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Life Cycle Cost and Environmental Impact Analysis of Diesel and Electric Buses: A Case Study on Butwal – Belahiya Route of Nepal

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Abstract
Due to climate change and global warming, one of the newest technologies is electric transportation. This study's main objective is to compare the life cycle costs and environmental effects of diesel and electric buses that travel the Butwal-Belahiya route.The study's chosen distance between Butwal and Belahiya is 27.9 km. A diesel bus costs US Dollars 165,825.28 over the course of eight years, but a bus powered by electricity costs US Dollars 222,738.46. According to this, an electric bus has a higher life cycle cost than a diesel bus of US Dollars 58,913. A diesel bus emits 197.82 tons of carbon dioxide during the course of eight years, compared to 46.55 tons from an electric bus. According to this, an electric bus produces 151.27 tons less carbon dioxide over a diesel bus. Consequently, even if it costs more, a bus powered by electricity is the best choice in terms of the environment. The sensitivity analysis shows that in Nepal, the life cycle cost of a bus powered by electricity (electric Bus) is lower than that of a diesel bus, which eventually rises. This is due to the fact that the price of electrical power is less expensive than the price of fuel made from diesel, and the falling price of batteries also lowers the cost of purchasing an electric bus. Diesel buses, on the other hand, are exempt from this and their acquisition costs are constant.

Keywords
Environmental Impact, Life Cycle Cost, Pollutant Emissions, Sensitivity analysis, Electric Bus

1. Introduction

The global trend towards renewable energy sources and away from petroleum fuels has led to significant progress in the field of vehicle electrification. Electric vehicles (EVs) have emerged as a viable solution to reduce the impact of transportation systems on the environment and mitigate the effects of climate change. The issue of air pollution has gained increasing attention from scholars, policymakers, and the public worldwide due to its adverse health and environmental impacts. Urban transport is a significant contributor to air pollution, which has spurred interest in EVs and other ecofriendly forms of transportation. As a result, many developed nations have revised their policies to promote the use of alternative-fuel vehicles. The automobile industry has also been driven by increasing environmental concerns and resource limitations of oil to develop various alternative fuel vehicles.

The adverse impacts of air pollution on living organisms have become a major concern. Transportation is one of the largest energy consumers and heavily relies on oil reserves, thereby causing significant environmental impacts. In addition to emitting nitrogen oxides and other specific pollutants, transportation also contributes to global warming by releasing carbon dioxide [1]. To mitigate the impacts of transportation on society and the environment, sustainable transportation measures are required. While increasing public transportation may prove to be a viable solution, diesel buses are among the major sources of air pollution and release harmful chemicals. Failure to take steps towards electrifying transport vehicles may eventually lead to the need for residents to wear protective eyewear and masks with multiple layers to shield them from lethal gases and dust particles. Such conditions are rapidly emerging in major cities outside of Nepal. Global warming is a result of the average air temperature rising, which alters the Earth's climate and weather patterns. As long as people continue to release heat-trapping greenhouse gases (GHG) into the atmosphere, rapid changes will continue to occur. Carbon dioxide CO_2 is the most important human greenhouse gas among these emissions because of its abundance and propensity to linger in the atmosphere for a very long time.

The European Union has agreed to implement climate mitigation measures as a signatory to a Paris Agreement in order to keep the mean temperature rise well below 2°C while pursuing attempts to reduce it to 1.5°C. The Intergovernmental Panel on Climate Change states that by roughly 2050, global net greenhouse gas emissions must be zero in order to achieve the more challenging goal of 1.5°C [2]. Developing nations face a predicament in meeting their net-zero emissions targets because of their aspirations for speedy economic growth, enhanced socio-economic conditions, and greater resilience to climate change. These objectives must be weighed against the feasibility, viability, and sustainability of low-carbon projects. In a recent investigation, Nepal's Long-term Strategy for Net-zero Emissions was analyzed using the Low Emissions Analysis Platform (LEAP), and potential co-benefits were estimated. The study discovered that, under a reference scenario, annual CO_2 emissions are expected to rise substantially. However, under a strategy scenario with additional actions, air pollutant emissions could be reduced by 70-85% by 2050, leading to significant improvements in energy security metrics and energy equality [3].

The relevance study in the context of transport electrification studies, initiatives, and Government of Nepal policies. This study is centered around the rising number of net-zero emissions goals for CO_2 to aid in accomplishing the Paris Climate Agreement's objectives of curbing global average temperature increase. Developing nations confront substantial hurdles in reaching these targets due to their aspirations for swift economic development, better social and economic conditions, and greater resistance to climate change. They examine the co-benefits of low-carbon initiatives, including transport electrification, in Nepal. The studies highlight the need for sustainable low-carbon transportation development strategies in emerging cities, such as Kathmandu Valley, to mitigate environmental impacts, reduce energy import dependency, and improve energy security and equity. The findings of this study will provide useful input to policymakers, private sector, societal actors, and researchers in support of successful implementation of initiatives for sustainable socio-economic transformation pathways [4, 5, 6].

1.1 Problem Statement

The LCC of diesel and electric buses and their impact on Nepal is a significant problem that needs to be addressed. Nepal is a developing country that heavily relies on the transportation sector for economic growth and development. However, the transportation sector is also responsible for significant environmental pollution and high operating costs due to the reliance on fossil fuels. According to the Nepal Energy Situation Report, the country imported approximately 1.5 million metric tons of petroleum products in the fiscal year 2019-2020. This high dependency on petroleum products for transportation not only creates a heavy burden on the country economy but also contributes to air pollution, which affects public health and the environment. The initial investment for electric buses may be higher, their LCC is lower than that of diesel buses due to lower fuel and maintenance costs. Moreover, electric buses produce zero emissions, making them a cleaner alternative to diesel buses. Determining the most economical and environmentally responsible modes of transportation for Nepal, therefore, requires evaluating the LCC of petroleum and electric buses as well as their effects on the country. Children, young people, and the elderly are those who suffer the most from the effects of air pollution. Additionally, the impact of pollution on tourism has a detrimental influence on the economy.

