Life Cycle Costing Comparison of Diesel Bus vs Electric Bus in the Context of Nepal

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***Abstract*— Government of Nepal is planning to purchase 300 Electric buses in Kathmandu valley with the motive of providing some relief to the denizens of Kathmandu. As the transportation sector is considered as significant sources of the pollution in the valley, it forms the rationale behind the decision to switch from Diesel buses to Electric buses despite investing the large sum of money. In this paper, we make an effort to compare the life cycle costing of Diesel buses versus electrical buses with considerations of the time value of money and environmental impact in the context of Nepal. Our study shows that savings on fuel cost and maintenance cost of Electric buses are significant to offset the higher purchase price, NPR 16 Million, of the buses. The life cycle cost of Diesel Bus is NPR 20.3 million for 10 years, whereas the life cycle cost of Electric bus is NPR 21.2 million for the same period. However, if the environmental costs of NPR 1.3 million due to CO_2 emission by diesel bus is considered, Electrical buses already have lower lifetime cost by NPR 0.4 million. Given the purchase price of electric buses decreased by NPR 1 million, which is likely to happen due to the ongoing trend of decrement in cost of the electric buses, electric buses will become financially competitive against Diesel buses with additional local environmental benefits. Also, if the operation time of buses is beyond the breakeven time, 10.7 years, Electric buses have financial advantages over the Diesel Buses This analysis will help to ease the decisions regarding acquisition of buses and subsidies in the future for prospective transportation companies and the government.**

Keywords— Diesel Bus; Electric Bus; Life-cycle costing; Sensitivity Analysis

I. INTRODUCTION

As transport is considered the prerequisite of development, its growth is needed and inevitable. Out of many transport systems, most transport means still use fossil fuel as their energy input. In spite of the recent improvement in the efficiency of vehicles, overall CO2 emissions from road transport have not decreased instead increased due to an increase in the number of fleets [1]. Although Electric Buses (EBs) powered by overhead catenary lines have a long history, EBs powered solely based on the battery are a recent innovation at the end of the twentieth century[2]. Since then, electric buses are being used commercially and promoted by the different government as it is considered as an effective and viable option against the Internal Combustion Engine Buses (ICEBs). The government of Nepal is also planning to deploy 300 electric buses in the Kathmandu valley as the beginning of the implementation of its action plan regarding Electric mobility [3]. Improved air quality, low maintenance and fuel cost, comfortability, and efficiency in acceleration are its fortes whereas enormous upfront cost, as well as needs of numerous charging points, are hindrances of EBs.

The issue of the economic viability of EBs vs ICEBs is contentious. Comparison of the life cycle cost of Electric and Diesel Buses by Potkany [4] shows that an EBs needs Euro 132,000 more than ICEBs. Deploying Electrical Buses in the Kathmandu Valley: A Pre-Feasibility Study Report by Global Green Growth Institute(GGGI) [1] claims that switching to Electrical Buses has clear operational and financial advantages despite higher initial investment cost. In contrast to the Potkany [4], the report by GGGI [1] claims that EBs will be United States Dollar (USD) 130,000 cheaper to operate than ICEBs over the life of 10 years in Nepal. While the previous article has not monetized the environmental costs of Diesel Buses, the second report fails to consider the time value of money. GGGI [1] report also exaggeratedly incorporate the economic cost of energy insecurity showing $ 101,102 contribution of each Electric bus, as they may encourage tourist to plan a visit to country even in the case of fuel supply disruptions from India. Cost due to noise pollution is calculated based on the United Kingdom's data, claiming USD 75,111 savings, which may be unrealistic in Nepal. In this paper, we attempt to compare life cycle costing between EBs and ICEBs, considering both the time value of money and environmental costs.

