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COMPARISON BETWEEN ELECTRICAL-POWERED AND DIESEL BUSES FOR PUBLIC TRANSPORTATION IN EGYPT

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Abstract:

Travel in Egypt is dominated by private cars, comprising 48.2 % of Egypt passenger trips, with limited use of all other modes. Reliance on personal automobiles has resulted in widespread growth, severe traffic congestion, and few public transportation options. Overcrowding means an increase in harmful emissions and reliance on diesel-powered buses for most public transportation adds to the emissions produced. As a result, emerging technologies to reduce emissions and costs, and to attract more travelers to improved transit services should be considered.

This research aims to estimate electric-powered buses' social costs and benefits represented by a reduction in vehicle operating cost, travel time, and air pollution with a concentration on the calculation to using formulas that suit the Egyptian conditions.

Benefits calculation models will be applied to a specific bus route, which has two working models of buses on it. One is diesel and the other is an electrically powered bus. The comparison between them was made using data collected from Mwasalat Misr- one of the companies working in the field of passenger transport in Egypt - and also by conducting interviews and asking questions to some decision-makers and users of both busses models.

Results indicate that one electric bus has a much higher equivalent annual value (EAV) than one fossil fuel- bus. Plus, the annual maintenance cost of one diesel bus is also higher than the electric bus. Consequently, although an electric bus can annually save 95000 L.E(6035 $) from fuel consumption, its annual vehicle cost (AVC) is 579225 L.E (36796$), which is higher than another diesel bus. In terms of air pollution evaluation, the value of the damage cost resulting from harmful gas emissions from one diesel bus is 173291 L.E (11,000 $) per year.The findings tell fleet operators and manufacturers about the financial ramifications of switching a bus fleet to electric power, as well as the cost factors that allow electric buses to outperform diesel buses and the societal benefits of converting to sustainable clean energy.

Key Words: Cost-benefits, Greenhouse gas, Air pollutants, public transportation Cost, electrical-powered buses, and Urban area.

مقارنة بين حافلات النقل العام التي تعمل بالطاقة الكهربائية والتى تعمل بالديزل في مصر

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الملخص

تهيمن السيارات الخاصة على رحلات الركاب في مصر ، حيث تشكل ٤٨,٢٪ من الرحلات . أدى الاعتماد على السيارات الخاصه والخيارات المحدودده لوسائل النقل العام إلى نمو واسع النطاق فى اعداد السيارات الخاصه وازدحام مروري حاد. يعني الاكتظاظ المرورى زيادة في الانبعاثات الضارة والاعتماد على الحافلات التي تعمل بالديزل لمعظم وسائل النقل العام يضيف إلى الانبعاثات الناتجة. ونتيجة لذلك ، ينبغي النظر في التقنيات الناشئة للحد من الانبعاثات والتكاليف ، وكذلك تحسين خدمات النقل لجذب المزيد من الركاب.

