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LIFE CYCLE COST ANALYSIS FOR ELECTRIC VS DIESEL BUS TRANSIT IN AN INDIAN SCENARIO

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ABSTRACT

The "business as usual" scenario for most cities in India involves utilization of fossil fuels (diesel and CNG) for bus transit. Electric mobility is a potential solution to reduce the carbon footprint of city public transport. This paper analyzes the feasibility of this and computes the life cycle cost (LCC) of the procurement and operation of electric as opposed to diesel buses based on a functional unit of one bus driven 100 km per day. The research indicates that the total cost of ownership (TCO) of an electric bus, calculated over a life cycle of 25 years, is 5-10% less compared to a diesel bus. Sensitivity analysis is performed for the TCO of the electric bus in order to prepare a robust case to accommodate market fluctuations and the research assumptions. Component-wise analysis indicates several potential measures that may be taken to improve the viability and feasibility of electric buses. The research goal is to enable decision-making on the adoption of electric mobility by respective urban local bodies. This would promote the use of sustainable transport in urban localities and would also help in reducing the carbon footprint.

Keywords: Electric bus; Feasibility analysis; Life cycle cost analysis; Sustainable transport; Total cost of ownership

1. INTRODUCTION

The transportation sector in India is a significant contributor to the deteriorating urban air quality and human health. More than 50 cities in India have a population greater than one million, all of whom are subject to transport sector emissions. This is because the "business as usual" case for the cities involves use of fossil fuels (e.g. diesel and CNG) for transportation. There is an established need for energy conservation, energy security (reduction in fossil fuel dependency), an improved carbon footprint (reduction in greenhouse gas emissions) and improved air quality (a reduction in other pollutant emissions). The goal of this research is to synergize electric mobility for bus transport in Indian cities. The case of pure electric buses (zero emissions) is considered for implementation, together with life cycle cost assessment (LCCA). The life of road-based infrastructure projects in India is close to 25 years and therefore the analysis is conducted based on this life span. The functional unit used for arriving at the life cycle costs and comparative assessment is one bus travelling 100 km a day. LCCA and net present value (NPV) with internal rate of return (IRR) computation are two vital decision-making tools which can be applied for the feasibility analysis of a complex infrastructure project. The primary objective of this study is to compare the life cycle cost analysis for an

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electric bus compared to a diesel one through tools such as total cost of ownership (TCO) and net present value (NPV) analysis and to analyze the feasibility of using electric buses as a sustainable transport mode for mass rapid transit systems (MRTS). Both TCO and NPV analysis are performed for the functional unit of one bus for 100 km trip length. The analysis is predominantly based on the assumptions of cost data, which inherently vary depending on market and policy fluctuations. In order to make a more robust analysis, the sensitivity of various data parameters to the TCO is evaluated and presented in a later section. A secondary objective is to obtain an insight into the external costs of pollution associated with electric and diesel buses.

2. LITERATURE REVIEW

LCCA is a decision-making tool which can be effectively used to establish the economic feasibility of a project. Berawi et al. (2016) employed it for the energy infrastructure of Indonesia on a time scale indicating a positive move towards transportation sector sustainable development. Use of alternative fuels other than fossil ones needs urgent promotion. Many debates have been held and views expressed on the topic of "post diesel mobility" and much research and testing is being conducted worldwide exploring the alternative mechanisms for vehicle transportation. Although there is no doubt that electric mobility will lead to lower local emissions, and is accepted as an environmentally friendly practice compared to diesel-based mobility, there have been concerns over energy security, as well as the environmental pollution caused by the fossil fuels used for transportation. Energy security can be enhanced by promoting more usage of renewable energy. One of the significant causes of the slow pace of adoption is the economics involved. The sustainable development of infrastructure projects such as Mass Rapid Transit Systems (MRTS) is a challenge if the mode of operation is renewable energy based, such as electric or biodiesel vehicles. The demand for such projects needs to be studied and forecast. Husin et al. (2015) also applied a system dynamic approach to forecasting the demand on mega- infrastructure projects. Until very recently, India did not have any indigenous technology for electric buses as a viable mode of transportation for MRTS. The capital costs of these buses are almost three times those of diesel buses and there have been few cost fluctuations. Another major expense is the high storage battery, which has to be imported and replaced every few years in the life of a bus. Fortunately, battery technology has advanced rapidly and costs have seen a gradual reduction, combined with improvements in efficiency. The government of India has been proactive in the domain of smart and sustainable cities in recent times, and the policy landscape has been suitable to enable the adoption of electric vehicles. Some of the relevant policies in the country are the national electric mobility mission plan (NEMMP 2020); the faster adoption and manufacture of electric vehicles (FAME) scheme; the national auto fuel policy; the national urban transport policy (NUTP); and the smart city mission. The FAME scheme introduced by the Department of Heavy Industry, for example, provides a demand-based incentive of INR 3.0-6.6 million for electric buses. The report on "Electric buses in India: technology, policy and benefits" by the Global Green Growth Institute and Centre for Study of Science, Technology and Policy (2015) captures the current scenario of electric buses in India very well.