This paper does not disregard the economical and other strategic benefits of switching to EBs. But the primary question is it right time to switch to EBs? The major hindrance of EBs is its high acquisition cost compared to ICEBs. However, it has comparatively lower fuel costs and significantly lower maintenance costs than ICEBs. The environmental cost of EBs due to carbon is near zero, whereas ICEBs has negative environmental costs. As Bloomberg New Energy

Finance expects EBs to reach upfront cost parity with ICEBs by 2025, the total cost of EBs is bound to fall soon. So, we will find the net present value of the cost of both type of buses with the consideration of the time value of money over its lifetime. The analysis presented in this paper will ease the decision regarding the investment in an electric bus and related subsidies.

Woodward [5] defines Life Cycle Costing (LCC) as the optimization of the cost of acquiring, owning and operating physical assets over their useful life using the present value technique. LCC is concerned with quantifying different options to ensure the adoption of the optimum asset configuration. The first International standard for property life - cycle costing BS ISO 15686-5:2008 defines LCC as the methodology for the systematic economic evaluation of life cycle cost over the analysis period. Similar to [5], Dhillion [6] defines the life cycle cost of a system simply as the sum of all costs incurred during its life span. The total sum of acquisition and ownership costs is calculated as ownership costs are as significant as acquisition costs. One of the deciding factors for the achievement of a successful outcome of the LCC calculation method is the correct estimation of overall costs and other factors such as the length of the product life cycle.

II. EVOLUTION OF ELECTRIC MOBILITY

While the mass application of modern E-Mobility is in the incipient stage, the idea of E-Mobility itself is not new. Robert Anderson, a Scottish inventor, had invented rudimentary battery-electric carriage in the 1830s [7]. Internal Combustion Engine Buses (ICEBs) eventually became the predominant technology as they offered more route flexibility. EBs were less convenient to ICEBs due to lower ranges dictated by the battery. However, with the improvement in the technology of battery and ever-increasing concern toward the environment, EBs are increasingly being seen as a sustainable form of transport in the future. This idea has been strengthening through government policies all-around the globe and collective understanding to reduce greenhouse gas emissions and increasing usage of the renewable source of energy.

Nepal had a pioneer mass transit project in South Asia, which used to serve commuter from Tripureshwor to Suryabinayak (13 Km) operating from 1975 to early 2000 [8]. But it was unfortunately suspended in 2008 and officially closed in 2009 as a result of political interference, incapable bureaucracy, and mismanagement. Another experience of Nepal's innovation in clean energy was the conversion of diesel engine three-wheelers into battery-powered vehicles, but with the increasing number of commuters, para-transit does not help to lessen the congestion, another dimension of urban transport problems. National Action Plan for Electric Mobility [3] has an ambitious target of increasing the share of the electric vehicle up by 2020 to 20% from 2010 level. As Nepal is capable of producing ten thousands of Megawatts of electricity, using EBs will boost our energy independency, reducing long-existing pain of foreign oil dependency.

Other than Trolley bus, Nepal had no experience of running EBs but Sundar Yatayat Pvt. Ltd, a private bus company, has started operating EBs in Kathmandu Valley from September 09, 2019. EBs are being promoted by Government of Nepal in policy Level hence with truncation of import duty. In addition, Nepal Electricity Authority, Provincial Government and Local Government are also supporting companies to set up charging station as well as for capital investment. Companies are motivated to capitalize on this opportunity, as Sundar Yatayat has already signed a deal with Chinese Manufacturer of electric Buses, making their total fleets number 18. Sajha Yatayat, a public transportation company, is also planning for investing NPR 45 million for electric buses and their infrastructures, with the assistance of Province Three Government, Kathmandu and Lalitpur Metropolitan Government.

III. DATA, METHODOLOGY, AND ANALYSIS.

As the GGGI report [1] has estimated the cost of bus operations for the Nepalese context, we take it as the reference for the cost of purchase and maintenance. Data of purchase cost of Diesel Bus &, maintenance cost are from GGGI [1], whereas environmental costs are from Institute of policy integrity [9]. Out of four bus model in [1], Ashok Leyland–Viking is adopted as the ICEB model, which purchase cost is USD 31,031 according to the report. In the electric model, BYD-K9, BYD-K7, and Ashok Leyland Circuit are analyzed in the report. BYD- K9 has only length 12 m which is comparable to Ashok Leyland–Viking Diesel bus which has 11 m length. In addition, we consider Leda brand Electric bus of length 10.5 m, which is imported by Sundar Yatayat, as another model for EBs.

