ISSN 2959-6149

Embracing Pure Electric Buses: Vision, Risks and Challenges

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Abstract:

In this paper, we mainly focus on the current hot discussion of pure electric public transportation trends. First, we discuss the ecological environment improvement of a city if the original fuel buses are converted to pure electric buses. We use a carbon emission model, an indirect one, and a direct one. Through the quantitative consideration of different factors, the carbon emission model of the whole life cycle of a pure electric bus is finally proposed, and the model is cross-verified by sensitivity analysis. Then, taking Hong Kong as an example, we collected the operation data and cost of public transport in Hong Kong and considered the cost pressure brought by replacing its buses with pure electric buses. We considered acquisition costs, operating costs, operating maintenance and repair costs, and battery replacement costs, etc., combined with government subsidy programs, we obtained the relationship between the relevant replacement costs and the number of replacements. Then, we consider whether our model in Hong Kong, New York, and London can provide reference opinions for replacing pure electric buses in these cities. In addition, with the support of a large number of data, we have formulated a government-funded timetable for the replacement of pure electric buses in three cities within ten years, which has a certain reference value. Finally, considering the current situation of buses in Hong Kong, we propose financial and environmental recommendations to the Transport Department of Hong Kong, as well as future forecasts and prospects.

Keywords: Carbon Emission Model, Full Life-Cycle Analysis, Pure Electric Bus.

1. Introduction

1.1. Background information

With the gradual popularity of electric buses in major cities worldwide, people have begun to pay attention to the future development of electric buses. Under the current circumstances, many cities have doubts about the future of electric buses. Some people think that they will cause invisible pollution. However, there are still many countries and regions in the world that are confident about electric buses. This article will focus on this solution.

1.2. Problem restatement

This article focuses on the following issues. Firstly, to measure the ecological consequences of switching to all-electric buses, we used an algorithm to measure the overall ecological consequences regarding carbon emission indicators and simplified the problem. For financing, we take into account the cost of operation and the cost of its entire life cycle to achieve better accuracy. In addition, we applied our model to two metropolitan areas, New York and London, to explore the model‘s generalizability. Finally, considering that the progress of pure electric buses in Hong Kong is relatively backward, so far only 5% of the buses are pure electric buses; we choose Hong Kong as the city we focus on analysis and recommend their officials to make some necessary changes.

1.3. Our work

This paper adopts a carbon emission model to measure the contribution to reducing urban carbon emissions after converting the original bus fleet to a pure electric bus fleet. Secondly, we analyze what replacement frequency will cause less financial pressure through the financial fund model. In addition, the model is applied to other cities in the world where diesel buses are still operating. Finally, we wrote a letter to Hong Kong’s transportation officials, pitching our rationale and proposal for converting Hong Kong’s buses to electric buses.

1.4. Model Overview

Model 1: Ecological emissions and pure electric vehicle equipment. When considering the emission model, we start from two angles: thehe indirect model of emission ann the non-indirect model of emission.
Model 2: The replacement capital and cost model of pure electric bus. The model is mainly analyzed by cost, considering several parts divided into initial acquisition cost, operating cost, operating maintenance and repair cost, and battery replacement cost.

2. Basic Assumptions and Symbols

CO2 emissions generated by the whole life cycle of vehicles and power batteries are not considered.
Only water is considered when analyzing the sensitivity of the power structure to the greenhouse gas emissions of the whole life cycle of the energy chain of pure electric buses. The substitution of renewable energy sources such as electricity, wind power, and solar power for coal power.
In the scenario analysis, the energy consumption per 100 km of buses is assumed to remain the same under different scenarios.

3. Model 1: Ecological emissions and pure electric vehicle equipment

3.1. Model Establishment

We establish the model based on the example of Hong Kon. The total fuel consumption data of its operating vehicles during the use stage are complete and have a unified statistical caliber, which can be obtained from urban bus operating enterprises or urban bus operation supervision departments. Therefore, based on the energy consumption data and the "bottom-up" model construction logic, this paper constructs the CO_2 emission model of urban buses in the whole life cycle based on the energy chain from the two processes of direct and indirect emission stages.