When it comes to the domain of electric vehicles, the aforementioned reports, as well as many other researchers, have suggested adopting life cycle cost analysis (LCCA) and total cost of ownership perspectives in order to enable decisions to be made on adopting electric mobility. However, much of the testing and research has been conducted on light duty vehicles (cars), with few papers addressing the case of electric buses. This study contends that if the transition to electric mobility is bound to take place in a city, it might be easier to transform the technology for public transport as opposed to private transport. Besides, subsidies offered by the government might be more available and easier to justify in the public domain, as well as any risks being easier to bear. Consequently, this research addresses the issue of electric mobility with respect to bus transport in India. Adheesh et al. (2016) studied the feasibility of electric buses compared to conventional diesel buses in Bangalore, India. The initial investments in electric buses were found to be much higher than for conventional diesel buses. The operation and maintenance costs of electric buses were also found to be very high. A study on the total cost of ownership and externalities for conventional, hybrid and electric vehicles by Mitropoulos et al. (2017) suggests a life cycle cost analysis method, which includes the external costs of emissions with more detail on the comparison with light duty vehicles. As an outcome of the study, the researchers have a strong view on the dynamism of transport policies with respect to regional data. According to Helmers et al. (2017), most of the attempts at LCA by past researchers have been on generic vehicles. Their work aimed at developing and quantifying LCA through the real-time data of vehicles in use globally, with data pertaining to energy consumption before and after the conversion of vehicles into electric modes.

Nordelöf et al. (2014) conducted a detailed literature review of the usefulness of the different methods that can be used for the life cycle assessment of the different electric vehicles. In addition, Steubing et al. (2016) developed a modular LCA approach to optimize the vital parameters involved in and associated with the value chain in the sustainable transportation sector. Bauer et al. (2015) made an assessment of the environmental performance of vehicles used at present, which was intended to be used in future by computing the life cycle cost of all the available modes using a novel scenario analysis framework. Their study reveals that electric modes are the best available sustainable methods of transport. Zulkarnain et al. (2012) reviewed the recent market forecasts and analysis of all types of electric vehicles. Their study reveals that the future of the electric vehicle market has strong growth potential and that appropriate business models need to be developed to satisfy the aspirations of consumers. Gnann et al. (2018) conducted a study to assess the fast charging infrastructure needs for present and future situations. They conclude that infrastructure requirements for charging largely depend on power rates and battery sizes. Both these parameters are likely to increase in the future. Levay et al. (2017) conducted a total cost of ownership (TCO) study to ascertain how the initial costs and the sales of electric vehicles are related to each other, and also to study the role of fiscal incentives in reducing TCO costs to encourage an increase in the sales of electric vehicles. Heidrich et al. (2017) studied the effectiveness of the policies and mitigation strategies pertaining to climate change which might support the uptake and use of electric vehicles. Bubeck et al. (2016) made an attempt to compute the TCO of electric vehicles in Germany. Their study highlighted that electric vehicles can be a feasible and attractive option for achieving the climate change mitigation targets of the EU and the German government. Furthermore, Jochem et al. (2016) computed the external cost components that affect electric vehicles. These costs include those of accidents, congestion, environmental pollution, climate change and noise. They observed that in most cases these costs are lower than those incurred by internal combustion engine vehicles.

