Urban Public Transport Roadmap Planning Based on Benefit Analysis

The popularity of electric buses represents the possibility of further progress towards the goal of sustainable development of urban transportation. This paper collected the city characteristic data of St. Louis, established carbon emission model, atmosphere model, life cycle cost model, cost-benefit model and comprehensive evaluation model, introduced linear programming, analytic hierarchy process and other methods, comprehensively analyzed the ecological and economic benefits of electric buses, and helped the city plan the update roadmap of electric buses, which has strong practical significance.

For problem 1, we need to analyze the ecological benefits that electric bus fleets can bring. From a practical point of view, electric buses use electric energy as a power source, and the operation process has the environmental protection characteristics of zero emission of pollutants. We determined that the object of the study is the most important factor affecting the ecological environment emitted by diesel vehicles, namely carbon dioxide. Carbon emission model was established, performance data of electric bus and diesel bus were collected, linear analysis method was introduced to calculate the total annual carbon emission of each bus, and benefit analysis was conducted by comparing the data of the two. Secondly, considering that the damage of diesel vehicles to the ecological environment is partly due to the emission of air pollutants, we established an atmospheric model and calculated the total emissions of different types of air pollutants of the two types of buses in the service life, and drew a conclusion from the analysis.

For problem 2, what we need to analyze is the financial cost-benefit problem. From the current industry development point of view, the operating costs of electric buses are decreasing, which is reflected in the reduction of battery prices and the continuous investment of government financial subsidies, which is cost-effective. Therefore, we first established the life cycle cost model, divided the cost generated in the life cycle of the two types of buses into two types, and analyzed and compared the cost difference between the two. Secondly, a cost-benefit model is established to analyze the benefits of the electric bus fleet and calculate its total upfront investment cost. The net present value income analysis method is introduced to calculate the net present value income that can be produced during the service life cycle of electric buses, and the economic benefits of electric bus operation are analyzed from the data.

For problem 3, we need to create a 10-year roadmap to help St. Louis plan the renewal of its electric bus fleet. After analysis, we divide the project cycle into four parts. During the initial assessment and planning period, we conduct market research and infrastructure evaluation and identify government financial subsidy options. In the pilot stage, a small number of electric buses are put into pilot use on selected routes, and the operation data of electric buses and passenger feedback are collected, so as to determine the detailed operation plan. In the phased deployment phase, the main problem is to solve the infrastructure problem and optimize the route. In the comprehensive transformation phase, the entire bus fleet will be electrified and a long-term vehicle maintenance update mechanism and a regular fleet evaluation mechanism will be established. Therefore, we establish a comprehensive evaluation model, introduce linear programming analysis method, determine the weight of factors affecting route planning, and combine the actual data to determine the optimal deployment route of electric buses.

Keywords: LaTeX, Roadmap, Benefit Analysis

Contents

1. Introduction

1.1. Restatement of the Problem

With the continuous deterioration of the ecological environment, more and more people are aware of the importance of environmental protection and practice environmental protection in all aspects of life, and public transportation has become the choice of more and more people. At present, most buses still use diesel as a power source, but some cities have put electric buses into operation, which has a huge boost to energy conservation, emission reduction and pollution reduction. More and more countries and regions are aware of the superiority of electric buses, and are adopting policies to vigorously support the development of electric bus industry.

However, challenges include high initial costs, charging infrastructure development,lengthy charging times, and potential range limitations.

Based on this situation, we need to solve the following problems:

•Construct a model to aid cities in understanding the ecological consequences of transitioning to an all-electric bus fleet.

•Construct a model that focuses on the financial implications associated with a conversion to e-buses.

•Transportation officials in metropolitan areas are exploring approaches in which they gradually change their fleet from combustion engines buses to electric. Assuming the goal is to have a fully electric fleet no later than 2033, utilize your previously developed models to craft a 10-year roadmap that urban transport authorities can leverage to plan their e-bus fleet updates.

•Write a one-page letter to the transportation officials of one of your chosen metropolitan areas in which you detail your recommendation for their transition to e-buses.

1.2. Overview of Our Work

1.2.1. *Problem 1:Ecological Benefits Analysis*

This question mainly studies the ecological benefits brought by electric buses. After analysis, we decided to directly reflect the impact of electric buses and diesel vehicles on the ecological environment through detailed data and then compare the ecological benefits brought by electric buses. First of all, considering that the main substance emitted by bus operation is carbon dioxide, we establish a carbon emission model, analyze the carbon emission size of the two types of vehicles combined with the collected performance data, and compare the results. Secondly, considering the impact of global warming, cars will also cause air pollution. Therefore, we established an atmospheric model to collect pollutant emission factors of other harmful substances in the two types of cars except carbon dioxide, and then calculated the emissions of different kinds of pollutants during the operation of the two types of buses, and finally conducted data analysis and comparison.