3.1.1. Direct emission model

CO_2 emissions from vehicle fuel use can be divided into emissions from fuel combustion and non-combustion emissions from fuel use. The total fuel consumption of the vehicle in the use stage is FC_0, and the direct emissions in the combustion stage are:

$$E^{direct,c} = FC_0 \times \alpha_{01} \times (1-\alpha_{02}) \times EH_{h,c} \tag{1}$$

Where $E^{direct,c}$ is CO_2 emission (g) in the direct combustion emission stage; α_{01} is the fuel filling and replenishment efficiency; α_{02} is the rate of fuel loss during vehicle use; $EH_{h,c}$ is the emission factor of CO_2 during the combustion of fuel h.
The non-combustion emission generated by the fuel filling, replenishment, and use process is:

$$E^{direct,nc} = FC_0 \times (1-\alpha_{01}) \times E_{h,nc} + FC_0 \times (1-\alpha_{01}) \times \alpha_{02} \times EF_{h,}\,\mathrm{NC} \tag{2}$$

Where $E^{direct,nc}$ is CO_2 emission (g) in the non-combustion emission stage; $EF_{h,nc}$ is the CO_2 emission factor in the non-combustion process of fuel h. It can be seen that the CO_2 emission in the direct emission stage can be obtained from equation (3).

$$E^{direct} = E^{direct,c} + E^{direct,nc} \tag{3}$$

Where E^{direct} is the CO_2 emission in the direct emission stage.

3.1.2. Indirect emission model

In this paper, the indirect CO_2 emission stage of the fuel chain is simplified into seven processes, including the production, transportation, and storage of primary energy, as well as the production, transportation, distribution, and storage of fuel, the CO_2 emission of the indirect emission process is:

$$E^{indirect} = \sum_{j=1}^{7} E_j^{inderect} \tag{4}$$

$E^{indirect}$ is the CO_2 emission at the indirect emission stage (g), and $E^{indirect}$ is the CO_2 emission (g)of process j in the indirect emission stage. For combustion emissions, it is known that the emissions of fuel combustion in any process are related to the type of fuel, consumption, and equipment used, so CO_2 emissions generated by fuel combustion can be calculated by equation (5).

$$E_j^{inderect,c} = \sum_h \sum_k EF_{h,k} \times FC_{in,j} \times \eta_h \times \beta_{h,k} \tag{5}$$

$$\sum \eta_h = 1 \tag{6}$$

$$\sum \beta_{h,k} = 1 \tag{7}$$

Where $E_j^{inderect,c}$ is the combustion emission of CO_2 (g) in process j; $EF_{h,k}$ is k The emission factor of CO_2 in the combustion process of fuel h used in the class energy device; η_h is the consumption ratio of fuel h; $\beta_{h,k}$ is the proportion of k type energy devices in the process of fuel h consumption. According to the "bottom-up" model construction logic, the energy conversion efficiency of each process in the indirect emission stage is α_j, then there is:

$$FC_{1,in} = \frac{FC_0}{\alpha_1} \tag{8}$$

$$FC_{j,in} = \frac{FC_{j-1,out}}{\alpha_j} \tag{9}$$

Where $FC_{1,}$ it is the amount of energy input in the first stage; $FC_{j,}$ it is the amount of energy output in stage j. For the fuel leakage generated by the production, transportation and storage of primary energy and fuel, as well as non-combustion emissions such as evaporation, which are denoted as $E^{indirect,ncj}$, the total CO_2 emissions in the indirect emission stage can be transformed from equation (4) to:

$$E^{indirect} = \sum_j (E_j^{inderect,c} + E_j^{inderect,nc}) \tag{10}$$

The whole life cycle emission model. According to the above analysis, the CO_2 emission of the city bus energy chain in the whole life cycle is:

$$E = E^{direct} + E^{indirect} \tag{11}$$

Where E is CO_2 life cycle emission (g).