يهدف هذا البحث إلى تقدير التكاليف والفوائد الاجتماعية للحافلات التي تعمل بالطاقة الكهربائية والمتمثلة في خفض تكلفة تشغيل المركبات ووقت السفر وتلوث الهواء مع التركيز على استخدام الصيغ والمعادلات التي تناسب الظروف المصرية .فى هذا البحث سيتم تطبيق نماذج حساب الفوائد على مسار حافلات محدد ، والذي يحتوي على نموذجين عاملين من الحافلات عليه. أحدهما تعمل بالديزل والآخرى تعمل بالكهرباء. تمت المقارنة بينهما باستخدام البيانات التي تم جمعها من شركة مواصلات مصر - إحدى الشركات العاملة في مجال نقل الركاب في مصر - وأيضًا من خلال إجراء المقابلات وطرح الأسئلة على بعض صانعي القرار ومستخدمي نموذجي الحافلات .تشير النتائج إلى أن حافلة كهربائية واحدة لها قيمة سنوية مكافئة أعلى بكثير (EAV) من حافلة وقود أحفوري واحدة. بالإضافة إلى ذلك ، تكلفة الصيانة السنوية لحافلة ديزل واحدة أعلى أيضًا من الحافلة الكهربائية. وبالتالي ، على الرغم من أن الحافلة الكهربائية يمكن أن توفر ٩٥٠٠٠ جنيه مصري (٦٠٣٥ دولارًا أمريكيًا) سنويًا من استهلاك الوقود ، فإن التكلفة السنوية للمركبة (AVC) تبلغ ٥٧٩٢٢٥ جنيهًا مصريًا (٣٦٧٩٦ دولارًا) ، وهي أعلى من تكلفة حافلة أخرى تعمل بالديزل. من حيث تقييم تلوث الهواء ، تبلغ قيمة تكلفة الضرر الناتج عن انبعاثات الغازات الضارة من حافلة واحدة تعمل بالديزل ١٧٣٢٩١ جنيهاً مصرياً (١١٠٠٠ دولار أمريكي) في السنة ، وتُعد نتائج البحث مهمه لمشغلي الأسطول والشركات المصنعة ذلك لانها تعطى فكره عن التداعيات المالية لتحويل أسطول الحافلات الحالى الذى يعمل بالديزيل الى اسطول حافلات يعمل بالكهرباء ، فضلاً عن عوامل التكلفة التي تسمح للحافلات الكهربائية بالتفوق في أدائها على حافلات الديزل والفوائد المجتمعية للتحول إلى طاقة مستدامة نظيفه .

الكلمات المفتاحية: التكلفة - الفوائد ، غازات الاحتباس الحراري ، ملوثات الهواء ، تكلفة النقل العام ، الحافلات التي تعمل بالكهرباء ، والمناطق الحضرية.

1. INTRODUCTION

In Greater Cairo, the urban transportation problem is a major crisis. There are numerous transportation issues in cities. The most pressing issues are traffic congestion, poor public transportation, and pollution. These problems hurt one's quality of life as well as economic growth. Addressing transport sector fuel consumption and emissions is a priority among planners and policymakers in Egypt, especially given the fiscal burden of fuel subsidies: EGP 53 bn had been allocated to subsidize petroleum products in 2020, with most burden attributed to the largely imported diesel fuel. With 10.8 million licensed vehicles in Egypt, half of which are private cars

4.9 million, there is an urgency for planning alternative solutions to improve the framework of public mobility.

Adding electric vehicles (EVs) to the mix of options is seen as a promising contributor. Taxis, buses, microbuses, and company fleets, among others, should be prioritized when EVs are introduced to maximize relative Total Cost of Ownership (TCO).

Electric buses (EBs) are a potential replacement for traditional diesel vehicles. However, public transportation agencies must choose from a variety of electric bus technologies and system solutions to introduce electric buses. These options each have their own set of advantages and disadvantages in terms of technology, capital, and operational costs. When greenhouse gas emissions and the cost of urban air pollution are taken into account, e-buses have already reached parity in some areas.

Diesel buses are currently the most popular mode of public transportation. Due to finite fossil fuel supplies and rising global demand, the long-term supply of diesel and natural gas as fueling choices is uncertain. Furthermore, in most situations, concerns about climate change and local pollutants make diesel powerless appealing than alternatives. Furthermore, while waiting for boarding and alighting diesel buses, many passengers may detest the noise and local air pollution (as well as the engine and air conditioner heat emitted). For these reasons, transit agencies should look into non-petroleum power choices.

Electric buses (EBs) are another option that can be fossil-free if the electricity is generated from renewable sources (hydroelectric power, sun, and/or wind). (Tong, Jaramillo, Azevedo, & technology, 2015) demonstrate that BEBs lower emissions by 31% when compared to petroleum-fueled buses, even when powered by non-renewable natural gas electrical generation. Electric vehicles are now in use as personal autos and public transportation buses, and the technology (and associated costs) are improving all the time.

