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The Study of Electric Buses and Their Impact on Environment in Urban Networks

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ABSTRACT

Climate change, fossil fuel depletion, and environmental pollution have become one of the greatest challenges of the 21st century. Hence, the use of renewable energy sources is considered as one of the best environmentally friendly methods. In this regard, electric buses have received attention in cities. The present paper uses documentary and analytical methods to investigate the types of electric buses and their impacts on environment. The conducted studies indicate that electric transportation vehicles are highly environmentally friendly, of course having clean energy. Moreover, they provide a suitable alternative to diesel vehicles for reducing environmental pollutants. It is worth noting that the reduction in pollutants varies depending on the source of electricity generation, with solar energy reducing 80 to 90 percent, natural gas reducing 25 to 50 percent, and coal reducing 10 percent. Furthermore, the levels of noise pollution from electric and diesel buses in the urban environment at a constant speed range show a 5 to 9 decibel difference in a logarithmic scale. Despite the mentioned benefits, the lifetime cost (12 years) of an electric bus is approximately 5.12 percent less than that of a diesel bus.

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1. Introduction

The detrimental effects of air pollution are considered as a major problem. Air pollution resulting from pollutants and the combustion of old vehicles, buses, and motorcycles has become one of the prominent social issues in countries, particularly in metropolitan areas. The issue of environmental pollution has repeatedly brought cities to a standstill, leading many individuals to seek medical treatment for cardiovascular, respiratory, gastrointestinal diseases, cancers, and tumors, besides death for some others. Accordingly, transportation, through the production of nitrogen dioxide and particulate matter, contributes to air pollution and contributes to global warming through the release of carbon dioxide [1]. Improving public transportation systems can be an appropriate solution to reduce the impact of transportation on the environment and society. Since diesel buses are the largest source of air pollution and produce more pollutants such as nitrogen oxides, sulfur dioxide, and particulate matter compared to personal gasoline vehicles [2], governments are moving towards developing clean energy vehicle technologies and replacing diesel vehicles.

Reji Kumar Pillai (2015) investigated the relationship between electric vehicles and air pollution reduction in Delhi, concluding that the phased approach recommendations for implementing electric vehicles in Delhi could be applied in other cities in India and abroad [3]. Evaluations by Judah Aber (2016) on electric buses in New York City revealed that electric buses produce significantly fewer greenhouse gases than diesel buses and have a lifespan cost approximately 12.5 percent less than diesel buses [4]. Grutter (2013) compared diesel and hybrid buses and found that using hybrid buses could reduce greenhouse gas emissions by 30 percent compared to diesel buses [5]. Campbell Jerome (2015) compared electric and diesel buses in Los Angeles and found out that using battery electric buses resulted in an 83 percent reduction in carbon dioxide emissions per mile [6]. Moreover, Antti Lajunen conducted a comparison between six types of

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buses, including diesel, compressed natural gas, hybrid (series and parallel), fuel cell, and electric (overnight and flash). They measured the energy consumption reduction in these vehicles compared to diesel buses. Accordingly, battery electric buses (overnight and flash) showed the highest energy consumption reduction at 75 percent, followed by fuel cell buses at 48 percent [27]. In 2017, Greenlink Institute published a report on the benefits of electric buses. According to the report, electric buses have had a significant impact on maintaining community and regional health, reducing respiratory diseases and strokes for millions of households. Furthermore, in 2014 in Guangzhou, a comparison was made between the performances of various types of buses, including hybrid, diesel, and compressed natural gas buses, and the greenhouse gas emissions of each type of bus were measured per kilometer. The results indicated lower carbon dioxide emissions per kilometer for hybrid electric buses.

Moreover, based on research conducted in Finland by Antti Lajunen, a comparison was made between six types of buses: diesel, compressed natural gas, hybrid (series and parallel), fuel cell, and electric (overnight and flash). The results of this research revealed a significant reduction in energy consumption in these vehicles compared to diesel buses. Among all the aforementioned buses, battery electric buses (overnight and flash) showed the highest energy consumption reduction at 75 percent, followed by fuel cell buses at 48 percent. Series hybrid buses had a 32 percent reduction, and parallel hybrid buses had a 29 percent reduction in energy consumption compared to diesel buses.