In fact, the air in Nepal is among the dirtiest in the world, and large numbers of people in Lumbini Province lose their lives annually due to chronic lung-related diseases and bronchitis. Sadly, despite this awareness, there has not been enough public pressure to spur action. Every year, up to 35,000 Nepalis die due to air pollution-related illnesses, and the average life expectancy of Nepalis is reduced by over two and a half years due to air pollution [7].

Public transportation provider, Sajha Yatayat, began operating in July 2022, in collaboration with the Provincial Government of Province Three, the Kathmandu Metropolitan Government, and the Lalitpur Metropolitan Government. This service employs electric buses and the necessary infrastructure. In addition to Sajha Yatayat, other private companies are also exploring the use of electric buses for mass transportation in various cities. Electric vans are also available for travel between Kathmandu and Bardibas via the BP Highway. According to Alogaili et al. (2021), electric buses' energy consumption can vary significantly based on factors such as the number of passengers, the route's characteristics, weather conditions, and driver behavior [8]. While electric buses consume minimal energy, these variables can affect their overall energy consumption. The adoption of electric vehicles in Nepal presents a significant opportunity to decrease petroleum oil consumption and improve air quality in major urban areas. To ensure that everyone has access to clean energy, the Ministry of Energy, Water Resources, and Irrigation (MOEWRI) intend to generate 10,000 MW by 2028 and provide 100% electricity access by 2023. The 15th periodic plan of the National Planning Commission also plans a generation of from renewable energy sources of 4000MW by 2030 (NPC, 2020). With a goal of producing more than 550MW by 2024, the government also wants to boost the proportion of solar energy generation through the private sector. Also, as part of the NDC target, Nepal intends to add 2100MW of solar energy to the national grid by 2030, meeting 15% of the nation's total energy consumption with renewable energy sources [9]. Depending on the process employed, producing hydrogen can have an influence on the environment or be energy efficient. The most popular techniques are electrolysis and natural gas reformation. In order to produce synthesis gas, a blend of hydrogen, carbon monoxide, and a trace quantity of carbon dioxide, natural gas is reacted with steam at high temperatures. Carbon monoxide and water react to make more hydrogen. The most extensively utilized, effective, and economical method is this one. On the other hand, electrolysis uses an electric current to split water into oxygen and hydrogen [10].

The Intergovernmental Panel on Climate Change (IPCC) has eliminated many uncertainties about climate change. It is now unequivocal that the existing climate system will worsen in the future. Human-generated greenhouse gas (GHG) emissions are primarily responsible for the current global climate warming. Atmospheric carbon dioxide concentrations have increased from 278 parts per million to 396 parts per million since the pre-industrial era. It is projected that GHG emissions could rise by 25-90% compared to 2000 by 2030,reported by intergovernmental Panel on Climate Change(IPCC) in 2014 and the Earth could warm by 3^oC this century. Even a small temperature rise of $1-2.5^oC$ could have significant consequences, such as reduced crop yields in tropical regions, leading to increased food insecurity and the spread of climate-sensitive diseases [2].

The transportation sector contributes to 14% of the world's annual GHG emissions, according to the IPCC report of 2014. In 2010, the transportation sector emitted 7.0 GtCO_2eq of direct GHG emissions, which accounted for about 23% of the total energy-related CO_2eq emissions (6.7 GtCO_2eq). Nepal depends on India for its refined oil products since it neither produces nor owns any oil. Petroleum products like motor spirit, high-speed diesel, superior kerosene oil, air turbine fuel, and liquefied petroleum gas are imported, and about 1.0 million tons of oil equivalent (Mtoe) are consumed annually, with demand increasing by approximately 10% each year on average.

The Asian Development Bank (ADB) predicts a 1.9% annual expansion in Nepal's final energy demand until 2035, which is slower than the predicted GDP growth rate of 3.7% for the same period. Final energy consumption will moderately increase by 1.7% in the residential, commercial, agriculture, and fisheries sectors, which accounted for the most significant proportion of the total in 2010, at 90.2%. However, their share is predicted to fall to 84.9% by 2035. In contrast, the energy demand in the industrial and transport sectors will rise more quickly over the same period, with an average increase of 4.0% and 3.5% per year, respectively. By 2035, these sectors' share will increase to 6.0% and 9.1%, respectively [11].

2. Materials and Methods

2.1 Vehicle Selection

The present study investigates the Techno-Economic Analysis and Environmental Impact of diesel and electric buses and electric bus on the Butwal-Belahiya route, which covers a distance of 27.9km. The aim of this research is to assess the feasibility of using Electric Bus (EB) on the Golpark-Belahiya-Golpark Route in Lumbini Province by comparing their LCC with the current Diesel Bus employed on this route. Furthermore, the study carried out an analysis of the EB's environmental impact. Only one route in Lumbini province is currently serviced by two electric buses, with the route scheduled to provide service up to three times per day, running hourly from 6 am to 10 pm every day. The bus model selected for the electric bus has a seating capacity of 32. Technical specifications of both buses are presented in Table 1.

Table 1: General parameters of the chosen vehicles

Mechanical Specification	Electric Bus	Diesel Bus
Maximum Speed	70 Km/hr	80 Km/hr
Passenger Capacity	32	34
Model	e-Bus	Ashok Leyland Lynx
Batteries	Lithium Iron Phosphate	3 PACK with 204 kWh
Dimension	10,990mm × 2,495 mm × 3,390mm	8230 mm × 2550 mm × 3020 mm
Charging System	DC Plug in	Diesel Station
Power	204 kWh	127HP @ 2400 rpm
Torque	2200 Nm/435 ps	450 Nm @ 1400-2000 rpm
Gross Vehicle Weight	13626 kg	11000 kg
Battery weight	1890kg	52kg
Engine	Permanent magnet motor	3839 cc
Fuel Tank Capacity	204 kWh	165 ltrs
Mileage	-	5-6 km/l

2.2 Research Area

The trade route between Belahiya and Butwal, located in Lumbini province, is crucial for the country and sees heavy traffic flow every day. This road stretch has been upgraded to a six-lane highway and connects the two major business hubs, with a distance of 27.9 km between them. Butwal is approximately 81 km away from the capital Kathmandu, while Belahiya is 100 km away from Pokhara and 184 km from Kathmandu. The route is mostly served by diesel buses, and due to the potential for reducing emissions through the use of green energy vehicles, this study has selected this route for analysis as shown in figure 1.