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. The structure of the paper is as follows: The first section includes a summary of related literature, while the next section gives an overview of the application methods and the methodology of this study. Both sections are followed by highlighting the specification of the model and the outcomes of estimating the entire data. The last section sheds light on the conclusions of this study along with giving some recommendations for further research.

2. LITERATURE REVIEW

Cities in emerging countries face difficulties such as noise and air pollution, traffic congestion, road accidents, and public transportation. These challenges, environmental degradation, climate change, and energy depletion, must be addressed.

To achieve a balanced and sustainable transportation system, five key goals must be met. 1)A dynamically integrated transportation and land-use system.2) A mode of transportation that encourages active, accessible, and healthy living choices. 3)A system of transportation for people, products, and services that is safe, equitable, and efficient. 4)Well-maintained transportation infrastructure. 5)A financially viable transportation system. Several critical components that can help attain these strategic goals are conceptualized in(Abdel Wahed Ahmed & Abd El Monem, 2020).

The sale of EBs has increased all across the world in the recent decade. A lot of studies have been conducted to help with the introduction of alternative electric power technologies in transit applications in several countries. (Quarles, Kockelman, & Mohamed, 2020) analyzed the financial implications of switching a bus fleet in Austin, Texas to electric power, as well as the cost criteria that allow electric buses to be more cost-effective than diesel buses.

To better understand BEVs and their transformative potential in the United States, (Arivazhagan, 2020) conducted a total lifetime economic cost and environmental effect analysis of lithium-ion battery electric cars (BEVs) vs internal combustion engine vehicles (ICEVs). According to their findings, BEVs have a lower Global Warming Potential (GWP) than equivalent ICEVs, but a higher Total Cost of Ownership (TCO) over a twenty-year vehicle lifetime.

On the other hand, Six different electric bus options were assessed based on seven different criteria by (Hamurcu & Eren, 2020), to Propose a multicriteria decision-making method in the context of an electric bus in Ankara, Turkey. using the analytic hierarchy process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS).

In Canada (Ferguson, Mohamed, & Maoh, 2019) investigate Canada's evolving transition to electrified transportation. A cross-country tour was organized to conduct semi-structured in-person interviews with prominent municipalities and transit companies.

(Teoh, Khoo, Goh, Chong, & Technology, 2018) examined the possibilities of operating an electric bus as a substitute for a traditional bus in Putrajaya, Malaysia. The proposed methodology is designed with the use of traffic modeling software. The findings demonstrated that the developed electric bus operating system beats traditional bus operations, not only in terms of providing a bigger profit margin for the bus operator but also in terms of better-satisfying passengers.

The Nanjing Bus China’s Company conducted a test based on actual road testing to aid in bus selection, which was described in (Gong et al., 2020). Road tests are straightforward and reliable and take into consideration current traffic conditions. The performance, cost, safety, environment, and other indicators of electric buses with the support of operation data and the goal of normal operation service are of great importance to be quantified, and the method proposed makes progress in electric bus selection, thereby proving the application value, in terms of both process and indicators.

Due to institutional, technical, and financial hurdles, e-bus adoption has not progressed as quickly as many had planned(Graham, 2020). The application of electric buses may face some challenges, necessitating efficient fleet management. (Houbbadi, Pelissier, Trigui, Redondo-Iglesias, & Bouton, 2019)employs an optimization algorithm to find optimal plans that minimize an objective function (charging cost, load power variations, battery aging, etc.) while taking into account several constraints, such as bus operating constraints and charging infrastructure constraints.