3.1.3. Analysis method of CO2 emission reduction effect in the whole life cycle

This paper adopts the single-factor sensitivity analysis method to study the influence of different influencing factors on the change of CO_2 emission at different stages of the whole life cycle, and the analysis method can be expressed as follows:

$$\triangle E = \frac{\delta E(\beta)}{\delta \beta} \tag{12}$$

Where β is the influencing factor in the CO_2 life cycle emission model, E (β) indicates that when sensitivity analysis is carried out, the CO_2 emission model of the whole life cycle is a single variable function of the influencing factor β; δE is the change of CO_2 emissions during the whole life cycle when the influencing factor β changes. Based on the sensitivity analysis results of the above-influencing factors, this paper adopts the scenario analysis method to analyze the CO_2 emission reduction effect of the whole life cycle of pure electric buses. The total daily CO_2 emission reduction under different scenarios can be expressed as:

$$ER_t = ER_t^d \times S_t = \frac{(E_{diesel,t} - E_{electric,t}) \times D_t \times S_t}{100} \tag{13}$$

Where ER_t is the total CO_2 emission reduction under scenario t (kg); ER_t^d is the average daily CO_2 emission reduction per single vehicle (kg); $E_{diesel,t}$, $_{electric,t}$ is CO_2 emissions per 100 km of diesel buses and pure electric buses under the scenario of t (kg/100 km); D_t is the average daily operating mileage of urban buses under the t scenario (km); S_t is the scale of pure electric buses (vehicles) under scenario t.

3.2 Model verification

Based on the line operation data and fuel consumption data of vehicle use stage provided by the Hong Kong Transport Department, as well as the parameters of each stage of the full life cycle of the diesel and electric energy chain [13-15], as shown in Table 1 to Table 2, CO_2 emissions per 100 kilometers per stage of the full life cycle of the energy chain of pure electric buses and diesel buses can be calculated according to equations (1) to (11). When calculating the CO_2 emissions of each process in the indirect emission stage, when the calculation result of the two adjacent iterative processes is less than one thousandth, the calculation is stopped, as shown in Table 4.

The results show that under the same operating environment, in the direct emission stage, the CO_2 emission of pure electric buses is zero, and 100% emission reduction can be achieved. In the indirect emission stage, CO_2 emissions per 100 km of pure electric buses were reduced by 46.09% compared with diesel buses. In the whole life cycle process, the pure electric bus can reduce CO_2 emissions by 61.20% per 100 kilometers.

Table 1 CO_2 emissions per 100 kilometers of Vehicle type

Vehicle Type	Per 100 km Energy consumption	Direct emission stage CO2 emission	Indirect emission stage CO2 emission	Full life cycle CO2 emission
Diesel buses	49.97L/100km	125.72kg/100km	322.8kg/100km	448.52kg/100km
Pure electric buses	116.49L/100km	0.00kg/100km	174kg/100km	174.01kg/100km

3.3 Analysis of CO_2 emission reduction effect

Based on the above setting scenario model, the CO_2 emission reduction effect of the whole life cycle of the energy chain of pure electric buses in Hong Kong under different scenarios is shown in Table 6. It can be seen that under different scenarios, greenhouse gas emissions per 100 kilometers of pure electric buses and diesel buses show a downward trend as the proportion of coal electricity decreases. According to the calculation of greenhouse gas emissions under different scenarios, considering the operation scale of pure electric buses under different scenarios, it is predicted that 2028 and 2033 will achieve CO_2 emission reduction of 200405.72 t and 271332.33 t per day, respectively.

4. Model 2: Capital and cost of pure electric bus replacement

4.1. Model establishment

4.1.1. Full life Cycle cost method:

This paper mainly adopts the whole life cycle cost method. The cost of two kinds of buses in different periods is analyzed by establishing the whole life cycle cost model of buses. Secondly, the sensitivity analysis method is adopted, assuming that other factors are unchanged, only one factor is changed, and its impact on the total cost in the whole life cycle is analyzed. The bus life cycle cost model consists of four parts: the first part is the acquisition (Ca), that is, the purchase price of the vehicle a, the purchase tax of the vehicle b, the government subsidy c, and the profit and loss of the bus scrapping d. The second part is the cost of use (Ce). The third section is the cost of repair and maintenance (Cf). The fourth part is the core parts replacement cost (Cg). Among them, the use cost is mainly fuel cost and charging fee, which is determined by the product of the annual unit price of energy (P), the energy consumption of 100 kilometers (E), and the annual mileage of the vehicle (S). Therefore, the whole life cycle cost model is:

$$C = a + b - c - d + \sum_{i=1}^{n} P \times E \times S + C_f + C_g \tag{14}$$

4.1.2. Cost calculation and variance analysis of the whole life cycle

Based on the established full life cycle cost model as a metrological model, this paper calculates the full life cycle cost of six types of urban buses: fuel, CNG natural gas, LNG natural gas, gas-electric hybrid, pure electric, and hydrogen energy. The economic evaluation of urban buses of different energy types is completed through the comparative analysis of the cost differences of their whole life cycle.