Figure 1: Research Area

2.3 Techno-Economic Analysis

2.3.1 Life Cycle Cost Analysis

The LCC study takes into account all expenses incurred over an object's lifetime, including the costs of procurement, operation, depreciation, and maintenance. This economic research is beneficial for finding pricey components that can prevent the swift market expansion of goods like autos. Equation (1) was used to determine the LCC, which takes into account all expenses linked to using the cars [12]:

$$LCC = AC + \sum_{i=1}^{n} (OC_i + MC_i + DC_i) \qquad (1)$$

where AC=acquisition cost, OC_i= operating cost, DC_i=Disposal cost, and MC=maintenance cost.

2.3.2 Acquisition Cost

The term "acquisition cost" refers to the overall price paid for an asset, which includes the costs of the construction process, installation, and testing in addition to transportation, taxes, and customs duties. The acquisition cost of the Diesel bus (Ashok Leyland Lynx) is 45455 USD, including all charges such as excise duty, customs, and others, according to data from IME Motors Nepal in 2022. The acquisition cost of the electric bus (Eurabus, Germany) is 200,811 USD, including a 1% custom duty, 3.5% road construction charge (RCD), and 13% VAT, according to data taken from Sundar Yatayat. Electric vehicles up to 100kW have to pay a 10% customs duty, while electric vehicles of 100 to 200 kilowatts have to pay a 15% customs duty, and electric vehicles of 200 to 300 kilowatts have to pay a 40% customs duty. The excise duty, customs, and other charges on petroleum private vehicles are more than 240%, while private electric vehicles pay ten times less, according to Nepali Times in 2022.

2.3.3 Operation Costs

The operating costs refer to all expenses associated with the use and maintenance of the asset, including energy supply, water, security, administration, and other related costs. For vehicles, these costs include fuel expenses for diesel buses and the average cost of recharging for electric vehicles. The expenses related to services, such as taxes on holdings, inspections for emissions of pollutants, and insurance charges are part of the overall operating expenses. Equation (2) [13] was used to calculate the operating costs:

$$OC = \sum_{i=1}^{n} (CCom_i + CTen_i + CS_i + CV_i) \quad (2)$$

The equation used to calculate the fuel costs, CCo_m, is dependent on various parameters, such as the vehicle efficiency type, η_j, domestic recharging efficiency for EVs, $\eta_{charging}$, annual distance traveled in period i, D_i, electricity cost, $C_{elect,i}$, and gasoline fuel cost, $C_{gas,i}$. The calculation for fuel costs for the diesel bus can be derived from Equation (3), while the calculation for EVs can be derived from Equation (4) [14]. The other operating costs that must be considered include holding taxes, CTen, which amounts to 8400 NPR per year, pollutant emissions checks, CV, at 350 NPR per 6 months, and insurance coverage, CS, at 10,747 NPR [15]. Cten for electric vehicles will be 4200 NPR per year and insurance cover remains the same.

$$CCom_{VCI,i} = \eta_{ICV} \times D_i \times C_{gas,i} \quad (3)$$

where, $\eta = 55\ to\ 60\%$,[16] $D_i = 240$ working days, $3\ trips = 6 \times 27.9(km) = 167.4km$, $C_{gas,i} = 30.48(liter) \times 176.44(price, 2023Jan) = 5370.192NPR$ Assuming a mileage of 5.5 km/l, the daily diesel consumption of the bus is 30.44 liters. At a price of 1.32 USD per liter of diesel, the daily fuel cost is 40.18 USD (NOC, 2023). The bus covers a distance of 40,176 km in a year with 240 working days per year. For electric buses, the total distance that can be covered on a full charge is 261.2 km (204 kWh) [17]. The cost of 1 kWh of electricity for business purposes is 9.210 NPR [18], which translates to a daily energy cost of USD 9.13 (1204.126 NPR) for the electric bus.

2.3.4 Maintenance Cost

The cost of corrective and preventive care, such as service fees based on mileage, battery replacement fees, and tire replacement fees, are included in the cost of maintenance applied to cars. Preventive maintenance of vehicles prioritizes smaller repairs throughout a vehicle's lifetime, thereby avoiding the need for larger repairs. In contrast, corrective maintenance involves addressing changes in vehicle batteries and tires. The maintenance cost can be calculated using Equation (4) [14]:

$$MC = \sum_{i=1}^{n} (PMC_i + CMC_i) \quad (4)$$

The costs associated with maintaining a vehicle include both preventive and corrective maintenance expenses. Preventive maintenance involves routine servicing to prevent potential problems over the lifetime of the vehicle, while corrective maintenance includes repairs such as battery and tire replacements. The preventive maintenance cost can be computed using the preventive maintenance index (IMP_i) and the distance traveled. Equation (5) can be used to determine the preventive maintenance cost, where PMC refers to preventive maintenance cost and CMC represents corrective maintenance cost.