3. DATA COLLECTION

Egypt is one of Africa's and the Middle East's most populous countries. According to the most (Worldometers, 2019) estimates, Egypt's current population is 105,189,019 people, putting it at number 14 on the list of countries by population. Cairo is Egypt's capital, and the city of Greater Cairo is growing in size as new suburbs spring up. It has one of the greatest population densities in the world, because of rapid population growth and significant migration rates from rural to urban areas. Because of the high population, there is a lot of pollution and traffic congestion. The Egyptian government is aware of the situation, and as a response, it is expanding its road networks to alleviate traffic congestion and increase the investment in the transportation sector to reduce air pollution.

Electric mobility deployment, particularly in public transportation, is regarded to be a panacea for Egypt's pollution problem because it is a great way to reduce CO_2 emissions in the future.

As a result, Egypt's government and China's BYD Company signed a contract for 15 pure K9 electric buses, marking Egypt's first electric bus order. By the end of 2018, 15 electric buses were in preliminary pilot operations, with more vehicles to follow once the market test is completed. Egypt and China's Foton Motor Company struck an agreement in April 2019 to produce 2,000 buses in an Egyptian factory over four years, with a local manufacturing rate of up to 45 percent.

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.

The air-conditioned X-bus began with an express service that stops only at six major bus terminals along its route. The buses are equipped with Wi-Fi and are designed to "preserve the environment and do not produce pollution due to the usage of traditional fuels." They also have an electronic payment system in place that allows passengers to purchase a ticket from a machine on the bus.

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.

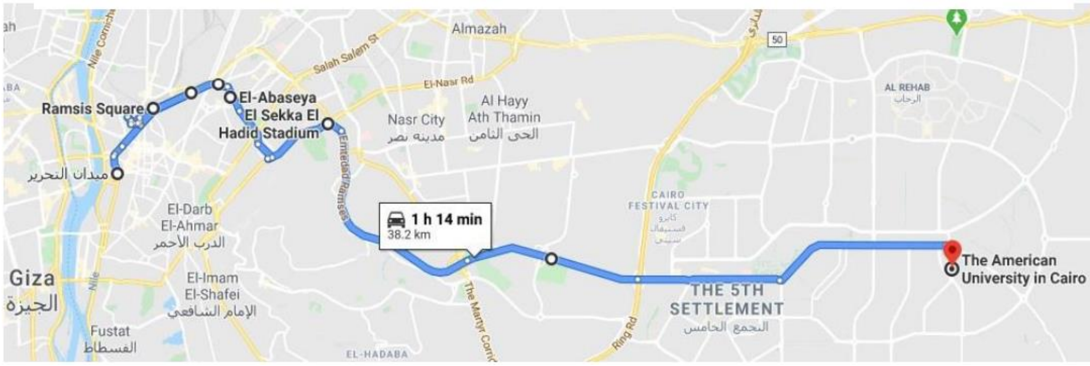

figure 1: Mwasalat Misr bus route for Diesel and electric bus between Abdel-Moneim Riyad Square and New Cairo

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), 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. Table 1 presents a complete list of key parameters that can be used to choose an electric bus model over a diesel bus type.

Table 1: A review of the components of the electric bus vs the diesel bus

Segment	Diesel Bus	Electrical-powered Bus
Model	Mercedes-Benz O500M - MCV C120RF	WANXIANG SXC6129GBEV
Seats	49	40
Length(m)	12	12
Width(m)	2.50	2.55
Height(m)	3.11	3.20
Gross weight (Kg)	16200	18000
Purchase Costs	2300000 L.E 140000 $	4150000 L.E 220000 $
Fuel Efficiency	0.40 L/Km	1.12 KW/Km
Range (Km)	450	250 with A/C 300 without A/C
Fuel Tank size	250 liter	-
Charging time	-	3/6 hour
Max power	290 BHP	230 kW
Rated Torque (Nm)	950	1400/3000
Battery Type	-	CATL 6LH3L8 Iron Phosphate Li-ion
Emission standard	Euro III	0 tailpipe emission

Source: Mwasalat Misr Company

4. METHODOLOGY

This section describes the modeling framework developed to computation the value of the reduction in vehicle operating cost, travel time, air pollution, and noise due to applying electric-powered buses.

