energy self-sufficiency and productivity. Organizations would be motivated to adopt green practices due to heightened awareness of corporate social responsibility and environmental conservation, while minimizing adverse ecological effects.

The development of eco-friendly transit networks and a standardized charging infrastructure would expand the range of electric vehicles accessible to consumers. The global shift away from petroleum-based fuels in transportation, coupled with heightened awareness of climate change, has catalyzed a significant rise in the adoption of electric vehicles (EVs) within the transportation strategies of numerous governments worldwide. In the case of Ethiopia, however, this transition is still in its nascent stages. This study has helped to precisely identify the key challenges that must be addressed to ensure a just and equitable reduction in carbon emissions from passenger road transport.

To expedite the transition to electric mobility in Ethiopia, several critical factors must be considered. Firstly, robust policies and regulatory frameworks are essential drivers for accelerating the adoption of electric and zero-emission vehicles. Ethiopia, however, faces a significant barrier due to the absence of clear policies and regulatory structures that support the widespread adoption of EVs. Currently, the Ethiopian government lacks emission standards or incentive schemes designed to stimulate the production and sale of EVs. Consequently, the development of new or the enhancement of existing policies is imperative to facilitate the transition towards a cleaner and more sustainable transportation sector. Despite the Ethiopian government's efforts to incorporate EVs as a mechanism to curb carbon emissions, concerns regarding the feasibility of this strategy persist. These concerns stem from issues such as the affordability of EVs, high upfront costs, limited access to affordable financial services, and the overall viability of EV financing. As a result, there is a pressing need to design financial instruments, subsidies, and incentive structures to promote price parity with conventional internal combustion engine (ICE) vehicles and reduce the overall cost of EV ownership. In addition to financial challenges, Ethiopia's infrastructure presents considerable obstacles. The country's electricity networks are underdeveloped, and there is a scarcity of public electric charging stations, both of which hinder the widespread adoption of EVs. Therefore, a comprehensive public charging infrastructure strategy is needed, which includes the integration of solar-powered charging stations and residential charging solutions. This strategy must address various technological challenges, such as the impact on the electrical grid, while accommodating the diverse charging needs of consumers. Engagement with the private sector, particularly automobile manufacturers, will be crucial. These stakeholders must adopt business models that incorporate customized charging solutions and facilitate the deployment of EVs within their service offerings to support the country's transition towards sustainable transportation. To maximize the benefits of sustainable transportation, comprehensive research and discussion are necessary. It is important to recognize that this topic is closely linked to Sustainable Development Goals 7 and 13, which aim to provide universal access to clean, reliable energy and foster global cooperation in researching cleaner energy and improving technology and infrastructure to make sustainable energy accessible, especially in the transportation industry.

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