$$CMP_i = IMP_i \times D_i \quad (5)$$

The (IMP_i) can be calculated with equation (6):

$$IMP_i = \frac{PM_i}{kmperyear} \quad (6)$$

The preventive maintenance cost for each period i can be represented as pm_i. If PM_i for Diesel Bus for three months intervals are equal to 303 USD (Rs. 40,000 NPR), then the total preventive maintenance cost for one year is 1212 USD. According to GGGI, the maintenance expense for a diesel bus during the first year of operation rises by 30% annually. Thus, the total PMC is 28915.50 USD. Considering PM_i for Electric Bus for 3 months interval is 15.16 USD [7]. The cost of changing the battery (BC_i) and replacing the tires (TC_i), both in the period I, can be used to compute the cost of corrective maintenance. Calculating the cost of corrective maintenance can be done using Equation (7):

$$CMC_i = BC_i + TC_i \quad (7)$$

For the Electric Bus, the battery change cost (BC_i) is zero for 8 years because it is under warranty. Typically, tires last for about 40,000km nowadays, which is an improvement over the 32,000km lifespan in the 1970s. However, it is difficult to estimate the exact lifespan of tires [19]. In general, tires need to be replaced 4 times in 8 years, which means a total of 24 tires for the vehicle. The cost of one tire is 104 USD [20], so the total cost of 24 tires is 2496 USD. With a 5% customs duty on tires [21] and 13% VAT, the total price is 2961.50 USD. Thus, the total maintenance cost for the diesel bus is 31876.50 USD, while the maintenance cost for the electric bus is 4407.20 USD.

2.3.5 Depreciation/Disposal Cost

Depreciation cost refers to the decrease in the value of a new item, and this cost is also applicable to vehicles. It represents the difference between the initial purchase cost and the current market value of the vehicle. In Nepal, the depreciation rate for automotive vehicles is set at 20% according to the country's depreciation law. To calculate the depreciation/disposal cost, we can use equation (8), which takes into account the vehicle's depreciation cost at the end of the period and the battery scrap cost, as outlined in Fuentes and González (2021):

$$CD = \sum_{i=1}^{n} (CDV_n + CSB_n) \quad (8)$$

The equation includes the following variables: CDV, which stands for vehicle depreciation cost (as calculated by Omni Calculator, 2023); and CSB, which represents the battery scrap cost. The cost of battery recycling is 0.22 USD per pound (1lb = 0.454kg) according to Battery Recycler (2023). As the weight of the battery in EB is 1890 kg, the scrap value is 915.85 USD. Thus, the total disposal cost for EB is 2410.411+915.85=3326.26 USD. For DB, the battery weighs 52 kg, so the CBS is 25.20 USD. Therefore, the total disposal cost for DB is 2410.411+25.20=2435.61 USD.

2.4 LCC Sensitivity Analysis

Technical and economic factors are taken into account when calculating life-cycle costs. A sensitivity study was conducted to examine the implications of several parameters on LCC, including purchase and battery costs, power and fuel expenses, and annual mileage. The manufacturer's suggested retail price (MSRP) and the company's official website were used to calculate acquisition costs. However, these costs can vary depending on local factors like import taxes, changes in the market, and new technology. Using a sensitivity analysis of acquisition prices, the study determined the percentage decrease required for electric cars to compete with diesel buses and gain market share. Fuel prices have a significant impact on overall operating costs.

The price of fuel for electric buses, denoted as $(CCom_{EB,i})$, and diesel buses, denoted as $(CCom_{DB,i})$, varies depending on the specific parameters of the area being studied. An increase in the cost of diesel does not have a direct impact on electric buses. However, if diesel becomes too expensive, the LCC of diesel buses will increase, which may make electric buses a more affordable option for users. The price of batteries is one of the most important variables that has an impact on the economic analysis. This element impacts the overall cost by having an impact on both the maintenance cost (MC) and the cost of changing the battery (BC i). Several studies have shown how crucial it is to take battery prices into account while examining the LCC of electric buses. The yearly distance traveled also has a significant impact on the LCC outcomes, operating expenses, and maintenance costs. Although it is assumed that all vehicles travel the same amount of miles on average, it is important to consider the fact that users are anticipated to drive a variety of distances annually.

2.5 Environmental analysis

2.5.1 GHG Emissions in the Vehicle Production Phase

The electric vehicle is equipped with a 330-volt lithium-ion battery system that includes 88 50-Ah cells, providing a storage capacity of 16 kWh. For the electric bus in our case, one battery pack weighs 630 kg, and there are three batteries, making the total battery weight 1890 kg. The mass of the electric bus is 13,626 kg. In comparison, the diesel bus's battery weighs 52 kg (AAM-HW-NTX00D04R), and the bus itself weighs 11,000 kg, as reported by Fuentes and González (2021).

$$IVA_j = (m_v - m_{bat})EGHC_v + m_{bat}EGHC_{bat} \tag{9}$$

The battery system of the electric bus comprises three battery packs, each weighing 630 kg, resulting in a total battery weight of 1890 kg. The mass of the electric bus is 13,626 kg. In contrast, the diesel bus has a single battery that weighs 52 kg, and the bus itself weighs 11,000 kg.

2.5.2 GHG Emissions in the Vehicle Operation Phase

In this phase of the study, the researchers took into account the greenhouse gas emissions generated both by the vehicles themselves and the fuel generation plants that power them. For the Ashok Leyland Lynx, this meant considering the emissions from gasoline combustion, while for electric vehicles, the emissions were related to electricity generation. Assuming a mileage of 5.5 km/l for the diesel bus, it consumes 7,304.73 liters for a yearly distance traveled of 40,176 km. Thus, the total diesel consumption in 8 years is 58,437.84 liters. With 2.79 kg of CO_2eq emissions per liter of diesel[22], the diesel bus emits 163,041.57 kg of CO_2eq or 163.04 tons over 8 years. Given that 4 grams of CO_2eq are generated to produce 1 kilowatt-hour of energy[23], the electric bus consumes 251,023.09 kilowatt-hours of energy over its lifetime of 8 years. Thus, the electric bus indirectly emits 1,004.085 kg or 1.004 tons of CO_2eq over 8 years.

As per the GGGI 2020 report, a carbon tax has been assumed to be levied on emissions from the transportation sector. The tax is expected to increase from USD 40 per ton in the first year to USD 80 per ton in the tenth year, which is consistent with the range of carbon taxes imposed by most countries around the world. Assuming an average cost of USD 60 per ton, the cost of emissions for the diesel bus, which emits 197815.46 kg of CO_2eq in 8 years, is calculated to be USD 11869.2. Similarly, the cost of emissions for the electric bus, which emits 49558.96 kg of CO_2eq in 8 years, is calculated to be USD 2973.60.