For our study, we take the same route as discussed in [1], from Lagankhel to Budhanilakantha with a one-way distance of 17 Km and a single day travel distance of 126.3 Km. Days of operation is assumed as 350 days, with an annual distance travelled by bus on this route is estimated at 44205 Km.

Environmental costs are based on the report by the Institute for Policy Integrity. We adopt a lifetime 10 years in resemblance with [1] and [4]. Different types of cost associated within the lifetime of buses are as follows 1) Initial Capital cost, 2) Fuel cost, 3) Maintenance cost, 4) Environmental cost, 5) Disposal cost, and 6) Overhead and Management costs. Among these six types of costs, disposal cost and Overhead/ Management costs, including a salary of drivers, conductors are assumed to be equal. Salvage value and revenue of both types of buses are anticipated to be equal.

All other types of costs are calculated to present equivalent costs and summed to find the Net Present Value (NPV) of each type of bus. Guidelines of the Asian Development Bank (ADB) for the choice of the social discount rate [10] show that developing countries use a discount rate of 8 to 15%. With the reference of the ADB report [10] for Cost-Benefit Analysis, we assume a discounting rate of 10% while calculating the present worth.

1) Purchase Cost:

The Purchase price of Ashok Leyland–Viking is Nepalese Rupees (NPR) 3,568,565 with the Conversion rate of 1 USD = 115 NPR (Exchange rate of Sep 10, 2019). We assume that there will not be significant changes in the price of the Diesel bus, but the price of electric buses is plummeting. In GGGI Report, purchase price of BYD K9 is USD 290,374 including USD 18,000 for one charging station, whose corresponding NPR rupees is well above 30 Million. However, the recent purchase price of electric buses is well below 30 Million NPR. The electric buses bought for Gautam Buddha International Airport cost NPR 20 million. Sundar Yatayat has purchased Leda model EBs recently at NPR 16.2 million each with a charging station per bus. Hence, we consider price of Leda Bus in our analysis as cost of EBs. Present worth is the same as the purchase cost.

2) Fuel Cost:

The current price of Diesel is NPR 95/L (Sep 10, 2019). The fuel economy of diesel bus average to around 2.75Km/L, whereas EBs need 1.12kWh/km [1]. For 44205 Km, 16075 liters of petrol is needed. It cost NPR 1,527,125 for one year. The present worth for fuel cost for running ten years is NPR 9,383,523. For Charging EB, it will cost NPR 207,941 annually with an average unit cost NPR 4.2, as stated by Sundar Yatayat. The equivalent present worth of fuel cost of EBs for ten years is NPR 1,277,707.

3) Maintenance Cost:

Sheth and Sarkar [11] have performed LCC analysis for Electric Vehicle Vs Diesel Bus in Indian Scenario, where they have assumed O & M cost for Diesel bus and electric bus to be Indian Rupees (INR) 25/km and INR 3.75 km respectively. However, the report by ADB on Sustainable Transport Solutions [12] predicts that only 10-30% of total maintenance cost is saved by EBs in comparison to ICEBs. We use the maintenance cost of EBs to be 50% of that of ICEBs as done in GGGI report [1] as Nepal has no previous experience of running EBs. 9.6% of the purchase price of Diesel bus is taken as maintenance cost as per GGGI pre-feasibility report [1]. The maintenance cost for the first year of operations of Diesel bus is NPR 342,600, which is increased by 30% every year. In GGGI report, 40% increment is taken, but we limit increment to 30% in our study because even the discounted value of maintenance cost with 40% (NPR 3,820,682) increment yearly just exceeds its purchase price in 10th year (NPR 3,568,565). It is implausible to assume that any bus owner will run the same bus when the maintenance cost of one year exceeds the purchase cost. The present worth of the total maintenance cost for the Diesel bus with 30% increment is NPR 7,391,666 with NPR 1,820,934 at 10th year. We also assume the maintenance cost of EBs is half of ICEBs with the total present worth of NPR 3,695,833.