2. Problem Definition and Research Objectives

The issue of reducing environmental pollution and fossil fuel consumption in light of the increasing emission of toxic and greenhouse gases and global warming is of paramount importance worldwide. Despite the costliness of replacing fossil fuels with renewable energy sources, advanced countries have moved in this direction, and the plans implemented in the energy sector in advanced countries promise to meet a significant portion of human energy needs through renewable energy sources in the future years. Hence, this paper is aimed at investigating the types of electric buses as alternatives to diesel vehicles and their positive effects on air and noise pollution in urban networks.

3. Electric Buses

The significant contribution of diesel vehicles to greenhouse gas emissions is undeniable, as diesel buses are considered the largest source of air pollution [7]. Several international cities have moved towards banning the use of diesel vehicles because even their new and efficient motors produce dangerous pollutants such as nitrogen oxides (NOX) and particulate matter larger than 10 microns [8]. The use of electric buses and optimizing the fuel consumption of vehicles has been highly effective in reducing the aforementioned problems. To this end, the most important step globally taken in this regard is the use of battery and electric motor technology in vehicles. These vehicles, in spite of numerous advantages, have weaknesses, for which efforts have been made over time to address these obstacles and deficiencies. One obstacle for electric buses is their higher purchase price compared to diesel vehicles, primarily due to their lithium-ion batteries. Another obstacle is the difficulty in accessing them, for which increasing the availability of electric charging stations is a suitable solution. While enhancing battery capacity and reducing their recharge time has been effective in overcoming this limitation, too. Today, there are two methods for charging such vehicles: standard charging and fast charging. Standard charging is the most common type of charging, taking about four to twelve hours for the battery to fully charge, while fast charging involves connecting a direct electrical current to the battery, and its full charging time is approximately 30 minutes to two hours [9]. Fig. 1 illustrates the sales volume of these vehicles from 2010 to 2016 and the increasing trend of countries towards sustainable transportation [10].

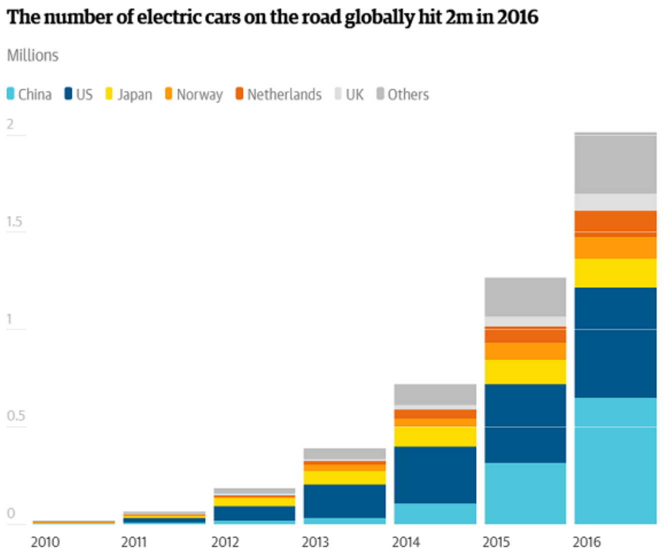

Fig 1. Electric Vehicle Sales from 2010 to 2016 [10].

3.1. Types of electric buses and their operation process

Electric buses operate in various ways depending on the type of propulsion system used in them, including hybrid electric bus (HEB) (series and parallel), fuel cell electric bus (FCEB), and battery electric bus (BEB) (overnight and flash) [12]. Table 1 schematically illustrates the operation mechanism and fuel type of these vehicles.

Table 1. Types of Electric Buses [8].