4.1. Cost Estimation

Promoting ecologically friendly automobiles as public transit vehicles may have good technical or environmental grounds. However, if the costs are regarded too high or the financial advantages are deemed insufficient, such an attempt may be avoided.

As a result, a financial study, such as cost estimation, is required. An analysis like this can show how an adequate technique can provide economic incentives to people who use it. As a result, the unit cost of each vehicle is assessed in this study, including the cost of purchasing, gasoline, and maintenance, so that decision-makers may determine how many new vehicles are required based on their mitigation targets and budget. Within the vehicle's service life, the purchase price was converted to equivalent annual value (EAV). By adding the corresponding annual value, fuel cost, and maintenance cost, the annual vehicle cost (AVC) can be calculated (Geng et al., 2013). The AVC and EAV formulae are listed below:

$$\mathrm{EAV} = \frac{\mathrm{C}_{Total} \times \mathrm{r}}{1-(1+r)^{-n}}$$

$$\mathrm{AVC} = \frac{\mathrm{C}_{Total} \times \mathrm{r}}{1-(1+r)^{-n}} + C_{AMC} + C_{Fuel}$$

Where total means total vehicle purchase cost, AMC denotes annual maintenance cost, fuel denotes yearly fuel cost, r denotes depreciation rate, which in this case was adjusted at 0.05 to National accounts based on variables average depreciation rate of the capital stock, and n denotes service life.

4.2. Emissions Estimation

Pollution comes from a variety of sources throughout Egypt, including point sources such as fossil fuels and diesel automobiles that run 24 hours a day, 7 days a week on the streets. The Egyptian government enacted various laws to safeguard the environment in Egypt to mitigate the detrimental effects of air pollution and other environmental issues. Sulfur dioxide (SO2) and suspended particulate matter are two of Egypt's most common air pollutants. Egypt has some of the world's highest average daily emissions of primary pollutants, such as hydrocarbons, nitrogen oxides, carbon monoxide, and others.

Egypt has comparable high levels of Total Suspended Particulate (TSP) emissions, with PM_{10} being one of the primary air pollutants. Its content in some sample sites can reach more than 400 g/m3 on a daily average, which is six times higher than Egypt's Air Quality Limit (70 g/m3). Without the use of sensors or tracking equipment, the impacts of these big particles can be detected and seen. Property is harmed, the sky darkens, surfaces are soiled, visibility is hampered, people's senses are irritated, and health is directly harmed.

There is little experience in measuring Egypt's sources of air pollution and developing effective solutions to keep pollution at levels that do not harm human health. The Regional Air Pollution

INformation and Simulation (RAINS) model developed at the International Institute for Applied Systems Analysis (IIASA)Laxenburg, Austria to estimate emissions of sulfur dioxide (SO2), nitrogen oxides (NOx), and particulate matter (PM) in Egypt was one of the most important studies applied in Egypt(Hassanien, 2003). Modules for emission generation (including information on present and prospective economic activity, energy consumption levels, fuel properties, and so on), emission control options and prices, atmospheric dispersion of pollutants, and environmental sensitivity are all included in RAINS (i.e., databases on critical loads and levels). Sulfur dioxide (SO2), nitrogen oxides (NOx), ammonia (NH3), volatile organic compounds (VOC), and fine particulate matter are all taken into account in the model. As a result, it tackles four environmental issues at once: human health, acidification, eutrophication, and tropospheric ozone. (Alcamo, Shaw, & Hordijk, 1991) provided a description of the overall strategy employed by the RAINS model.