3. Results and Discussion

3.1 LCC Analysis

The results for the LCC of the chosen vehicles are shown in Table 2 and Figure 2. By comparing diesel buses with electric vehicles (EVs), it can be seen that the LCC values for electric buses during an 8-year lifetime were substantially higher. For example, the LCC values for diesel buses and electric buses, respectively, were USD 165825.26 and USD 222,738.46. Based on 240 working days, 3 trips each day, and an average annual distance of 40,176 km, these figures were derived. Each journey had a 55.8 km distance. The table was calculated using equations (1), (2), (4), and (8). Figure 2 showed how LCC was obtained using diesel and electric buses. The observation demonstrates that over the course of an 8-year lifespan, the Ashok Leyland Lynx will cost USD 57 thousand less than an Electric bus. Table 2 shows that the acquisition costs for both DB and EV account for the largest portion of the LCC. Figure 2 illustrates this disparity graphically, showing that the LCC of an electric bus is still significantly larger than that of a diesel bus. In comparison to the Ashok Leyland Lynx or diesel bus, which are depicted in figures 4 and 5, it was determined that the acquisition cost for the electric bus accounted to 87.48% of the LCC for the electric bus. Due to annual fuel cost savings, verification cost savings, and holding tax savings, electric buses have an advantage in terms of operational costs. Table 3 shows that, of all the costs associated with the LCC, the running costs of the electric bus made the smallest contribution. The outcomes

Table 2: LCC results

Cost (USD)	Diesel Bus	Electric bus
Acquisition Cost	45455.00	200811
Operating Cost	79060.19	18053.78
Maintenance Cost	31876.50	4407.20
Disposal Cost	2435.61	3326.26
GHG Cost	11869.2	2973.60
Total (USD)	**165825.28**	**222738.46**

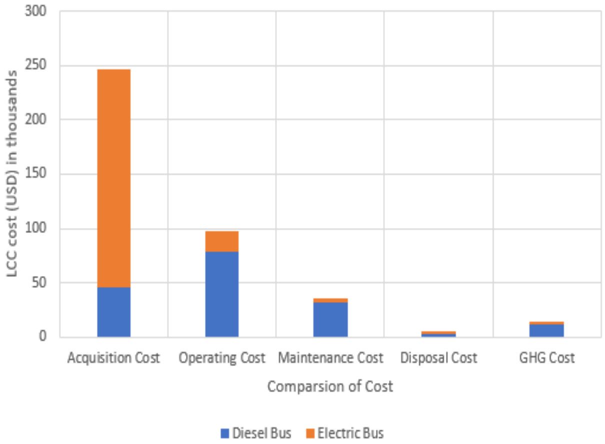

Figure 2: Difference Cost

demonstrate an advantage for electric buses when compared to LCC when the annual mileage was set at 40176 km. Figure 3

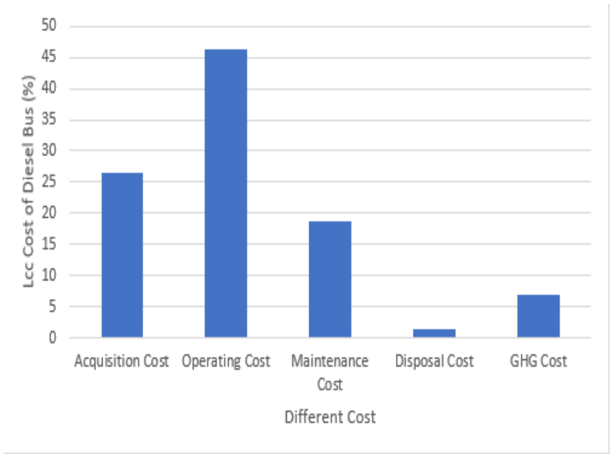

Figure 3: Cost contribution by the percentage of Diesel Bus

shows the cost percentage paid to LCC throughout the course of eight years for diesel buses. The observation demonstrates that running expenses are more than other expenses still due. Because operating costs were heavily reliant on diesel prices, which have fluctuated since 1991 as shown in Figure 6, operating costs made up 46.31% of the total LCC and have continued to do so over time. The price of diesel is rising daily when predictions are taken into account. As a result, operational costs are getting more expensive and can only be replaced by electricity, which is getting cheaper in Nepal. Moreover, maintenance costs rank third in terms of high costs, contributing 8.88% of the overall LCC. According to GGGI, the maintenance expense for a diesel bus during the first year of operation rises by 30% annually. As a result, the cost of maintenance will rise yearly and, in eight years, will account for a sizable portion of the cost of LCC. Figure 4 shows the cost percentage paid to LCC during the course of eight years for electric buses. According to the observation, acquisition costs are higher than other costs. The acquisition cost made up 88.20% of the overall LCC and fluctuates over time because it is heavily reliant on battery prices and because several organizations, nations, and scientists have made commitments to lower battery costs. Hence, purchase cost gets cut in the future more than the current and this cost reduces LCC of electric bus. In recent years there is significant cost reductions for lithium-ion batteries, and more experience curve-driven cost reductions are anticipated[24]. Also, because the Nepali government promised to lower the cost of electricity, operating costs will also decrease in Nepal. Moreover, this lowers the LCC of electric buses globally and in Nepal.

