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# Life Cycle Cost Analysis of Electric-Powered Buses in Public Transportation in Egypt

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## Abstract

The transportation sector is a significant contributor to greenhouse gas emissions and air pollution. In an effort to reduce the carbon footprint of public transportation, electric-powered buses have emerged as a potential solution. Conducting a Life Cycle Cost Analysis (LCCA) of electric-powered buses in public transportation in Egypt can provide valuable insights into their economic viability and environmental benefits. Life Cycle Cost Analysis (LCCA) is a method used to evaluate the total cost of ownership of a product or service over its entire life cycle. In the context of electric-powered buses in public transportation in Egypt, LCCA can be used to compare the total cost of ownership of electric-powered buses to diesel-powered buses. The aim of this research is to estimate the life cycle cost of electric-powered buses in public transportation in Egypt. Additionally, research has been conducted to calculate the financial and economic benefits of implementing electric buses in urban areas. This research analyzed the feasibility of electric mobility for bus transport in Egypt, with a specific focus on the life cycle cost assessment of electric-powered buses. By comparing the total cost of ownership (TCO) of electric buses to diesel buses over a life cycle of 25 years. The findings of this research contributed to the understanding of the economic and environmental benefits of electric-powered buses in public transportation in Egypt. Decision-makers in the transportation sector can utilize this information to make informed decisions regarding the procurement and operation of buses, with the goal of reducing carbon emissions and improving air quality.

**Key Words**: Life Cycle Cost Analysis, public transportation Cost, electrical-powered buses, and Urban area.

## Introduction

Public transportation is a critical part of the transportation system in many cities around the world. It provides a reliable and affordable way to get around, and it can help to reduce traffic congestion and air pollution. Electric buses are becoming increasingly popular as a way to reduce the environmental impact of public transportation. Electric buses produce zero tailpipe emissions, which can help to improve air quality in urban areas. Additionally, electric buses are quieter than diesel buses, which can make public transportation more pleasant for riders and residents.

One of the key considerations for public transportation agencies when deciding whether to switch to electric buses is the life cycle cost (LCC) of electric buses compared to diesel buses. The LCC includes all of the costs associated with owning and operating a bus over its lifetime, including the purchase price, operating costs, maintenance costs, and disposal costs. However, one of the key considerations for public transportation agencies when deciding whether to switch to electric buses is the cost. Electric buses are typically more expensive to purchase than diesel buses. This is due to the higher cost of the batteries and other electric components.

A number of studies have been conducted on the LCC of electric buses in public transportations. These studies have generally found that electric buses have a lower LCC than diesel buses by 5-10% over a 25-year lifetime [1] and by

10-20% over a 12-year lifetime [2], [3], and [4]. Also, Kleine and Keoleian found that the LCC of an electric bus in the United States is 15-25% lower than that of a diesel bus over a 12-year lifetime[1]. In addition, Ayodele and Mustapa, found that the LCC of an electric bus is 10-20% lower than that of a diesel bus over a 12-year lifetime[2]. Another study found that the lower operating and maintenance costs of electric buses offset the higher upfront cost [3] and the total cost is 15-25% lower than that of a diesel bus over a 15-year lifetime. Also, a number of studies found that electric buses have a lower LCC than diesel buses when the external costs of air pollution and climate change are considered. For example, Xu et al found that the LCC of an electric bus in the United States is 20-30% lower than that of a diesel bus when the external costs of air pollution and climate change are considered [4]. Overall, the LCC studies of electric buses in public transportation have consistently found that electric buses have a lower LCC than diesel buses, especially over the long term. This is due to the lower operating and maintenance costs of electric buses, as well as the lower external costs of air pollution and climate change. However, it is important to note that LCC analysis has some limitations that it does not consider all of the potential costs and benefits of electric buses. In Egypt, the electric-powered buses' social costs and benefits represented by a reduction in vehicle operating cost, travel time, and air pollution has been estimated and compared to diesel bus[5],the result tell fleet operators and manufacturers about the financial ramifications of switching a bus fleet to electric power .

Despite the relevance of this issue, only a little amount of research has been published on it in developing nations. The technology assessment of battery-electric public bus systems is presented in this paper, which is based on technical and economic key performance factors. As the cost of electric buses continues to decline and the availability of charging infrastructure increases, electric buses are expected to become even more cost-competitive with diesel buses. As a result, it can be expected to see a growing number of public transportation agencies switching to electric buses in the coming years.