4.1.3 Initial acquisition cost CI

For fuel city public transport, the initial acquisition cost CI mainly consists of two parts: urban public transport purchase cost CI_1 and vehicle purchase tax CI_2. The corresponding purchase tax is exempted for new energy city buses, and the government purchase subsidy CI_3 needs to be deducted. In the formula CI= $CI_1 - CI_2$, CI_1 is the purchase cost of urban public transport; CI_2 is the government purchase subsidy of new energy city buses.
Government purchase subsidies for new energy city buses We assume that the two types of pure electric city buses enjoy the government purchase subsidy CI_3, and the subsidy standard is at most 50% of the purchase replacement cost according to the title.

4.1.4 Operating cost CO

The operating cost of CO is mainly composed of CO_1, the fuel cost of urban bus operation. CO_2 from the government operation subsidy should be deducted for energy-saving and new energy buses.
(1)Fuel cost CO_1. The mileage of an urban bus in the whole life cycle, the average energy consumption of 100 kilometers, and the fuel price are used to calculate the fuel cost CO_1:

$$CO_1 = M \times S \times P \tag{15}$$

Where M is the average 100km energy consumption of urban public transport (L / 100km); S is the mileage of an urban bus in its whole life cycle (10,000 km); and P is the unit fuel price (yuan /L).
According to the survey results and data analysis, the average annual mileage of urban public transport in Hong Kong is 80,000 kilometers, the service life of public trans-

port is 18 years, and the total mileage of the life cycle is 1.44 million kilometers. The research assumes the market price of fuel and the 100 km energy consumption of six types of vehicles remain unchanged during the life cycle, and the least square method is used to fit the fuel price according to the Hong Kong Price yearbook.

(2) CO_2 subsidized by government operation

Based on the analysis, the operating cost list of pure electric urban buses is shown in Table 2.

Table 2 Cost of Fuel class

Fuel class	Total mileage (10000km)	100km fuel cost(yuan)	CO1 fuel cost (10000yuan)	CO2 operation subsidy (10000yuan)	CO operating cost (10000yuan)
Diesel	44	241	106	0	106
Pure electric	44	94.5	41.6	64	-22.4

4.1.5 Operation maintenance and repair cost CM + CF

Based on the statistical results of the cost data of operation and maintenance, primary maintenance, secondary maintenance, and overhaul of all types of public transport in the vehicle life cycle within five years, this paper mainly considers the cost of materials, excluding the cost of infrastructure investment and labor costs, and calculates the annual average cost to estimate its operation and maintenance and repair cost CM + CF.

$$CM + CF = \sum i = 15(CM_i + CF_i) \qquad (16)$$

Where: CM_i and CF_i are, respectively, the maintenance and repair costs per year (i = 1, 2,...,5). According to the survey, the average annual maintenance and repair cost of fuel city buses in Hong Kong is 11,232. The pure electric bus motor, battery, and electric drive system supplier warranty are eight years or more. At the same time, the traditional engine, gearbox, and clutch assembly components are canceled, the amount of maintenance has dropped significantly, and the average annual maintenance and repair costs are 6637 yuan, according to the pure electric basis of 20% increase in maintenance and repair costs, It is estimated that the average annual maintenance and repair cost is 7964 yuan. According to the above research, the whole life cycle cost of a pure electric urban bus is calculated according to the whole life cycle formula.

According to the configuration parameters of Alexander EV500, BYD K8 uses a lithium iron phosphate battery; the battery has a long cycle life; even if the cycle is used 6000 times, the battery power can still reach more than 75%. Theoretically, the battery life can reach ten years. And Alexander EV500 scrap life is also 18 years, and in these 18 years, we do not need to replace the battery, so the cost of replacing the battery is 0.