The Emissions are estimated according to the following formula:

$$E_{i,y} = \sum_{j,k,m} E_{i,j,k,m,y} = \sum_{j,k,m} A_{i,j,k} ef_{i,j,k,y} (1 - eff_{m,y}) X_{i,j,k,m,y}$$

where:

i,j,k,m : Country, sector, fuel, abatement technology

Y : Pollutant (SO2 or NOx) or Size fraction of PM

$E_{i,y}$: Emissions of PM in country i for size fraction y

A : Activity in a given sector, e.g. coal consumption in power plants

Ef : Uncontrolled or “Raw gas” emission factor

$eff_{m,y}$: Reduction efficiency of the abatement option m for size class y

X: Actual implementation rate of the considered abatement, e.g., Electrostatic precipitators account for a small percentage of total coal utilized in power plants.

The abatement efficiency is zero ($eff_{m,y} = 0$) and the application rate is one (X = 1) if no emission controls are used. In that situation, calculating emissions is as simple as multiplying the activity rate by the "raw gas" emission factor.

4.3. Noise Estimation

In cities, traffic noise is a serious environmental issue. The engines of the vehicles produce the majority of the noise at low speeds. Low-frequency noise is produced by heavy vehicles that run on traditional fuels, making them a substantial source of noise pollution even within buildings.

Electric buses' motors emit significantly less noise, and it is not of the same low frequency as diesel or gas-powered vehicles.

Outdoor noise assessments reveal a considerable variation in noise levels between electric and diesel buses. This is true not only for the volume of noise but also for the frequency. Both parameters influence noise perception, but the frequency has a considerable impact on indoor noise levels. The comparison between the noise levels of a diesel bus and an electric bus at the same route is shown in table 3 and table 4. The measurements were made at a distance of 50 m on a certified test track, showing indoor and outdoor noise at a variance speed.

Table 3: Estimated outdoor noise levels on the same route by both electric bus and diesel bus

Speed(km/hr)	10	20	30	40	50
diesel bus outdoor noise (dBA)	65	69	72	75	76
electric bus outdoor noise (dBA)	54	60	64	69	74

Source: data collected by the manufacturing company of electrical bus using the sound level meter (decibel scale)

At regular operating speeds in an urban area, outdoor tests of noise levels from diesel and electric buses at constant speeds show a difference of 11-2 dBA.

The perceived difference is great due to the logarithmic scale. A difference in the noise level of 5-9 dBA might be described as "a discernible difference" or "a perceived doubling" of the noise level. As the bus's speed increases, the difference in noise levels between electric and diesel operation decreases. Because tire noise becomes dominating about 50 km/h.

Table 4: Estimated indoor noise levels on the same route by both electric bus and diesel bus

Speed(km/hr)	Low speed	High speed
diesel bus indoor noise (dBA)	63	70
electric bus indoor noise (dBA)	53	64

Source: data collected by the manufacturing company of electrical bus using the sound level meter (decibel scale)

Inside an electric bus, noise levels are also far lower than in a diesel bus. The noise level is cut in half at low speeds. As the speed of the bus increases, the difference between the two types of buses becomes less noticeable.

5. RESULTS

5.1. Cost Analysis

The technological and policy-based techniques used by electric buses have shown to be beneficial in decreasing emissions of greenhouse gas and air pollutants in the transportation sector. However, the cost is an important consideration in determining whether or not such a project should be performed in practice. Table 5 shows the data of vehicle purchase cost. Fuel prices and annual maintenance costs are represented in Table 6 and Table 7 respectively.

Table 5: Basic information about unit cost and fuel efficiency

Buse model	Life service year	Cost per unit (EGP)	Energy consumption per 100 km
Diesel bus	12	2300000	40 liters
Electrical bus	12	4150000	112 KW

Source: Mwasalat Misr Company

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 table٦.

Table 6: Fuel prices in Egypt 2021

Fuel price	Diesel liter	Electricity KW Hour
EGP Pound	6.750	1.65
US Dollar	0.430	0.10

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 7 for two buses model exposed to the same operating conditions, on the same route.