Hybrid Electric Buses		Diesel pump to the bus → Ice produces electric power → Battery stores electric power → the bus moves
Fuel Cell Electric Buses		Hydrogen pump to the bus → fuel cell to generate electricity → electric power storage battery → the bus moves
Battery Electric Buses		Charging the bus with electric power → energy storage battery → the bus moves

3.1.1. Electric hybrid buses

Hybrid vehicles, both series and parallel, are designed to emit less pollution than conventional diesel buses by reducing the power of internal combustion motors and using batteries to provide average power. They also allow for driving longer distances compared to battery electric buses without the need for frequent stops for battery charging [11]. In series hybrid buses, only electric motors are used as the driving force for the wheels, and these motors are powered by batteries connected to the grid during stops and by low-emission generators during driving. In series hybrids, the mechanical power generated in the internal combustion motor is converted into electrical power by a generator. After passing through an inverter to convert alternating current to direct current, it is transferred to the battery for storage and to the motor drive for propulsion. In parallel

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hybrids, the vehicle is driven by internal combustion motors, similar to conventional diesel or gasoline vehicles, but electric motors are used for extra acceleration when needed. The main difference between these technologies is the power source for the electric motor [13].

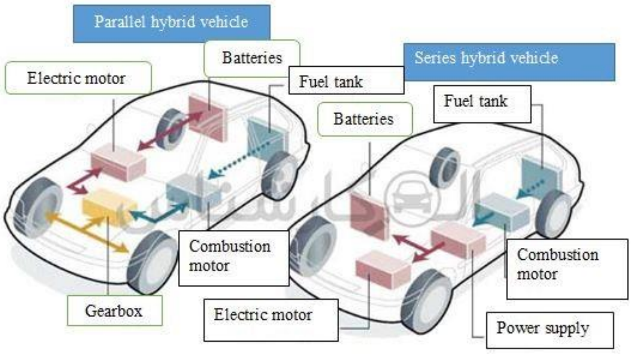

Fig 2. Comparison of Parallel and Series Hybrid Electric Bus Configurations [13].

3.1.2. Fuel cell electric buses (FCEB)

Fuel cells are new technology for energy production [16], producing electricity with high efficiency without causing environmental or noise pollution by directly combining fuel and oxidant [17]. The mechanism is based on the direct generation of electricity without the thermodynamic limitations of the Carnot cycle to convert the chemical energy of fuel into thermal and mechanical energy and ultimately electricity, minimizing energy loss and achieving high theoretical efficiency [14-15].

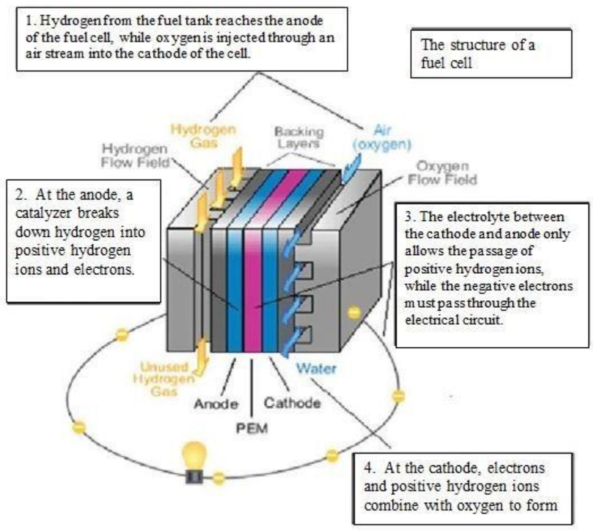

Fig 3. Configuration of Fuel Cell Electric Bus [13].

3.1.3. Battery electric buses (BEB)

BEBs are purely electric and store electricity in a battery installed in the bus. In this technology, there are no mechanical parts [17], and there are two types of batteries: overnight and flash. The difference between these two types lies in the charging time and the distance covered by the vehicle. Flash electric buses have a smaller battery capacity and can cover about 20 to 30 miles [18], and it takes 5 to 10 minutes to fully charge them (80-100%). In comparison, the overnight type has a larger battery capacity, allowing it to cover more than 200 miles, requiring a longer charging time (2-4 hours). These buses, like buses with overhead wire systems, do not require infrastructure for wiring and have controllable routes without infrastructure changes compared to buses with overhead wire systems.

Moreover, with an energy consumption of approximately 1.2 kWh/km, they have lower costs compared to diesel buses [19]. The operational mechanism of these vehicles is schematically illustrated in Fig. 4.