LCCA research work on diesel and electric public transport buses in the United States by Cooney et al. (2013) made strong suggestions to focus on the electricity mix in the grid, while recommending the use of electric buses. Therefore, the means of electricity generation has been addressed as part of this study. Presently, Indian states have a variable share of renewable and coal-based electricity generation; therefore, three cases are illustrated: (i) the case of 100% thermal energy, which will account for powerhouse emissions; (ii) the case of 100% renewables, with which no emissions are assumed; and (iii) the case of a 50−50% share of both.

One of the challenges faced in the study was arriving at the monetization of costs of air pollution, both for the use of diesel and for electricity generation. The external costs of emissions have been adopted from the research of Matthews et al. (2001), who estimated the unit of social damage due to air pollution from the transportation sector. Hawkins et al. (2013) compared the environmental LCA of conventional and electric vehicles. Their study concluded that the environmental benefits of electric vehicles are much higher than those of conventional vehicles and thus can be a feasible sustainable mode of transport in urban localities. Karaaslan et al. (2018) developed a hybrid input-output LCCA method to estimate the impacts on the environment, primarily greenhouse gas emissions, water consumption and the energy consumption of sports utility vehicles. The hybrid LCCA model was supplemented by sensitivity analysis using Monte Carlo simulation. A comparative environmental assessment of the potential of battery electric vehicles in Brussels by Mierlo et al. (2017) revealed the results of greenhouse gas emissions and well-to-tank emissions, which are seemingly lower than in conventional and biomethane vehicles, thus reducing pollution. An important point which arose in their discussion was the generation of toxic emissions in the life cycle of EVs for batteries from the mining process. Furthermore, there have been many life cycle evaluations made on alternative-fuelled vehicles and their respective environmental impacts. In future, we would like to address the alternative fuels for bus transport, such as biodiesel, but are presently concentrating on pure battery electric buses. Other researchers, such as Karaaslan et al. (2018,) have developed a hybrid input-output LCCA method for estimating the impacts on the environment. Moro and Helmers (2017) developed a new hybrid method for reducing the gap between the well-to-wheel (WTW) method and life cycle cost analysis to assess the greenhouse gas (GHG) emissions from vehicles on the road. Bubeck et al. (2016) developed a TCO model for electric vehicles in Germany. The model developed in this study for the computation of TCO for diesel and electric buses is relevant for the procurement and operation phase, and comprises bus procurement costs, fuel costs, electricity costs, financing costs, operation and maintenance costs, and additional infrastructure costs (charging stations and batteries). External pollution costs are incorporated, but it was observed that these are not very significant in the Indian scenario.

From the review of the available literature, it has been observed that detailed computation of LCC for electric vehicles and diesel buses operated in Mass Rapid Transit Systems (MRTS) has not been performed by any of the researchers to check the economic and technical feasibility of both modes. This research therefore aims to undertake detailed computation of the LCC of electric and diesel vehicles in order to check the feasibility of both modes as eminent MRTS modes in the Indian context.

3. METHODOLOGY

The LCCA of any vehicle can be computed by calculating the TCO with respect to the time value of money; the initial purchase price of the vehicle including freight charges; the depreciation costs of the vehicle over its economic life; alteration and replacement costs; operation costs; maintenance costs; financing costs including interest; costs associated with taxes; and insurance costs. De Clerck et al. (2016) explain the various components of TCO and highlight the significance of each one. Their work also explores the totality of TCO. They developed a segmented TCO model for alternative vehicle technologies, together with the external costs associated with the vehicle use and ownership. The societal perspective was also considered, whereby the cost to society due to the effect of technology was computed. This was termed as the “total cost for society (TCS)”.

The final TCO model was obtained by integrating various costs (purchase cost, operational costs, non-operational costs, and external costs of pollution) with respect to the time value of money. Thiel et al. (2010) computed the costs associated with vehicle emissions and attempted to forecast the LCA of future vehicles under new energy policy scenarios.

The basic assumptions that were made for this study were for the purpose of estimating various infrastructure-related costs, such as: (i) the cost of bus procurement; (ii) the cost of diesel; (iii) the cost of operation and maintenance; (iv) cost of bus replacements; and (v) the cost of electricity. In addition, the assumptions were based on the quantity of various emissions such as CO_2, CO, PM, HC, NO_x and SO_x, and external costs of pollution associated with these emissions. These assumptions are shown in Tables 1 and 2. The costs were derived from the literature and interaction with professionals in the field. As far as possible, an attempt has been made to be realistic with regard to the Indian scenario for these values. However, the external costs of pollution have been assumed from a global perspective (Matthews et al., 2001). The costs are discounted at a rate of 8% over a life of 25 years wherever applicable.