Table 7: Vehicle maintenance per month

Buses model	Average Maintenance cost
Diesel bus	5500 **L.E** 350 **$**
Electrical bus	3850 **L.E** 245 **$**

Source: interview and market survey performed by authors

With a fuel consumption cost of 13500 L.E per month equal to 857.63 $, 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. though, the ultimate AVC is lower than that of a single electric bus.

This is since the purchase price of the electrical bus is much higher than the purchase price of the diesel bus, As a result, the value of EAV is higher than that of the diesel bus. Therefore, the government is now working to manufacture these buses locally, which will reduce the cost of ownership. Table 8 below shows the estimated values of EAV and AVC for both types of buses.

Table 8: Equivalent annual value (EAV) and annual vehicle cost (AVC)

model	EAV		Annual fuel cost		Annual maintenance cost		AVC	
	L.E	**$**	**L.E**	**$**	**L.E**	**$**	**L.E**	**$**
Diesel bus	259498	16485	160000	10164	66000	4192	485498	30842
Electrical bus	468225	29745	65000	4129	46000	2922	579225	36796

Although an electric bus can annually save 95000 LE about 6035 US$ from fuel consumption, its AVC is 36796 US$, significantly higher than diesel bus types. One of the reasons is the cost of a rechargeable battery (50000US$ for one vehicle) with a life span (usually 4 to 5 years). The batteries used in pure electric buses attenuate normally with the increase of service time. The average attenuation of a new battery's capacity is 6.05 % in the first year, 9.77 % in the second year, and 14.87 % in the third year, according to the CHINA EV100 SUMMER FORUM 2016. The battery should no longer be utilized after the capacity attenuation reaches 20%. The cost of buying a new battery each period raises the cost of maintaining the electric bus.

5.2 Emissions Analysis

The Regional Air Pollution INformation and Simulation (RAINS) database has been separated into distinct fuel types, energy sources, and economic sectors for Egypt to reflect the unique emission rates of different fuels and different energy-consuming sectors. Table 9 shows the findings of research on emissions from Egyptian buses a GCBC (Greater Cairo Bus Company).

Table 9: The air pollutants emitted by diesel buses in Egypt.

Average bus daily driving distance	290 km
Fuel economy	
Conversion efficiency of fuel oil production from crude	90%
SO_2	1.2 g/km
NO_x	13 g/km
CO	18 g/km
HC	2.9 g/km
Particulates	0.8 g/km

Source: Study by the International Institute for Applied Systems Analysis (IIASA),Laxenburg, Austria(2003)

The valuation of noxious gas and particulate emissions is more difficult because the effects of noxious gas emissions are directly proportional to the number of receptors (exposed persons), the severity of their health conditions, and the extent to which their health impairments will result in increased medical costs. Measuring these consequences takes a significant amount of time and resources, which may explain why there are not many studies has been conducted in this field. The unit values of noxious gas and particulate emissions assessed in the World Bank research of 2002 and JICA PREPARATORY SURVEY ON GREATER CAIRO METRO LINE study of 2009 which is based on the trend of per capita health expenditures in Egypt. Estimates of the "damage costs" incurred in Egypt as a result of the release of specific pollutants are shown below in table 10. Per capita Health Expenditures were reported to have increased from LE 72.61 to LE 149.97 between 2002/03 and 2007/08, corresponding to a growth factor of 2.065. (Organization, 2018) decided that the per capita health expenditure in Egypt amounts to 125 $, which is equivalent to about 1964 L.E . In this case, the growth factor between the base year 2002 and 2018 is 27.2. And the value of pollutants (LE per ton) as of July 2018 will be clarified in Table 11.

Table 10: Egypt's "Damage Costs" of Air Pollution Estimates.