1.2.2. *Problem 2:Cost-effectiveness Analysis*

The purpose of this question is to find out whether electric buses are competitive in the market compared with diesel buses in terms of both costs and benefits, that is, to analyze whether the economic benefits of electric buses are worthy of large-scale use by the local government. First of all, considering that both electric buses and diesel buses have service life, and the process of replacing diesel buses with electric buses is gradual, we established a life cycle cost model, determined the life cycle length as the service life of buses, and roughly divided the cost into acquisition cost and maintenance cost within the life cycle. Combined with the collected performance parameters of the two types of vehicles and the relevant city characteristics data of St. Louis, the various costs generated during the life cycle of the two types of vehicles were simply summed up and compared, and the market competitiveness of the two types of buses was compared. Secondly, the cost-benefit analysis model is established, the net present value calculation formula is introduced, the income is converted into data, and the economic benefit of electric buses is judged by judging the size of the data.

1.2.3. *Problem 3:Optimal Roadmap Planning*

This question requires us to develop a 10-year roadmap for the city's transportation authorities to help them update the city's electric bus fleet. First of all, we make it clear that due to the characteristics of electric buses themselves, problems such as infrastructure, public acceptance, and available funds need to be solved before they are put into trial use, and the completion of the all-electric bus fleet needs to be carried out gradually from the pilot stage where a small number of buses are put into use. Therefore, we will divide the 10-year renewal cycle into four stages, and will complete the renewal and mature use of the all-electric bus fleet at the end of these four stages. We establish a comprehensive evaluation model, enumerates multiple factors affecting route planning, and introduces analytic hierarchy process (AHP) to confirm the respective weights of the influencing factors, so as to achieve the goal of maximum passenger flow coverage and minimum operating cost in the roadmap planning.

2. Assumptions and Justifications

We make the following assumptions to help us with our modeling. These assumptions form the background for our subsequent analysis.

•Assumption 1:the bus will run normally, independent of personal factors such as the driver and other small probability events such as extreme weather. This is because we need ensure that the many factors in the model such as service frequency, emissions, etc., do not produce abnormal extreme values.

•Assumption 2:the investment plan of electric buses is not affected by external factors and is continuously supported by policies. This is done to ensure that the model is built according to the established plan.

•Assumption 3:the purchase and maintenance cost of buses changes according to the constant annual growth rate.

•Assumption 4:the electric bus does not have a small probability event such as a car accident and other abnormal circumstances in 10 years, resulting in the change of the given number and revenue

cost. This is to reduce the impact of small probability events on the model.

3. Notations

Symbol	Definition
ER	emission reduction
CEE	$C_{Emission_{\text{ebus}}}$
$CEDD$	$C_{Emission_{\text{diesel}}}$
$CPEE$	$C_{PollutantEmission_{\text{ebus}}}$
$CPED$	$C_{PollutantEmission_{\text{diesel}}}$
$NPVE$	NPV_{ebus}
$NPVD$	NPV_{diesel}
LCC	Life cycle costing
R_i	Rating

4. Problem 1:Ecological Benefits Analysis

4.1. Comparison of Carbon Emission Based on Carbon Emission Model

4.1.1. *Establishment of Model*

4.1.2. *Data Analysis*

Table 1: Carbon emissions influence factor table

	amount	**annual mileage**	**Average energy consumption**	**emission factor**
ebus	500	30000miles	1.3kwh/mile	0.75 pounds CO_2e/kWh
diesel bus	500	30000miles	0.2gallon/mile	22.38 pounds CO_2e/kWh