Table 1 Infrastructure-related assumptions for Life Cycle Cost Assessment (LCCA)

Component	Value	Unit
No of buses	1	-
Travel distance of buses	100	Km per day per bus
Cost of a diesel bus	60,00,000	INR
Cost of an electric bus	150,00,000	INR
Cost of diesel	65	INR per litre
Cost of electricity	7	INR per unit
Mileage of diesel bus	2.2	Km / litre
Mileage of electric bus	1.3	Km / unit
Cost of O&M for diesel bus	25	INR/km
Cost of O&M for electric bus	3.75	INR/km
Cost of charger	1,00,000	INR per charger
No of chargers per bus	1	-
Life of charger	25	Years
Cost of battery	26,00,000	INR
Life of battery	5	Years

(Source: Global Green Growth Institute and Center for Study of Science, Technology and Policy, 2015)

Table 2 Emission-related assumptions for Life Cycle Cost Assessment (LCCA)

Type of pollutant	Local emissions from diesel bus (gm/km)[1]	External cost of pollutant in INR per ton (Matthews et al., 2001)
CO	3.92	33,800
HC	0.16	104,000
NO_X	6.53	182,000
CO_2	602.01	845
PM	0.3	279,500
SO_2	-	130,000

(Source: The Automative Research Association of India., 2008)

The present model developed for the computation of TCO for diesel and electric buses is relevant for the procurement and operation phase and comprises bus procurement cost, fuel cost, electricity cost, financing cost, operation and maintenance cost, and additional infrastructure cost (charging stations and batteries). The external pollution costs are incorporated, but it was observed that these costs are not very significant in the Indian scenario, partly because of less public transport share and partly because of relatively higher other cost components associated with the project. The general assumptions are based on a life cycle of 25 years and an 8% discount rate. The present worth of all capital, annual and one-time costs has been calculated and integrated to reflect the total cost of ownership.

4. RESULTS AND DISCUSSION

4.1. Total Cost of Ownership (TCO) Analysis

4.1.1. Diesel bus

The present worth (PW) of the initial cost of bus procurement is estimated. Further, the present worth of annual costs (PWA), which are primarily fuel costs and operation & maintenance (O&M) costs, is calculated by factoring the PWA at 8% for 25 years. Next, the present worth of financing charges is calculated using a capital recovery factor (CRF) at 8% for 25 years. For the diesel bus, its replacement cost is calculated at the end of its life using a single payment capital recovery factor (SPCF) of 8% at the end of 7 years, 14 years and 21 years.

4.1.2. Electric bus

Similar to the diesel bus, the PW of bus procurement, as well as the PW of annual costs (electricity and O&M) are calculated. The additional initial cost of chargers is also considered. The PW of the battery replacement costs is considered at the end of 5 years, 10 years and 15 years using an SPCF of 8% in the requisite period. The PW of the bus replacement cost is considered at the end of 15 years.

4.1.3. Total cost of ownership (TCO) calculations

The total cost of ownership is assumed to be the sum total of the initial costs, annual costs, financing costs and other costs. The distribution of these costs and the magnitude of the total cost are studied for analysis. The total cost of ownership calculations for a functional unit of one bus with 100 km per day of travel is illustrated in Table 3 (for a diesel bus) and Table 4 (for an electric bus).