Pollutant	Value (LE per ton) As at July 2002	Value (LE per ton) As at July 2008
PM_{10}	16,000	**33,046**
NO_x	2,200	**4,544**
SO_2	6,800	**14,045**
CO	700	**1,446**
NMVOC's	1.80	**3.72**

Sources:1) The Energy-Environmental Review 2002, World Bank and EEAA; Consultant's estimations
2) jica preparatory survey on greater Cairo metro line no. 4

To estimate the value of emission of air pollutants emitted from one diesel bus, it's necessary to convert g/km pollutant bus emissions to ton/year.

Each g is one-millionth of a ton, knowing how many km driven in a year, then convert the associated g to a ton. As mentioned in Table 9 average bus daily driving distance is 290 km, which means 103240 Km driven per year. So, 103240 km driven in a year with 18 g CO/km would be 1858320 g, divided by 1000000 g/ton .it will be 1.85 ton of CO. value of CO (LE per ton) mentioned in table 11 above, by 19040 and upon it, one diesel bus Damage Costs from CO emission equal 2603 L.E. by the same sequence the value of other emissions from one diesel bus shown in table 11.

Table 11: Estimated Cost of emission from one diesel bus (L.E/year)

Pollutant	Damage cast (L.E) per ton of emission (2018)	Amount of emission from one diesel bus in ton /year	Cost of emission from one diesel bus (L.E/year)
PM10	435200	0.082	35686.4
NO_x	59840	1.34	80185.6
SO_2	184960	0.12	22195
CO	19040	1.82	35224
Total cost (L.E)			173291
Total cost ($)			11,000.93

In addition to the health and environmental benefits that accrue to society when switching to clean energy in transportation by converting diesel buses to electric ones. Electric buses are zero-emission buses, this saving value should be taken into account when evaluating the social and economic benefits of electric buses.

5.3 Noise Analysis

Because it interferes with essential activities like sleeping, resting, studying, and conversing, environmental noise can have a severe impact on people's health and quality of life. Noise has a significant societal cost. The social cost of traffic noise pollution is estimated to be around 1% of GDP in some European nations. Noise's potential impacts are determined not only by the noise's physical qualities (sound pressure level, time evolution, frequency spectrum, and so on) but also by subjective criteria unique to each individual." General traffic noise" was found as the source of noise that causes the most irritation among the other available sources.

Long-term noise exposure has health consequences, mostly stress-related health consequences such as hypertension and myocardial infarction, according to (Le Maître, 2015), the unit cost of noise may be established by knowing the noise level, and so the noise expenses can be calculated. The method entails using existing noise maps to calculate average costs that may be applied to other highways. The data in Table 12 were utilized for noise levels lower than the 70 dB level and several people were exposed to a 5 dB range of noise levels.

Table 12: values of noise in $€_{2010}$ per exposed person and per year

Noise level range	COST
55-60	75,4
60-65	136,2
65-70	248,8
70-75	427,6
75-80	715,2

Source: NOISE COSTS OF ROAD TRAFFIC study by Hélène Le Maître 2015

6. CONCLUSION AND RECOMMENDATIONS

Green and sustainable transportation has significant benefits, including environmental, health, and economic advantages. Some of the major advantages of employing electric buses in public transportation are stated below:

(1) Reduce reliance on nonrenewable energy sources

(2) Less to no greenhouse gas emissions

(3) Saves money: Supporting electric modes of transportation will reduce the consumption of fossil fuels, lowering the economy's emissions.

(4) Better health and quality of life: electric modes of transportation do not generate toxic gases that can hurt people's health and quality of life.

(5) Reduce traffic congestion: By encouraging electric buses in public transportation, with high standards of safety, efficiency, and operation. The number of private cars on the road will be reduced.

(6) Reduce noise emissions from diesel engines

To that purpose, the findings inform fleet owners and manufacturers about the financial implications of switching a bus fleet to electric power, as well as the cost parameters that allow electric buses to outperform diesel buses. In addition to assessing the societal benefits resulting from reducing air pollution and reducing noise.

In future work, it would be interesting to extend the methodology to an entire fleet of electrical and diesel buses, taking into account the cost of the infrastructure

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