4.2 Model Verification

Electric city buses have the lowest life cycle costs and obvious economic advantages. From the perspective of the specific modules of the whole life cycle cost, except the initial acquisition cost of the CI module, the cost of pure electric urban bus in other life cycle modules is the lowest. Especially the operating cost CO module, with the development of pure electric vehicle three-electric system related core technologies, the research results show that pure electric city bus has the lowest life cycle cost, has obvious economic advantages, meets the needs of the United Nations energy conservation and emission reduction blue sky defense war, and is the most ideal type of bus at present.

The implementation of urban bus electrification in the field of public service has great development advantages, but pure electric city buses also have limitations to be improved, which are as follows: due to the limitation of charging time and lagging charging facilities, the completed charging piles are in full load operation, and a large number of pure electric buses to be put into the market can only be suspended; Limited by battery range, the actual operating range of the 150 kWh battery of the pure electric city bus is about 150 kilometers, and when the air conditioning is turned on in summer, the range is reduced to about 100 kilometers, which cannot meet the needs of the main line with high load and large volume of traffic; Limited by the efficiency of the battery thermal management system, the battery thermal management system of the pure electric bus has little heating effect at zero temperature, and the cooling effect is not large in the high temperature environment in summer, which needs to be improved.

4.3. Sensitivity analysis

Through the formula, the content of the model is calculated to test the decisive role of the change of relative cost on the overall price factor. The life cycle cost of Alexander EV500 = purchase cost + use cost + repair cost + battery replacement cost. When the purchase cost changes by 1%, the full life cycle cost of the Alexander EV500 changes by 0.45%. When the use cost changes by 1%, the full life cycle cost of the Alexander EV500 changes by 0.28%. When the maintenance cost changes by 1%, the life cycle cost of Alexander EV500 changes by 0.27%.

5. Application in specific regions

Given the financial situation forecast mentioned in the above model, the process of upgrading Hong Kong's bus services to pure electric in 2024-2033 is proposed:

Table 3 shows the process of upgrading Hong Kong's bus services to pure electric in 2024-2033

Year	Goals expected to be achieved	Ratio of pure electrification
2024	Purchase 200 buses	15
2025	Purchase 400 buses	25
2026	Purchase 550 buses	30
2027	Replace 600 buses	35
2028	Replace 650 buses	40
2029	Purchase 700 buses	55
2030	Replace 650 buses	65
2031	Replace 700 buses	70
2032	Replace 800 buses	85
2033	Replace 850 buses	100

The reason for the target is that with 3.2 million dollars allocated for 2024, the Treasury can afford a subsidy of 22.7%, 200 buses should have been replaced that year, and 15% is an additional all-electric target.

For the 2025 allocation of 3403300 dollars, the Treasury can bear the subsidy at a rate of 24.4 %, 400 buses should have been replaced that year, and 25% is an additional all-electric target.

With an allocation of 3697000 dollars for 2026, the Treasury can afford a subsidy rate of 26.1%, 550 buses should have been replaced that year, and 30% is an additional pure electric target.

For the 2027 allocation of 4,022,000 dollars, the Treasury could have borne the subsidy at a rate of 27.8%, and 600 buses would have been replaced that year with an additional all-electric target of 35%.

For the 2028 allocation of 4,231,000 dollars, the Treasury can afford a 29.5% subsidy, and 650 buses should have been replaced that year, with an additional 40% all-electric target.

In the 2029 allocation of 4,339,000 dollars, the Treasury could have borne the subsidy at a rate of 31.2%, which would have replaced 700 buses that year, and 55% would have been an additional all-electric target.

In the 2030 allocation of 4,514,000 dollars, the Treasury could have borne the subsidy at a rate of 32.9%, and 650 buses would have been replaced that year, with an additional goal of 65% being all-electric.

In the 2031 allocation of 4,753,000 dollars, the Treasury could have borne the subsidy at 34.6%, 700 buses would have been replaced that year, and 70% would have been an additional all-electric target.

In the 2032 allocation of 4,897,000 dollars, the Treasury could have borne the subsidy at 36.3%, 800 buses would have been replaced that year, and 85% would have been an additional all-electric target.

In the 2033 allocation of 4,968,000 dollars, the Treasury could have borne the subsidy at a 38% rate, and 850 buses would have been replaced that year with an additional 100% electric goal.

Benefits of the replacement rate:

Excessive exhaust emissions in urban areas.