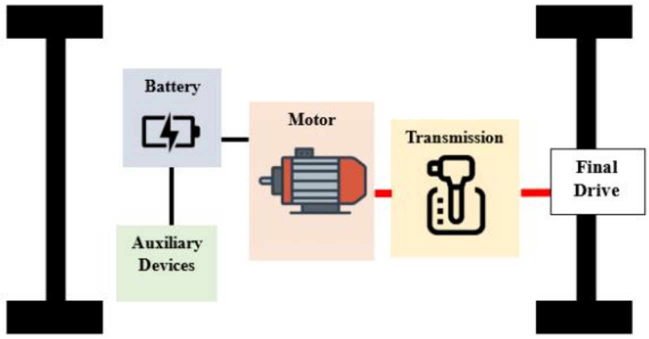

Fig 4. Configuration of Battery Electric Bus.

3.2. Positive impact of electric buses on air pollution reduction

As mentioned earlier, major contributors to air pollution include the emission of carbon dioxide, nitrogen dioxide, and particulate matter resulting from the indiscriminate use of diesel vehicles, exacerbated by the increasing number of vehicles in large cities [20]. The detrimental effects of this pollution include heart disease, lung cancer, and respiratory diseases such as asthma, reduced fertility, trade, and people migrating to other cities [21]. Table 2 compares different types of urban buses in terms of physical characteristics, pollutant emissions, and economic costs. This table indicates that compared to diesel buses, hybrid buses use less gasoline to meet some of their energy needs and, in terms of pollutant emissions, are similar to conventional vehicles. However, battery electric buses do not produce any pollutants.

Table 2. Comparison and analysis of different types of buses [22].

Section	Diesel buses		CNG natural gas bus	Hybrid electric bus	Electric bus with battery
Model	Volvo 8400(ac)	Tata Starbus	Tata Starbus	Tata Starbus hybrid	Byd k9 (ac)
Chairs	32	44	18	32	31
Length (meters)	12.3	12	12	12	12
Width (meters)	2.5	2.5	2.55	2.55	2.55
Height (meters)	3.2	3.2	3.35	3.35	3.49
Gross weight (Kg)	16200	16200	160000	16200	18500
Costs (thousands of dollars)	138	138	47	187	370
Fuel efficiency	2.2 Km/L	2.2 Km/L	2-3 km/kg	2.2-4 Km/L	1.5 Kwh/Km
Fuel cost (USD/Km)	0.36	0.24	0.25	0.21	0.16
Range (Km)	482	560	260-390	286-520	249
Fuel tank size (liters)	220	160	720	720	-
Charging time (hours)	-	-	-	-	3-6
Maximum power	290 BHP	177 BHP	230 BHP	230 BHP	180 kw
Maximum torque	1200 nm	685 nm	687 nm	678 nm	700 nm
Battery type	-	-	-	Li-Ion	li-ion iron(300Kw)
Pollutant production standard	Euro III	BS III	BS IV	Euro III	Without any exhaust emissions

Furthermore, it is evident that electric buses have a greater impact on reducing air pollution compared to conventional diesel and compressed natural gas buses, besides reducing the consumption and production of fossil fuels in the future [23]. Studies have shown that electric transportation vehicles are environmentally friendly, and their impact on pollution reduction depends on the source of fuel used to generate electricity [24-25]. Table 3 illustrates the impact of fuel sources on pollutant emissions.

Table 3. Reduction of emitted pollutants according to electricity generation sources [24].

Raw material	Pollutant reduction rate
Solar or nuclear	80-90%
Natural gas	25-50%
Coal	10%

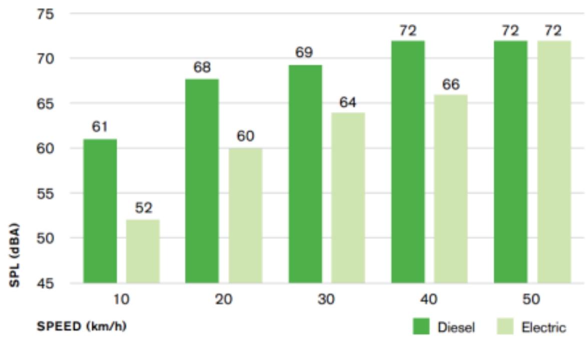

Fig 5. Comparison of sound pressure levels in diesel and electric buses [26].