Table 3 Total cost of ownership (TCO) calculations for diesel-based bus transit

No.	Component	Value in INR	Remark
1	PW of initial cost of diesel bus	6,000,000	-
2	PW of annual cost	21,252,556	Total annual cost is 1,990,909 INR factored by (P/A, 8%, 25) (P/A, i%, n years)
3	Annual charge with interest for initial cost	562,200	Initial cost of bus procurement is factored by (A/P, 8%, 25)
4	Annual charge without interest for initial cost	240,000	Initial cost of bus procurement per year of life cycle period
5	Difference in annual charge with and without interest for initial cost	322,200	-
6	PW of interest costs for initial cost	3,439,421	Item (5) factored by (P/A, 8%, 25)
7	Annual financing charge	159,273	8% of the annual costs
8	PW of interest for annual costs	1,700,205	Item (7) factored by (P/A,8%, 25)
9	Total present worth of financing costs	5,139,625	Item (6) + Item (8)
10	Bus replacement costs	6,736,200	Sum of replacement costs at the end of 7 years, 14 years and 21 years; Item no. (1) factored by (P/F, 8%, 7), (P/F, 8%, 14) and (P/F, 8% 21) respectively
11	Total cost of ownership	39,128,381	Item no. (1) + Item No. (2) + Item no. (9) + Item No. (10)

Table 4 Total cost of ownership (TCO) calculations for electric-based bus transit

No.	Component	Value in INR	Remark
1	PW of initial cost of electric bus	15,000,000	Subsidized cost of the bus assumed
2	PW of annual cost	3,559,122	Total annual cost is 333,413INR per year factored by (P/A, 8%, 15)
3	Annual charge with interest for initial cost	1,405,500	Initial cost of bus procurement factored by (A/P, 8 %, 15)

No.	Component	Value in INR	Remark
4	Annual charge without interest for initial cost	600,000	Initial cost of bus procurement per year of life cycle period
5	Difference in annual charge with and without interest for initial cost	805,500	Item no. (3) – Item no. (4)
6	PW of interest costs for initial cost	8,598,551	Item (5) factored by (P/A, 8%, 15) which is 8.5595
7	Annual financing charge	26,673	8% of the annual costs
8	PW of interest for annual costs	284,730	Item (7) factored by (P/A, 8%, 15), which is 8.5595
9	Total present worth of financing costs	8,883,281	Item (6) + Item (8)
10	PW of cost of charging stations	100,000	-
11	Total PW of battery costs at end of 5 years, 10 years, 15 years and 20 years	4,351,100	Total battery cost is 2,600,000 INR if replaced every 5 years, therefore factored by (P/F,8%,5), (P/F,8%,10), (P/F,8%,15) and (P/F,8%,20) respectively and totalled
12	PW of bus replacement cost at end of 15 years	4,728,000	Total battery cost is 2,600,000 INR if replaced every 5 years, therefore factored by (P/F,8%,10)
13	Total cost of ownership	36,621,503	Item no. (1) + Item No. (2) + Item no. (9) + Item No. (10) + Item No. (11) + Item No. (12)

The cash flow diagrams of the total cost of ownership for diesel bus and electric bus technology adoption are shown in Figures 1 and 2.

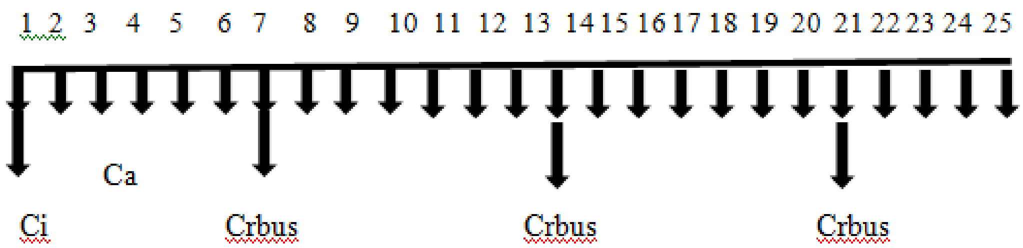

Figure 1 Cash flow diagram for TCO of diesel bus

Ca : Annual cost, comprising diesel fuel, operation and maintenance, and financing costs
Ci : Initial cost of bus procurement
Crbus : Cost of bus replacement

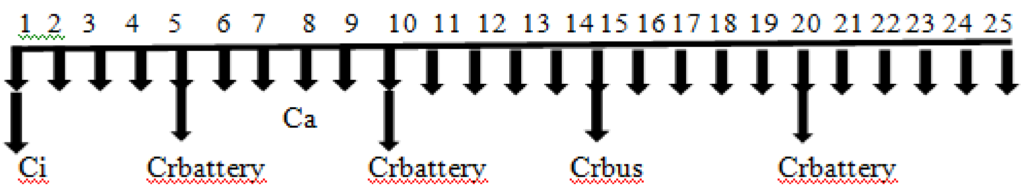

Figure 2 Cash flow diagram for TCO of electric bus

Ca : Annual cost, comprising electricity, operation and maintenance, and financing costs
Ci : Initial cost of bus procurement and charging stations
Crbus : Cost of bus replacement
Crbattery : Cost of battery replacement

The distribution of the TCO of diesel and electric buses is illustrated in Figures 3 and 4. It is interesting to note that with the given data, the total cost of ownership of the electric bus (~36.6 million INR) is less than that of the diesel bus (~39.1 million INR) over the 25 year life cycle.