This point, I think, is the most important reason for the popularity of electric buses; in all places, they emphasize the control of urban pollution and reduce exhaust emissions in the case of electric vehicles.

The electric bus mileage is fixed.

The biggest difference between electric cars and electric buses is not the difference in mileage, which may be longer per day for buses. Still, the biggest difference is the uncertainty, which makes the average user use electric cars to increase range anxiety. Electric buses are different from private cars; electric bus mileage is fixed, with a maximum of one or two hundred kilometers per day, and is completely within the range; even if the range is insufficient, you can flexibly arrange charging time.

The cost of electric buses is low.

The bus has to travel a long distance every day, which leads to a very big expense to use them for years. Switching to electric buses will undoubtedly save a large amount

of cost.
Electric buses have plenty of space for batteries.
The family car is subject to size, the space on the car is precious, and the battery can only be placed above the chassis, which also leads to the limited battery life of the electric vehicle. Many people take the electric bus will find that the electric bus tail has a very thick area is dedicated to placing the battery, such as BYD K9, fully charged working conditions range of 250 kilometers, The single battery capacity of the vehicle is 200Ah, and the total power reaches 324kw/h, which is 5-8 times that of ordinary household electric vehicles.
Special maintenance, easy to charge.
For home electric vehicle owners, if there is no charging pile at home, you need to go everywhere to find a charging pile, especially for long-distance travel. It is particularly inconvenient, but the electric bus is different; the bus company has a special charging station; after the car is collected every night, it will be charged, and the next morning, full of blood resurrection.
The manufacturer's warranty policy is different.
Many people do not want to buy electric cars to worry about the life of the battery. For such a large order of buses, electric vehicle manufacturers will strive for so both sides will agree on the battery warranty policy, which is likely to give a higher warranty policy than the family car or give a very favorable battery replacement price.
After constructing the model based on Hong Kong, we will promote this model to other regions. The model also applies to New York State and London.

Table 4 shows the process of upgrading bus services to pure electric in 2024-2030

Year	Goals expected to be achieved	Pure electrification ratio
2024	59	1
2025	472	5
2026	885	15
2027	1475	25
2028	2655	45
2029	4425	75
2030	5900	100

By converting all 5,900 internal combustion engine buses to pure electric buses according to our model, New York City could avoid more than 500,000 tons of greenhouse gas emissions per year while eliminating waste and related pollutants from burning diesel and better protecting the health of its citizens. New York City's bus fleet is so busy that the switch should not affect passengers' daily travel. For example, the 19 buses on the Q44 in Queens would only need to be replaced by two all-electric buses in the first year, three in the second year, and by the fifth year.

Table 5 The Process of Upgrading Bus Services to Pure Electric in 2024-2029

Year	Goals expected to be achieved	Pure electrification ratio
2024	480	5
2025	960	10
2026	1920	20
2027	3360	35
2028	6240	65
2029	9600	100

Converting around 9,600 internal combustion engine buses to pure electric buses in our model would reduce nitrogen oxide emissions in London by up to 90%. Similarly, the shift to buses in London will need to happen gradually. For example, three pure electric buses will be introduced on Route 80 in the first year, five in the second year, and finally, in the fourth year, together with other bus routes in the same region, the conversion of buses will be completed to increase the proportion of pure electric buses.
After collecting the relevant data about the two cities, we found some basic information about them.

Table 6 Basic Information about New York State and London

City	Number of buses in operation	Daily ridership	Air quality index
New York	5900	20100	AQI 15
London	9600	6 million	AQI 20

Plugging these data into our model, we found that the scheme worked well for both cities and could be applied to our model.

This model is very accurate. When we consider the CO_2 emission model, we start from two perspectives. This is very realistic, and the model is reasonable. For CO emissions, a lot of factors are considered, as well as various proportions, and the consideration is very comprehensive. In addition, the model does the sensitivity analysis, uses the derivative function to express, and then converts it into a general formula to solve broad ideas. The model's conclusions are listed in tabular form, which is very clear and explained. The second model is mainly analyzed in terms of cost, considering several parts, which are divided into initial acquisition cost, operating cost, operating maintenance and repair cost, and battery replacement cost. Each cost is expressed by a formula, which is very valid. When considering the purchase cost and operating cost, the electric bus purchase tax exemption is considered, as well as the operation subsidy, and the fuel car has a very obvious advantage; the factors considered are very comprehensive. The sensitivity analysis of the model is also carried out according to the change of a single cost to explain the change in the whole cycle, which is very clear and correct. Therefore, this model can be extended to different regions.