**Methodology**

The methodology of life cycle cost analysis (LCC) of electric-powered buses in public transportation research typically follows these steps:

- Define the scope of the study: This includes identifying the specific types of buses (electric and diesel) and the specific operating conditions that will be considered.
- Identify and quantify the relevant costs: This includes the costs of procurement, operation, maintenance, and disposal.
- Assign a time horizon to the study: This is typically the expected lifetime of the buses.
- Discount the costs to present value: This is necessary to account for the time value of money.
- Calculate the total LCC for each type of buses: This is done by summing the discounted costs for each category of cost.
- Find the feasibility study using B/C ratio method.

**Data Collection and Analysis**

In July 2019, Egyptian state officials debuted the country's first electric bus in Alexandria, marking a watershed moment in the country's transportation sector. After that, Cairo's first electric bus service was launched, running between downtown and New Cairo. Mwasalat Misr, an Egyptian transportation company, announced the introduction of Cairo's first electric public bus on a new route connecting downtown's prominent Abdel-Moneim Riyad Square and New Cairo in February 2020.Accordingly, this route- which is shown in figure 1 - was chosen to be subject to a comparison study between diesel-powered and electric-powered buses. As Mwasalat Misr company also has diesel buses run on the same route from downtown to New Cairo.

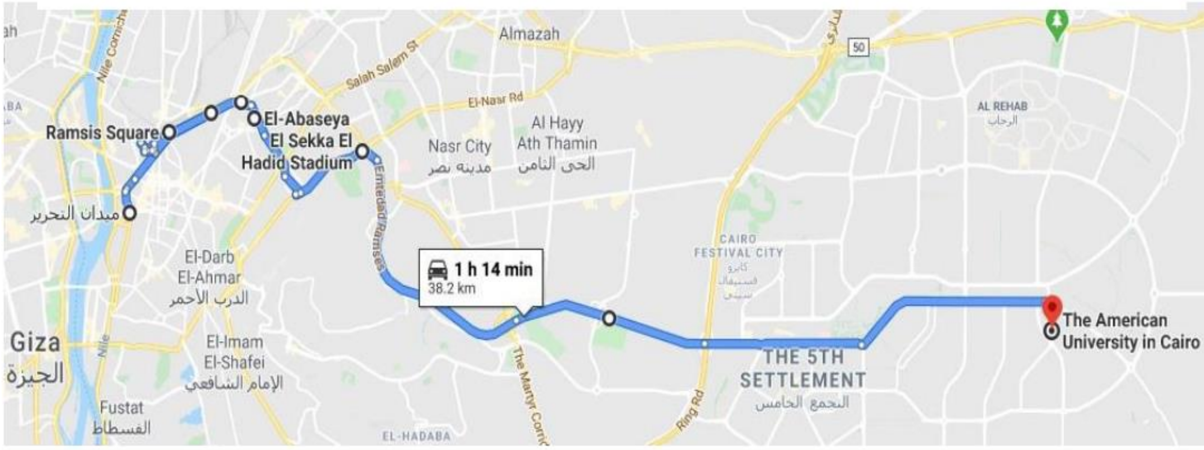


**Figure 1**: Mwasalat Misr bus route for Diesel and electric bus between Abdel-Moneim Riyad Square and New Cairo

To evaluate the cost-effectiveness of buses, information on vehicle purchase costs, fuel costs, vehicle fuel efficiency data (fuel consumption per 100 km trip of one vehicle) with the average bus daily driving distance is 290 km, and maintenance costs need to be collected. With the endorsement and support of Mwasalat Misr Company, the research teams contacted related stakeholders and make some interviews with buses drivers, and used route travelers to receive all the valuable data.

Compare the LCC of the two types of buses: This is done to determine which type of bus has the lower LCC. The following factors are typically considered when conducting an LCC analysis of electric buses:

- Purchase price: Electric buses are typically more expensive to purchase than diesel buses. However, the cost of electric buses is declining rapidly.
- Operating costs: Electric buses have lower operating costs than diesel buses due to the lower cost of electricity.
- Maintenance costs: Electric buses have lower maintenance costs than diesel buses due to the fewer moving parts.
- Disposal costs: The disposal costs of electric buses are typically lower than the disposal costs of diesel buses due to the lack of hazardous materials.

It is important to note that the LCC of electric buses can vary significantly depending on a number of factors, such as the cost of electricity, the climate, and the specific operating conditions. Table1 shows the data of vehicle purchase cost. Fuel prices and annual maintenance costs are represented in Table 2 and Table 3 respectively.