The distribution of the total cost of ownership shows a great disparity between the two cases, especially in the way initial costs, annual costs and financing costs are distributed. It is evident that the majority of the costs of a diesel bus are based on fuel, operations and maintenance, which are recurring costs. Given the current state of diesel prices in India, this share may be expected to increase further, leading to higher ownership costs. It is also evident from the electric bus case that the majority of the costs incurred are the high cost of bus procurement and financing costs. Further subsidies for the purchase of electric buses, low interest loans and public private partnership models may be instrumental in making the electric bus scenario more cost effective. Figure 3 shows the present worth (PW) cost distributions for the TCO of the diesel bus, and Figure 4 represents these for the electric bus. The cost variation over the 25 year life cycle is shown in Figure 5.

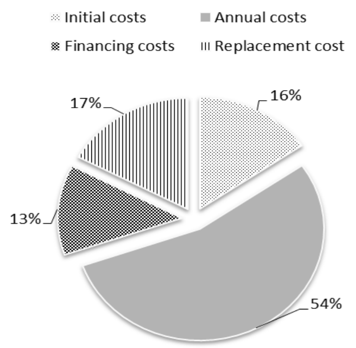

Figure 3 Present worth (PW) cost distribution for the TCO of a diesel bus

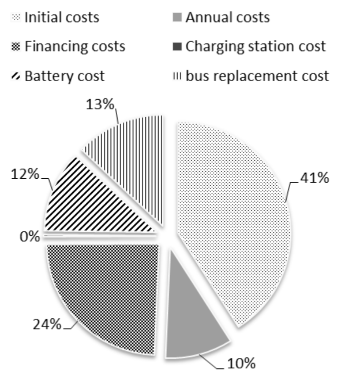

Figure 4 Present worth (PW) cost distribution for the TCO of an electric bus

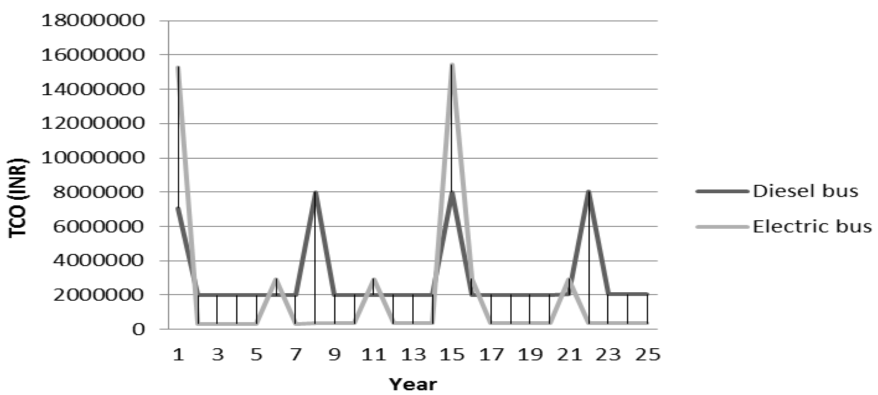

Figure 5 Cost variation over 25 year life cycle for diesel and electric buses

As can be inferred from the huge variations in cost components, as highlighted in Figure 5, there is a definite need to reduce the high capital expenses of bus procurement. It is necessary to analyse the best way to optimize the variation curve through soft loans and periodic instalments. Most obviously there is also need to raise the initial funds for the procurement for electric buses. The revenue model should target the other recurring expenses, mainly O&M and electricity. Even if the revenue model is decided on keeping in mind the diesel scenario, there are definite savings that can be accrued to procure a bus in the following cycle. There is great potential to explore a strong financial model that is based on the O&M and fuel savings of the electric bus.