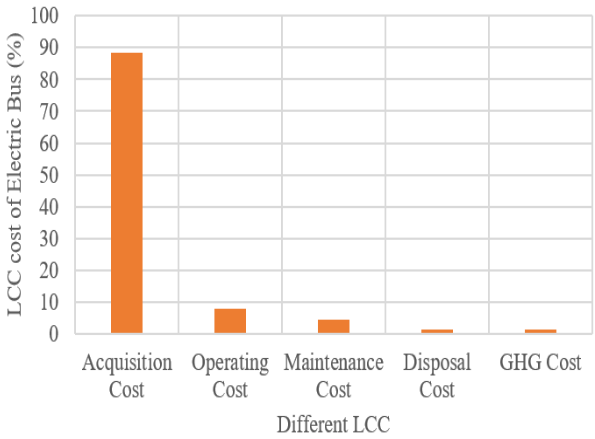

Figure 4: Cost contribution by the percentage of Electric Bus

3.2 Cost Comparison of Electric and Diesel Bus

Figure 5 compares the costs associated with purchase, operation, maintenance, disposal, and greenhouse gas emissions. Electric buses cost 4.42 times more to purchase than diesel buses, while diesel buses cost 4.38 times more to operate since diesel buses require more maintenance owing to different spare parts while electric buses don't. Similarly, the cost of diesel bus maintenance is 7.23 times greater than that of an electric bus. Because the oil price rate was discovered to have increased when analysis was taken into account since 1991, as shown in Figure 3, the operating cost is estimated on the basis of an increase in the oil price rate of 1.8%. It was also discovered that the price of electricity has decreased by 0.2005%.

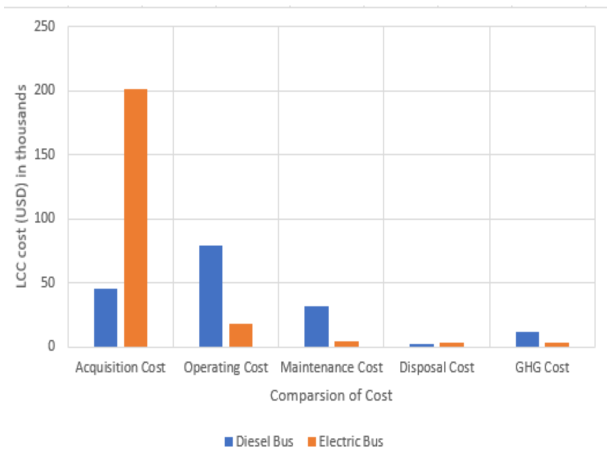

Figure 5: Comparison of Diesel and Electric Bus

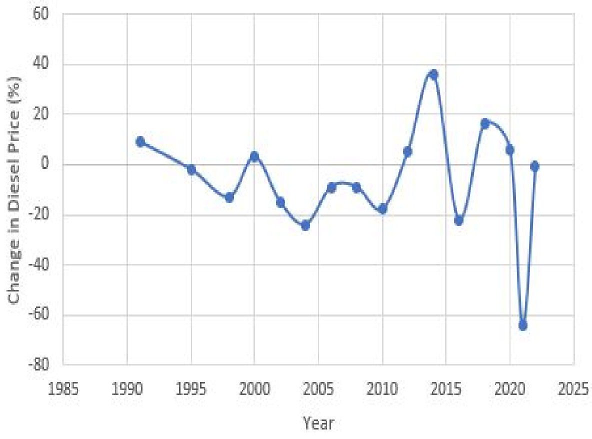

Figure 6: Price fluctuation with year and its tends

3.3 Sensitivity Analysis

The effects of several variables, including the price of the battery, purchase, electricity, and gasoline prices, were examined using a sensitivity analysis. For the analysis, the actual annual mileage was set as 40176 km. In order to become more competitive in a market that was previously dominated by internal combustion engines, electric cars must see an acquisition cost percentage decrease of roughly 40This is due to the fact that there is a great deal of research being done to lower the cost of batteries, which will eventually lower the cost of acquisition and LCC because the acquisition cost is a big factor in LCC for both buses. Figure

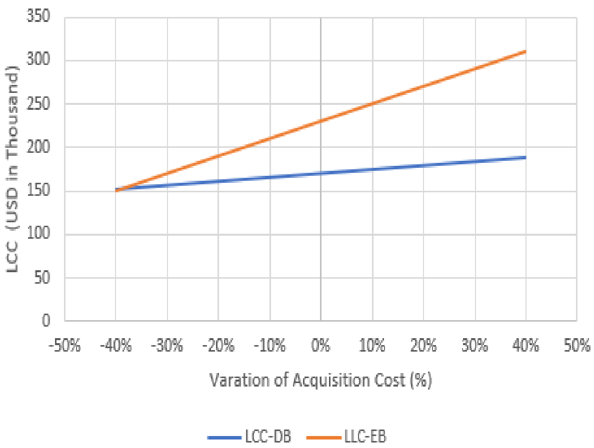

Figure 7: Variation of LCC of electric and diesel bus with variation of Acquisition Cost

7 shows the Variation Of LCC of electric and diesel buses. Here it is seen that upon a 40 %reduction in Acquisition cost, the LCC of both diesel and electric buses becomes the same. Figure 8 depicts the variation in LCC with varying distances traveled by 200 km to 1600 km in a year with a travel of 200 km. The LCC cost of an electric bus gradually decreases whereas the cost of a diesel bus gradually rises with increasing distance, assuming that distance varies over the course of a year. Diesel costs Rs. 176 NPR per liter, and electricity costs Rs. 9.48 NPR per kWhr. These prices are thought of as constant year-round.