**Table 1**: Basic information about unit cost and fuel efficiency

| Buse model | Life service year | Cost per unit (EGP) | Energy consumption per 100 km |
|---|---|---|---|
| Diesel bus | 25 | 2,300,000 | 40 liters |
| Electrical bus | 25 | 4,150,000 | 112 KW |

**Source:** Mowasalat Misr Company

The cost of replacing the rechargeable battery (500,000 L.E for one battery and increasing by 20% each a life span (usually 5 to 6 years) is added to the cash flow of operation cost of the electrical power bus. Although the cost of buying a single bus reaches 4 million pounds, which is almost double the cost of buying a diesel bus, it saves 60% compared to the consumption of diesel buses, given the prices of diesel and electricity shown in the Table2.

**Table 2**: Fuel prices in Egypt 2022

| Fuel price | Diesel Liter | Electricity KW Hour |
|---|---|---|
| EGP Pound | 6.750 | 1.65 |

**Source:** Ministry of Electricity and Renewable Energy and Ministry of Petroleum (Egypt)

In addition to the fact of the electric bus does not consume engine oils, air filters, or gasoline filters. It has an electric motor that is maintained at long intervals. The approximate value of the monthly maintenance cost for one bus that runs on diesel fuel and the other on electricity is shown in table 3 for two buses model exposed to the same operating conditions, on the same route.

**Table 3**: Vehicle maintenance per month

| Buses model | Average Maintenance cost |
|---|---|
| Diesel bus | 5500 L. E |
| Electrical bus | 3850 L. E |

Source: interview and market survey performed by authors

With a fuel consumption cost of 13500 L.E per month, one diesel bus has the highest fuel consumption cost, and its maintenance costs are increased due provide spare parts for the engine and the expenses of periodic maintenance and oil expenses. [6], this value has been taken as the growth rate of Annual Maintenance Cost. Finally, the following table 4 present life cycle cost analysis (LCC) of the application of electrical-powered buses in public transportation in Egypt using net present value.

While the average growth rate of Annual electricity cost and Annual Fuel cost estimated by following price variation over the last five years from 2016 to 2021 it's about 22% and 33% respectively, the annual average growth rate is the average of year-over-year percentage changes reported during a year. The annual Growth Rate in Egypt averaged 4.14% from 1992 until 2022

**Table 4**: life cycle cost analysis (LCC)

| N | Diesel bus Purchase price | Electrical bus Purchase price | Diesel bus Operating costs | Diesel bus Maintenance Cost | Electrical bus Operating costs | Electrical bus Maintenance Cost | Difference between diesel and electrical bus in operation and maintained cost | NPV |
|---|---|---|---|---|---|---|---|---|
| 0 | 2,300,000 | 4,150,000 | 0 | 0 | 0 | 0 | 0 | -1,850,000 |
| 1 | | | 285,795 | 66,000 | 195,640 | 46,200 | 109,955 | 99,959 |
| 2 | | | 380,107 | 68,732 | 238,681 | 48,113 | 162,046 | 133,923 |
| 3 | | | 505,543 | 71,578 | 291,191 | 50,105 | 235,826 | 177,179 |
| 4 | | | 672,372 | 74,541 | 355,253 | 52,179 | 339,482 | 231,871 |
| 5 | | | 894,255 | 77,627 | 933,408 | 54,339 | -15,865 | -9,851 |
| 6 | | | 1,189,359 | 80,841 | 1,138,758 | 56,589 | 74,853 | 42,253 |
| 7 | | | 1,581,847 | 84,188 | 1,389,285 | 58,931 | 217,819 | 111,775 |
| 8 | | | 2,103,856 | 87,673 | 1,694,927 | 61,371 | 435,231 | 203,039 |
| 9 | | | 2,798,129 | 91,303 | 2,067,811 | 63,912 | 757,709 | 321,343 |
| 10 | | | 3,721,512 | 95,083 | 3,122,730 | 66,558 | 627,307 | 241,854 |
| 11 | | | 4,949,611 | 99,019 | 3,809,730 | 69,313 | 1,169,586 | 409,933 |
| 12 | | | 6,582,982 | 103,119 | 4,647,871 | 72,183 | 1,966,047 | 626,443 |
| 13 | | | 8,755,366 | 107,388 | 5,670,402 | 75,171 | 3,117,180 | 902,936 |
| 14 | | | 11,644,637 | 111,834 | 6,917,891 | 78,284 | 4,760,296 | 1,253,535 |
| 15 | | | 15,487,367 | 116,464 | 9,159,827 | 81,524 | 6,362,480 | 1,523,127 |
| 16 | | | 20,598,199 | 121,285 | 11,174,989 | 84,900 | 9,459,596 | 2,058,684 |
| 17 | | | 27,395,604 | 126,306 | 13,633,486 | 88,414 | 13,800,010 | 2,730,258 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 18 | | | 36,436,153 | 131,535 | 16,632,853 | 92,075 | 19,842,761 | 3,568,895 |
| 19 | | | 48,460,084 | 136,981 | 20,292,081 | 95,887 | 28,209,098 | 4,612,413 |
| 20 | | | 64,451,912 | 142,652 | 33,396,338 | 99,856 | 31,098,369 | 4,622,574 |
| 21 | | | 85,721,043 | 148,558 | 40,743,533 | 103,990 | 45,022,077 | 6,083,859 |
| 22 | | | 114,008,987 | 154,708 | 49,707,110 | 108,296 | 64,348,289 | 7,904,928 |
| 23 | | | 151,631,953 | 161,113 | 60,642,674 | 112,779 | 91,037,612 | 10,166,913 |
| 24 | | | 201,670,497 | 167,783 | 73,984,063 | 117,448 | 127,736,769 | 12,968,552 |
| 25 | | | 268,221,761 | 174,729 | 90,260,556 | 122,310 | 178,013,624 | 16,429,945 |
| **$NPV_{Elec.-\ Diesel}$** | | | | | | | | **75,566,339** |