4.2. External Costs of Pollution

The external cost of environmental pollution is calculated separately and added to the respective scenarios. The local emissions of the diesel bus amount to an annual cost of INR 77,658 (USD 1107) per year, which corresponds to a PW of INR 8,28,985 (USD 11816). The source emissions from a thermal power plant amount to an annual cost of INR 78,485(USD 1119) per year, which corresponds to a PW of INR 8,37,816 (USD 11942). The observations that may be made are that the environmental cost of pollution is not reduced in the electric bus if the electricity is from a thermal power plant. It may however have less impact than the tail pipe emissions from bus as power plant source releases the emissions locally and at much higher altitude. It must also be noted that at present Indian states have adopted an electricity mix, which combines renewables. In Gujarat, for example, the share of coal-based electricity generation is around 55%. The effect of the electricity mix will have a big affect on the cost of environmental pollution. Needless to say, in the scenarios assumed, there is a predominant cost of infrastructure, as opposed to cost of environmental pollution, and the latter is not very different in the two scenarios considered. A summary of the total cost of ownership for diesel and electric bus mobility with a varied share of electricity mix in the grid is presented in Table 5. It is concluded that adopting electric mobility may be a fruitful investment for Indian cities, considering both the economic and environmental benefits of the option. The TCO for diesel and electric bus mobility is presented in Table 5.

Table 5 Total cost of ownership for diesel and electric bus mobility

Type of bus	Source of energy	PW of ownership cost (Million INR)	Environmental cost (Million INR)	Total cost of ownership (Million INR)
Diesel	Diesel	39.13	0.83	39.96
Electric	Thermal	36.62	0.84	37.46
Electric	100% renewable	36.62	0	36.62
Electric	50-50% thermal + renewable	36.62	0.42	37.04

5. CONCLUSION

The research has explored the life cycle costs involved in the procurement and operation of electric buses as opposed to diesel buses through TCO calculations and NPV analysis. It contributes to the academic and professional world in terms of creating awareness of the long-term benefits of using electric vehicles. The research also contributes towards identifying the niche cost components, which need to be addressed for the promotion of electric vehicles. According to the analysis, it was observed that when evaluated over a life cycle of 25 years, which is the normal life of transport infrastructure such as pavements in India, the TCO for electric buses (INR 36.6 million, or USD 571,875) is significantly lower than that of diesel buses (INR 39.1 million, or USD 610,938) even if the external costs of pollution are ignored. This trend is also supported by the NPV analysis, in which the electric bus option NPV (INR 26.2 million or USD 409,375) is significantly cheaper than that of the diesel bus NPV (INR 32.3 million or USD 504,688). Electric buses, although involving a high capital expenditure (two to three times that of diesel buses), have much lower recurring costs and seem to be feasible in light of long-term benefits. The TCO is most sensitive to the bus cost and therefore alternative funding mechanisms for the capital expenditure are identified as an urgent need for intervention. There is also a considerable component of financing costs involved with electric buses (almost a quarter of the TCO) and therefore this should be looked as an opportunity to make it further viable by introducing soft loans or alternative financing mechanisms. The savings in operational cost are the most promising part of the electric bus TCO. These savings can be invested to enable phase-wise procurement for the next set of buses.

Overall, it can be inferred that electric bus mobility is a promising initiative for Indian cities and can be a beneficial investment considering long-term value. A 5–10% life cycle cost benefit is expected by deploying electric buses instead of diesel ones for a functional unit of 100 km daily trips. For the assumed functional unit, minimum savings of INR 25,000 (USD 391) per bus per km are expected for electric buses over diesel ones, given that the trip length is at least 100 km. It should be noted that the longer the trip length, the greater the savings in operational costs and therefore longer routes yield better TCO benefits compared to shorter ones. Therefore, considering long term benefits, electric buses appear to be quite a feasible option as a mode for sustainable transportation over other conventional fossil fuel- based modes of public transport. For future research, it is recommended that similar studies based on computation of TCO are conducted for other modes of fuel technology, such as bio-diesel buses, hybrid-electric buses and hydrogen fuel cell buses. Detailed cost-benefit and value engineering analysis can be made to further validate the feasibility of electric and diesel buses.

6. ACKNOWLEDGMENT

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