Figure 9 displays the change in LCC and operating costs for electric buses in Nepal as a function of the price of electricity. We analyze electricity prices in descending order because the

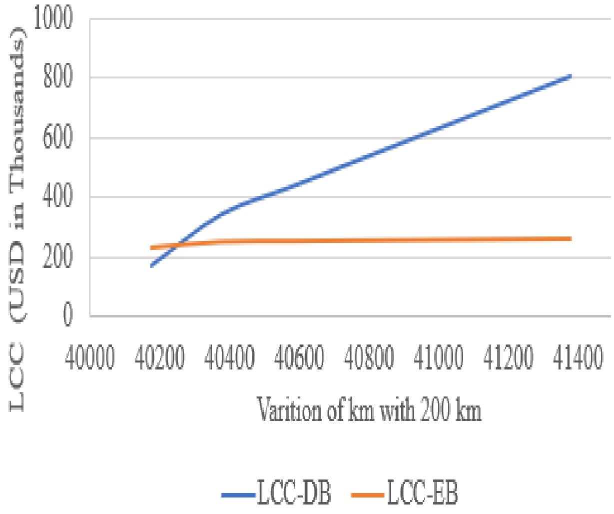

Figure 8: Variation of LCC of electric and diesel bus with the variation of operating cost with the variation of km

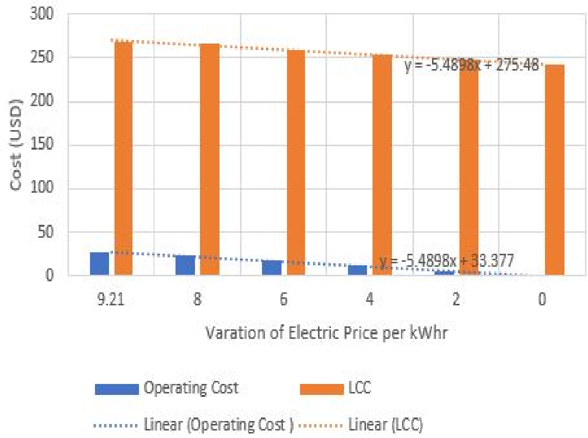

Figure 9: Variation of LCC and Operating cost of the electric bus with price variation of electric price

cost of electricity in Nepal has decreased and there is very little chance that it would rise. The finding demonstrates that lowering the price of electricity lowers operating costs, which in turn lowers the LCC of electric buses. It is preferable to replace the lower-efficiency electric bus with the higher one if the electric vehicle's efficiency is higher.

3.4 Environmental Impact Analysis

The CO_2eq emissions over an 8-year period are displayed in Figure 10 and Table 3. It is clear that the production of electric buses has a greater negative impact on the environment than diesel buses. Also, compared to diesel buses, electric buses emit less CO_2eq while operating. In our work, we take into account the approximately 4 mg of CO_2eq per 1 kW of electricity produced by hydropower plants. Figure 10 depicted the CO_2eq emissions from diesel and electric buses during the production and operation phases. While diesel buses emit less CO_2eq during vehicle production than electric buses while operation, the latter emit more CO_2eq during vehicle assembly. Figure 11 depicts the CO_2eq emissions from the production and operation of a diesel bus. Due to the fact that diesel buses use fossil fuel (diesel) as an energy source and produce CO_2eq as an output,

Table 3: Show the CO_2eq emissions over an 8-year period

CO_2eq emission (kg)	Diesel Bus	Electric bus
Vehicle Production Phase	34773.86	45542.59
Vehicle Operation Phase	163041.57	1004.09
Total Emission (Kg)	**197815.46**	**46546.68**
Total Emission (Tons)	**197.82**	**46.55**

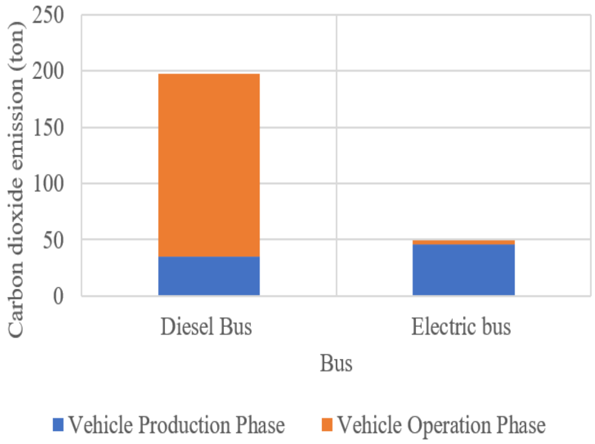

Figure 10: CO_2eq Production

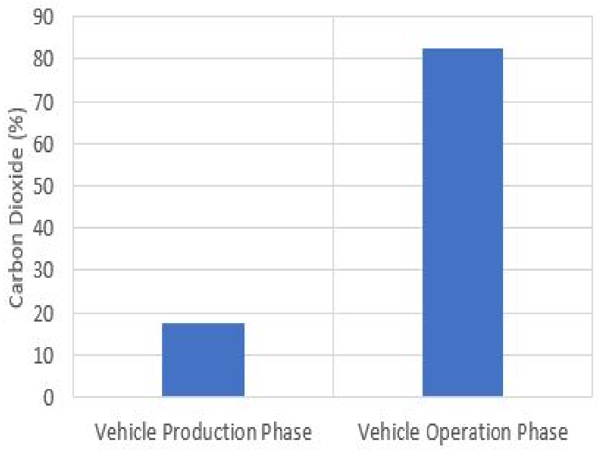

Figure 11: CO_2eq Production Diesel Bus

the CO_2eq emission during operation is higher. Joshi et al. estimate that diesel automobiles release 507 g/km of CO_2eq. In our example, a diesel bus burns 30.44 liters of fuel daily, emits 84.92 kg of carbon dioxide daily, and generates 28 kg of carbon dioxide per trip. In accordance with the data [25], a journey of 55.8 km results in a CO_2eq emission per km of 507 g. In addition, Mao et al. found that the CO_2eq emissions from diesel buses range from 1.009 to 1.341 kg/km, with the running phase accounting for 73.1% of those emissions, or around 790 g/km [26]. Because a diesel engine's efficiency decreases over time as it works harder, CO_2eq emissions from a diesel bus increase as each day goes by. During the production phase, CO_2eq is continuous and unaffected by time. Moreover, this work's limitations/neglect of the CO_2eq emission at disposal instance. Figure 12 depicts the CO_2eq emissions from the manufacturing and operation of an electric bus. While electric buses use electric energy (as fuel) as their primary energy source and do not produce CO_2eq when they are operating, the CO_2eq emissions during the manufacturing phase are higher. Nonetheless, the energy used by electric buses was produced as 4gm of CO_2eq per 1kWhr. A single electric bus uses 130.6 kWhr of electricity each day, resulting in 0.52 kg of CO_2eq emissions daily, and 0.17 kilogram of CO_2eq emissions per trip. While hydropower is becoming more efficient thanks to new and improved technology, CO_2eq emissions are decreasing as each day goes by when an electric bus is in operation. The amount of CO_2eq produced is constant and unaffected by time. Moreover, this work's limitations/neglect of the CO_2eq emission at disposal instance.