* Growth rate of Annual Fuel cost taken by 33%
**Growth rate of Annual Maintenance Cost taken by 4.14 %
* Growth rate of Annual electricity cost taken by 22%
**Growth rate of Annual Maintenance Cost taken by 4.14 %
*** Increasing of replacing the rechargeable battery by 20% each a life span (5 years) starts from year 5.
*** using discount rate 10%.

The benefit of an electrically powered bus is estimated as the difference between, annual costs of operation and maintenance costs, the emission cost, noise cost, and saving travel time costs of electrical bus units was not considered in this research. Also, the disposal cost was neglected. However, the benefit from the operated electrical bus exceeds the cost all over the 25 years of bus life service, The net present value (NPV) estimated using the following formal:

$$NPV = \sum_{i=1}^{n} \frac{(B_i - C_i}{(1+r)^i}$$

Where:

Bi = net annual benefits
r = discount rate taken by 10%
Ci = net annual costs
While B/C ratio estimated using the following formal:

$$(\frac{B}{C})_{2-1} = \frac{\Delta B_{2-1}}{\Delta C_{2-1}}$$

Where:

Bt = benefits in t, and
Ct = costs in t,

From the table above, the benefit cost ratio of investment in electrically powered bus is (**$B/C_{Elec.-\ Diesel}$** 77,416,339/1,850,000 = **42** > 1) and the net present value (**$NPV_{Elec.-\ Diesel}$= +75,566,339** ) during 25 years. So, the electric buses are so much better than diesel buses in public transportation.

**Conclusions**

Life cycle cost analysis (LCC) studies have generally found that electric buses have a lower LCC than diesel buses, especially over the long term. This is due to the lower cost of electricity compared to diesel fuel, as well as the lower maintenance costs of electric buses. However, it is important to note that the LCC of electric buses can vary depending on a number of factors, such as the cost of electricity, the fuel economy of the bus, and the maintenance costs. Here are summary of conclusion Electric-Powered Buses in Public Transportation in Egypt:

- Electric buses have lower fuel costs than diesel buses.
- Electric buses have lower maintenance costs than diesel buses.

- Electric buses have lower disposal costs than diesel buses.
- The LCC of electric buses can be lower than the LCC of diesel buses even when the higher upfront cost of electric buses is factored in.
- The LCC of electric buses is even lower when the external costs of air pollution and climate change are considered.

Additionally, the cost of electric buses is still higher than that of diesel buses, so the LCC of electric buses may only be lower over the long term. Based on the findings of LCC studies, the following recommendations are made:

- Public transportation agencies should consider the LCC of electric buses when making decisions about their fleet replacement plans.
- Governments should provide financial incentives to encourage the purchase of electric buses, such as tax breaks and grants.
- Utilities should work with public transportation agencies to develop charging infrastructure for electric buses.
- Manufacturers should continue to reduce the cost of electric buses and improve their performance.

Overall, the LCC of electric buses is becoming increasingly competitive with that of diesel buses. So, the electric buses are so much better than diesel buses in public transportation.

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