3.3. Significant impact of electric buses on noise pollution reduction

Noise pollution, a topic of contemporary concern in societies, involves unwanted sounds with detrimental long-term effects on human health. Motorcycles, passenger cars, and diesel buses are considered the main sources of noise pollution in metropolitans [20]. The adverse effects of noise pollution on communication, sleep, mood, as well as on the heart, blood vessels, and hearing, are undeniable. Fig.5 illustrates the significant difference of 5-9 decibels in sound pressure levels between electric and diesel buses at constant speeds in urban environments. Since the scale is logarithmic, the mentioned difference is very large and noteworthy [26].

3.4. Evaluation and economic comparison of electric and diesel buses

The lifetime costs of a vehicle include the cost of maintaining and repairing the internal combustion motor and its related transformer, oil and filter changes, tire changes, brake pad replacements, and other items. Electric buses do not have the complexities of internal combustion motors and do not require oil changes, etc. Moreover, experience shows that electric buses have less tire wear and brake pad breakage. Consequently, despite the health benefits of electric buses to society, an economic comparison of electric and diesel buses based on Judah Aber's research in 2016 indicates that the lifetime cost (12 years) of electric buses is approximately $168,000, which is 12.5% lower than the cost of diesel buses [4]. Thus, electric vehicles, despite their high initial cost, play a prominent role in reducing future costs and are in line with sustainable development indicators. Fig.6 illustrates the various factors affecting the lifetime cost of diesel and electric buses and the superiority of electric buses.

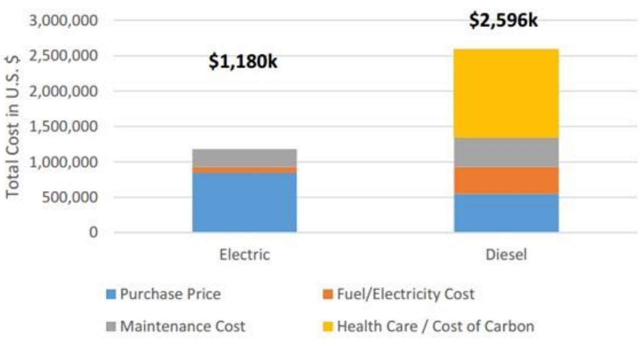

Fig 6. Comparison of total costs of diesel and electric buses [4].

4. Conclusions

The results of the conducted research include:

1. Caring about environmentally friendly transportation and sustainable development indicators to improve the air quality of metropolitan areas is essential.

2. Considering that the amount of pollutants produced (nitrogen monoxide, sulfur dioxide, and particulate matter) by diesel buses is much higher compared to personal vehicles, replacing buses with personal vehicles may have a reverse effect on the level of pollutant emissions from vehicles. Therefore, reducing air pollution through encouraging people to use buses may not be suitable.

3. Replacing diesel vehicles and buses with electric transportation vehicles significantly contributes to reducing air pollution, which is currently critical.

4. The reduction rate in pollutants varies depending on the power supply in vehicles, with solar sources achieving 80 to 90 percent reduction, natural gas achieving 25 to 50 percent reduction, and coal achieving only a 10 percent reduction. This statistic clearly indicates the superiority of solar sources in reducing air pollutants compared to other alternative sources.

5. Measuring the levels of sound pollution from electric and diesel buses at constant speeds in urban environments reveals a difference of 5 to 9 decibels on a logarithmic scale, indicating the significant role of electric vehicles in reducing sound pollution.

Regardless of all the aforementioned advantages, the lifetime cost (12 years) of electric buses is approximately 12.5% lower than the cost of diesel buses.

Conflict of interest

There is not conflict of interest.

References

[1] Fuglestvedt, Jan, et al. Climate forcing from the transport sectors. Proceedings of the National Academy of Sciences, 105(2): 454-458, 2008.

[2] Harford JD. Congestion, pollution, and benefit-to-cost ratios of US public transit systems. Transportation Research Part D: Transport and Environment.; 11(1): 45-58, 2006.