4) Environmental Cost:

Since the electricity in Nepal is from hydropower, both well to tank emissions and tank to wheel emissions is zero for EBs, but ICEBs of length 8-12 m have a tank to wheel emission of 48 ton CO2 in a year[12]. We have used 2.79 kg CO2 per liter of diesel, which produces 44.85 ton CO2 per bus per year. Report by the Institute for Policy Integrity [9] estimate the cost of CO2 per ton to be $4. With a conversion rate of NPR 112 per US $1, it accumulates to NPR 205,948 each year. Present worth over 10 years is NPR 1,265,462. Other local environmental impacts of new ICEBs are higher, but only to a small degree as per ADB report [12] entitled Sustainable Transport Solutions. Hence, in our study, the only cost due to CO2 is considered.

Analysis

Total life cycle cost is calculated in table1. From our calculation, LCC of Ashok Leyland Viking Diesel bus is NPR 20,343,754, and LCC Leda Electric bus is NPR 21,173,541 for 10 year life time. If Environmental costs due to CO2 is not considered, LCC of EBs is NPR 829,786 higher than LCC of ICEBs but will be NPR 435,676 lower if the cost due to CO_2 is considered. If the operating year is extended beyond 10.7 year, when the financial cost of Electric buses and Diesel buses are at breakeven, electric buses are cheaper than Diesel buses. Longer the life period, higher will be the profit of using electric buses.

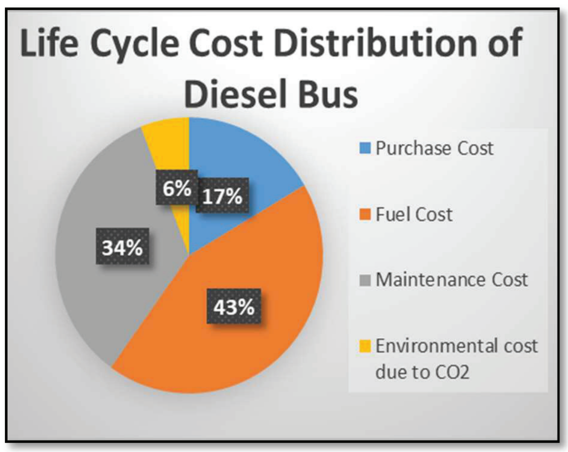

Fig. 1. Life Cycle cost distribution of Diesel Bus in present worth

The distribution of present worth of different cost items is shown in Fig 1.Out of NPR 21.6 million life cycle cost of Diesel bus in N, Fuel cost comprises the highest 43 %, followed by maintenance cost with 34 %. In a paradox, the purchase cost has only 17% contribution, and environmental cost comprises 6% cost.

A similar analysis is performed for Electric Bus and presented in Fig. 2. Huge 77% share of total life cycle cost is due to purchasing cost. In contrast, Environment cost is zero. 17% cost is due to the maintenance, and,

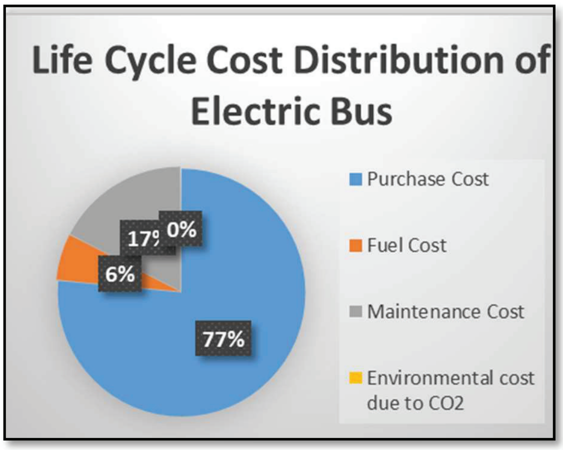

Fig. 2. Life cycle Cost Distribution of Electric Bus

6% is due to fuel cost. As we see the total life cycle cost of Diesel buses and Electric buses are similar, the reduction of cost in fuel and maintenance are huge which offsets the higher purchase cost of EBs, making it competitive with Diesel Bus.