6. Strengthens and weaknesses

6.1 Strengthens

We consider the CO2 emission model from two perspectives. The first is the indirect model of CO2 emission, and the second is the non-indirect model of CO emission, which is very realistic and reasonable.

The indirect model of CO2 emissions and the non-indirect model of CO emissions contain a lot of factors considered, as well as various proportions, and the consideration is very comprehensive. In addition, the model does the sensitivity analysis, uses the derivative function to express, and then converts it into a general formula to solve broad ideas.

6.2 Weaknesses

This paper did not consider practical factors and the contents that affect the endurance of pure electric vehicles and their endurance attenuation. It only regarded many problems that would change over time as constants and obtained the calculation results. We believe such calculation results are more ideal and optimistic than the actual operation. The model used in this article is not fully certified by the industry and is relatively innovative. In many problems, the solution does not have complete theoretical support.

7. Conclusion

First of all, based on our carbon emission model, we studied the CO2 emission and emission reduction ratio of pure electric buses in the direct emission stage, indirect emission stage, and the whole life cycle process and came up with a better solution: In different scenarios, with the decrease of the proportion of coal electricity, the greenhouse gas emissions per 100 kilometers of pure electric buses and diesel buses show a downward trend. According to the calculation of greenhouse gas emissions under different scenarios, considering the operation scale of pure electric buses under different scenarios, it is predicted that 2028 and 2033 will achieve CO2 emission reduction of 200,405.72 t and 271,332.33 t per day, respectively. Secondly, based on our capital budget model, we studied the full life cycle cost, initial acquisition cost, operating cost, and maintenance and repair cost of various types of buses. We predicted the financial situation of Hong Kong in the next ten years, and reached the following conclusions:

The full life cycle cost of electric city buses is the lowest, with obvious economic advantages. From the perspective of the specific modules of the whole life cycle cost, except the initial acquisition cost CI module, the cost of pure electric urban bus in other life cycle modules is the lowest. Especially the operating cost CO module, with the development of pure electric vehicle three-electric system-related core technologies.

The implementation of urban bus electrification in the field of public service has great development advantages, but pure electric city buses also have limitations to be improved, which are as follows: due to the restriction of charging time and lagging charging facilities, the completed charging piles are in full load operation, and a large number of pure electric buses to be put into the market can only be suspended; Limited by the battery range, the actual operating range of the 150 kWh battery of the pure electric city bus is about 150 kilometers, and when the air conditioning is turned on in summer, the range is reduced to about 100 kilometers, which cannot meet the needs of the main line with high load and large volume of traffic; Limited by the efficiency of the battery thermal management system, the battery thermal management system of the pure electric bus has little heating effect at zero temperature, and the cooling effect is not large in the high temperature environment in summer, which needs to be improved. In addition, due to the Alexander EV500's full life cycle cost = purchase cost + use cost + maintenance cost + battery replacement cost. When the purchase cost changes by 1%, the full life cycle cost of the Alexander EV500 changes by 0.45%. When the cost of use changes by 1%, the full life cycle cost of the Alexander EV500 changes by 0.28%. When the maintenance cost changes by 1%, the life cycle cost of the Alexander EV500 changes by 0.27%, which is not taken into account because the battery replacement cost is 0.

The financial projections for Hong Kong over the next ten years are as follows. With an allocation of US 3.2 million dollars in 2024, the finance can bear the subsidy at a rate of 22.7%, and with an allocation of US 4,968,000 dollars in 2033, the Finance can bear the subsidy at a rate of 38%. With the support of the above theoretical calculation, we plan the following. We apply the above model to other cities, such as London and New York, and plan updated schedules for them as their reference.

Therefore, our solution is applicable in Hong Kong and can be extended to other cities. It is a tried-and-tested solution.

Finally, we analyzed and predicted the financial situation of Hong Kong and the number, ridership, and air quality of the operating buses in New York and London, planned the process of upgrading the bus services in Hong Kong, New York, and London in the next few years, and proposed the plan of implementing pure electric buses in these three cities in the next ten years.

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