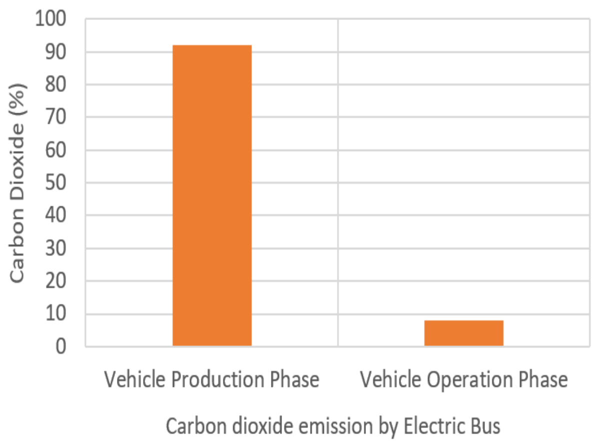

Figure 12: CO_2eq production for Electric Bus

3.5 CO_2eq comparison of Electric and Diesel Bus

Figure 13 compares the CO_2eq emissions from diesel and electric buses and reveals that, throughout the production process, the CO_2eq emissions from electric vehicles are 1.31 times greater than those from diesel. Diesel buses emit 4 times more CO_2eq while operating than electric buses. On the other hand, it may be said that during operation, diesel buses produce 97.59% of CO_2eq, whereas electric buses only produce 2.41%. Throughout the production process, both diesel and electric buses emit CO_2eq at rates of 42.79 and 57.21 percent, respectively.

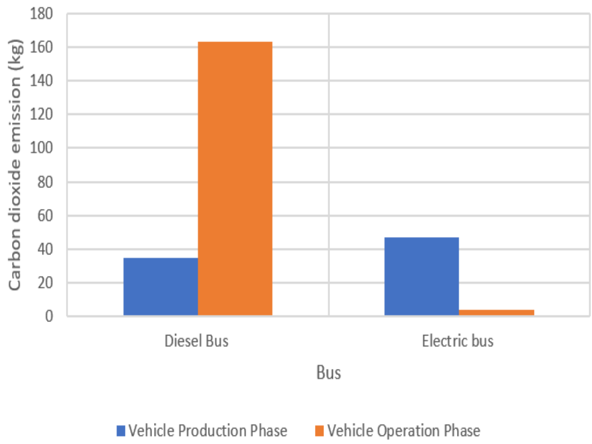

Figure 13: CO_2eq production at different phase

The study is focused on a specific area of research, which is limited to six-wheeler electrical and gasoline buses. The study site for this research covers the Butwal-Belahiya route only. To perform a comprehensive financial analysis, certain assumptions were made during the calculations. For instance, the lifespan of the vehicles was taken as 8 years. These assumptions were taken into consideration to ensure that the financial analysis is as accurate and reliable as possible. By focusing on a specific type of vehicle and a specific study site, this research can provide valuable insights into the financial feasibility of six-wheeler electrical and gasoline buses on the Butwal-Belahiya route. In addition, only CO_2eq gas emission (Manufacturing phase and Operating phase) is considered in our study.

4. Conclusion and Recommendations

This research analyses the technological, economical, and environmental aspects of diesel and electric buses on the 27.9-kilometer Butwal-Belahiya route. LCC values were shown to be greater for electric buses over their 8-year lifespan than for diesel buses. For the diesel and electric buses, respectively, the LCC values were USD 165,825.28 and USD 222,738.46. Diesel buses have a lower LCC cost throughout their eight-year lifespan than electric buses. According to the CO_2eq pollutant emissions over an 8-year period, diesel buses produced 197.82 tons of CO_2eq while electric buses produced 46.56 tons. This implies that diesel buses produced 151.27 tons more CO_2eq than electric buses. According to the sensitivity study, LCC was impacted by a number of parameters, including the cost of purchase, the cost of energy and fuel, and the cost of the battery. The study of Sensitivity analysis shows that LCC is affected by different factors like battery price, purchase price, electricity price, gasoline prices, etc. Therefore variation of these factors causes change is the LCC of electric and diesel buses. In addition, the acquisition cost an electric bus depends upon the battery, therefore variations of battery price vary the acquisition cost of an electric bus and hence LCC of an electric bus varies with the battery price. The study may be broadened further by selecting other route for feasibility study and perform a comprehensive financial analysis. The lifespan of the vehicles can be taken more than 8 years. This study is only conducted on Public Buses so it can be further broadened to other category of vehicles. In addition, only CO2 gases emission (Manufacturing phase and Operating phase) is considered in our study, so other GHG emission gases can be considered on further study.

Governments must develop regional and local strategies that successfully incorporate electronic transportation into urban planning in order to promote the usage of public transit. The unpredictability and lost time during travel are two major barriers to using public transportation. Thus, the government should establish distinct routes for commercial and public transit in order to remedy this so that travelers can save significant time. The establishment of charging stations at the start and finish of routes by the government will enable the electric bus to receive power continually without compromising mobility. In order to avoid traffic problems as well as provide prompt response, government should allocate a dedicated route for electric mobility. In order to encourage the adoption of electric vehicles, it is important to establish policies and regulations that support the development of a reliable and accessible charging network. This includes not only publicly accessible charging stations, but also the integration of charging infrastructure in private residences, workplaces, and other locations where electric vehicles may be parked for an extended period of time. Governments may contribute to lowering the environmental effect of transportation and promoting sustainable mobility through making it easier and practicable for people and businesses to purchase and operate electric vehicles.

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