The finding was in contrast with the study of Cooney [2]in US context, Potkany [4] in the European context, ADB [12] in the Chinese context , Anal[11] in Indian Context and GGGI [1] in Nepalese context. The difference is mainly due to a decrease in purchase price of electric buses with the ongoing innovation. Partly, the difference is due to different factors adapted in analysis. For instance, European Diesel Buses have already higher prices than the prices of Diesel buses in South Asia. Specifically, the difference in finding with Anal [11] may be due to the different lifetime used in calculation and differences in estimation of maintenance whereas differences with GGGI [1] is due to the incorporation of time value of money, 10% lower growth rate of maintenance cost and excluding energy insecurity and local pollution cost in our study.

IV. CONCLUSION

The main goal of this study is to compare the life cycle cost of electric buses and diesel buses in the Nepalese context. From our analysis, life cycle cost of Electric Bus for the 10-year life is NPR 21,173,541 and life cycle cost of Diesel Bus for the same period is NPR 20,343,754. Difference between life cycle cost between two buses is of NPR 829,786. If we consider environmental cost due to CO_2, NPR 1,265,462, electric buses are already cheaper in cost. Likewise, if the operation year exceed 10.7 year, where the financial cost of buses is at breakeven, Electric buses are cheaper than the Diesel buses. Therefore, if the purchase cost of an electric bus is further decreased by a, NPR 1 million, making the purchase cost NPR 1.52 million, Electric buses will be cheaper than Diesel buses even in financial term. Given the purchase cost of an electric bus likely to fall in the coming year along with increase in harnessing of Hydropower, Nepal has good chances of achieving target of decreasing dependency on fossils fuel in transport sectors.

TABLE 1. COMPARISONS OF LIFE CYCLE COSTING OF EBS VS ICEBS FOR 10 YEARS LIFE.

S.N.	Cost	Ashok Leyland Viking Diesel Bus		Leda Electric Bus		Remarks
		Actual Cost	Present Worth, discount rate 10%	Actual Cost	Present Worth, discount rate 10%	
1	Purchase Cost	NPR 3,568,565	NPR 3,568,565	NPR 16,200,000	NPR 16,200,000	PW to PW
2	Fuel Cost	NPR 1,527,125	NPR 9,383,523	NPR 207,941	NPR 1,277,707	AW to PW
3	Maintenance Cost	NPR 342,600 grows by 30% per year	NPR 7,391,666	NPR 171,300 grows by 30% per year	NPR 3,695,833	Annual Gradient to PW
4	Environmental cost due to CO2	NPR 205,948	NPR 1,265,462	0	0	AW to PW
Net Present cost without Environment cost (1+2+3)			NPR 20,343,754		NPR 21,173,541	
Net Present cost (1+2+3+4)			NPR 21,609,216		NPR 21,173,541	
Delta without Environmental cost of Cox			-NPR 829,786			
Delta with Environmental cost of Cox			NPR 435,676			

Table Sources: Authors

PW= Present Worth, AW= Annual worth, A= Annuity , i = discounting rate, N = useful year.

The formula for conversion from Annual worth to Present Worth, $P = A * \frac{(1+i)^N - 1}{i*(1+i)^N}$

The formula for conversion from Annual Gradient to Present Worth $P = \frac{A}{i-g} * \left[1 - \left\{ \frac{1+g}{1+i} \right\}^N \right]$

ACKNOWLEDGEMENT

The authors like to thank the Department of Civil Engineering, Kantipur Engineering College for continuous support and motivation. Also, we would like to express our deepest gratitude to Prof. Surya Raj Acharya for his continued guidance. We would appreciate the contribution of Er. Suman Neupane, Er. Kamal Katwal and Er. Arjun Poudel for making this paper a tangible value.

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