[3] kumarpillai, Reji. Electric vehicles: a Sustainable Solution to Air Pollution in Delhi. (December 2015).

[4] Aber J. Electric bus analysis for New York city transit. New York City, May 2016.

[5] Grütter, Jürg; Grütter consulting, A. G. Real world performance of hybrid and electric buses. Renewable energy & energy efficiency promotion in international cooperation, 2014.

[6] Campbell, JEROME. Five Electric Buses Join Metro's Fleet; More May be Coming, Los Angeles Times, April2015.

[7] EPD (Environmental Protection Department, Air Pollution Control Strategies, the Government of the Hong Kong Special Administrative Region, 24 September 2012.

[8] MRCegney. Electric Technology Transport Research Report, Final Report. June 2017.

[9] Satheesh.A. Exponential Growth Awaits EV Charging Infrastructure Market in Asia Pacific by 2020. Frost & Sullivan Market Insight, August2012.

[10] IEA (International Energy AGENCY), Understanding the Electric Vehicle Landscape to 2020: Organization for Cooperation, April 2013.

[11] Bayindir KÇ, Gözüküçük MA, Teke A. A comprehensive overview of hybrid electric vehicle: Powertrain configurations, powertrain control techniques and electronic control units. Energy Conversion and Management. 1;52(2): 1305-13, 2011.

[12] Yong JY, Ramachandaramurthy VK, Tan KM, Mithulananthan N. A review on the state-of-the-art technologies of electric vehicle, its impacts and prospects. Renewable and Sustainable Energy Reviews. 1;49:365-85, 2015.

[13] Chan CC. The state of the art of electric, hybrid, and fuel cell vehicles. Proceedings of the IEEE; 95(4): 704-18. 2007.

[14] Živanović Z, Nikolic Z. The application of electric drive technologies in city buses. INTECH Open Access Publisher; 2012.

[15] Hamut HS, Dincer I, Naterer GF. Analysis and optimization of hybrid electric vehicle thermal management systems. Journal of Power Sources. 1;247: 643-54, 2014.

[16] Maalej K, Kelouwani S, Agbossou K, Dubé Y. Enhanced fuel cell hybrid electric vehicle power sharing method based on fuel cost and mass estimation. Journal of power sources. 15;248: 668-78, 2014.

[17] Offer GJ, Howey D, Contestabile M, Clague R, Brandon NP. Comparative analysis of battery electric, hydrogen fuel cell and hybrid vehicles in a future sustainable road transport system. Energy policy. 1;38(1): 24-9. 2010.

[18] FCH J. Urban Buses: Alternative Powertrain for Europe. Fuel Cells and Hydrogen Joint Undertaking: Europa. 2012.

[19] BYD erhältRekordbestellungüber 2000 eBusse und 1000Elektroautos V, 12. May 2014.

[20] Abdi, M.H., and Bahari, M. "The Role of Transit-Oriented Development (TOD) Approach in Reducing Pollution Caused by Urban Traffic"; The Sixth Conference on Urban Planning and Management, Mashhad (Iran), 2014.

[21] Dissanayake S. Pollution Clouds Hong Kong's Future. BBC News. 2007.

[22] Global Green Growth Institute and Center for Study of Science, Technology and Policy, Electric Buses in India: Technology, Policy and Benefits, GGGI, Seoul, Republic of Korea, 2015.

[23] Electric Buses in India: Technology, Policy and Benefits, Copyright, (August) 2016.

[24] Funk K, Rabl A. Electric versus conventional vehicles: social costs and benefits in France. Transportation Research Part D: Transport and Environment; 4(6): 397-411, 1999.

[25] Union of Concerned Scientists and The Greenlining Institute, How Electric Buses and Trucks Can Create Jobs and Improve Public Health in California, May 2017.

[26] Electricity Cooperation for sustainable and attractive public transport, Status Report, june 2016.

[27] Lajunen A, Lipman T. Lifecycle cost assessment and carbon dioxide emissions of diesel, natural gas, hybrid electric, fuel cell hybrid and electric transit buses. Energy;106:329-42 2016،

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