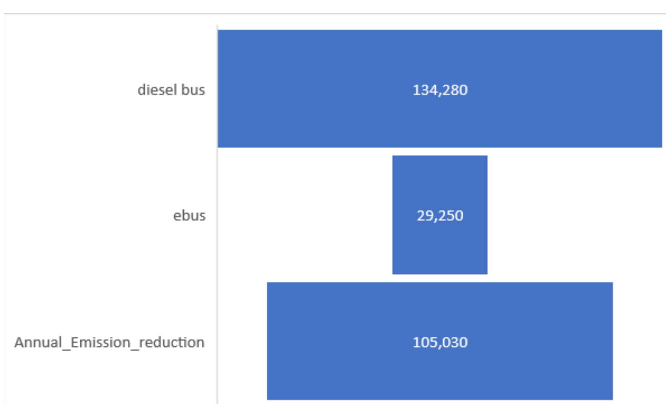

Figure 1: Carbon emission comparison chart

4.2. Comparison of Pollutant Emissions Based on Atmospheric Model

4.2.1. *Establishment of Model*

4.2.2. *Data Analysis*

5. Problem 2:Cost-effectiveness Analysis

Life cycle cost refers to the total sum of all expenses associated with a product, service, or project throughout its entire lifecycle, including costs incurred during the design, development, production, operation, maintenance, and disposal phases. Calculating the life cycle cost helps in a more comprehensive evaluation and management of the economic benefits and feasibility of a project or product. To explore the economic benefits and feasibility of the electric bus deployment plan, this study sequentially establishes life cycle cost model and cost-benefit analysis model to analyze the market cost competitiveness and economic benefits of electric buses.

5.1. Cost Comparison Based on Life Cycle Costing Model

5.1.1. *Establishment of Model*

Based on the life cycle theory, this paper establishes the life cycle cost analysis model of electric bus and diesel vehicle, and accounts the total cost of the two kinds of buses during the life cycle. First of all, the life cycle cost components of the two types of buses should be clarified. According to the life cycle stage of the bus, the whole life cycle cost is divided into two parts: acquisition cost and operation and maintenance cost.

•Acquisition Cost

In the electric bus investment plan, we need to take into account the total acquisition cost of electric buses in 10 years. In general, the acquisition cost is the cost of only purchasing buses in the initial stage of project construction, which is usually reflected in the product of the total number of vehicles purchased and the unit price of vehicles purchased. Then we get the formula for calculating the total acquisition cost $TC_{acquisition}$ as follows:

$$TC_{\text{acquisition}} = N \cdot C_{\text{initial}} \tag{1}$$

Where, N represents the total number of vehicles purchased and $C_{initial}$ represents the initial purchase cost of each vehicle.

•Operation and maintenance cost

In the process of formally implementing the 10-year investment plan, the operation and maintenance cost of electric buses can not be ignored. Operation and maintenance cost refers to the cost incurred during the operation and maintenance of buses, which is embodied in the electricity cost generated by the operation of electric buses after a distance, the fuel cost generated by the operation of diesel buses after a distance, and the cost incurred during the annual vehicle maintenance and maintenance of the two types of vehicles. The total operating cost $TC_{operation}$ of the bus is calculated as follows:

$$TC_{\text{operation}} = N \cdot D \cdot C_{\text{operation}} \tag{2}$$

Among them, the average annual driving distance of each bus is D, and the average electricity or fuel cost generated by each bus during operation is $C_{operation}$.

The calculation formula of bus total maintenance cost $TC_{maintenance}$ is as follows:

$$TC_{\text{maintenance}} = L \cdot N \cdot C_{\text{maintenance}} \tag{3}$$

Among them, the average annual maintenance cost of the bus is $C_{maintenance}$, and the expected service life of the bus is L.

The Operation and maintenance cost is the sum of total operation cost $TC_{operation}$ and total maintenance cost $TC_{maintenance}$.

•Salvage value In the process of officially implementing the 10-year investment plan, electric public vehicles will also have problems such as failure and cannot continue to operate. Because the buses that exceed the expected service life are no longer involved in the operation of urban bus lines, in order to maximize the benefits, the scrapped buses are usually sold to extract the residual value of the buses and save investment costs. Therefore, the total life cycle cost should also consider the impact of the residual value of the bus after scrapping. Assuming that the residual value of the bus after scrapping is $Residual_{value}$, the calculation formula of residual value $Residual_{value}$ is as follows:

$$Residual_{\text{value}} = C_{\text{initial}} \cdot \left(1 - \frac{l}{L}\right) \tag{4}$$

Where l is the number of years used and L is the expected service life of the bus.

The formula for calculating the total residual value is as follows:

$$Total_{\text{Residual}_{\text{value}}} = N \cdot Residual_{\text{value}} \tag{5}$$

•In summary, we give the calculation formula of the whole life cycle cost TC:

$$TC = N \cdot C_{\text{initial}} + L \cdot N \cdot C_{\text{maintenance}} + N \cdot D \cdot C_{\text{operation}} - N \cdot Residual_{\text{value}} \tag{6}$$

5.1.2. *Data Analysis*

We investigated Proterra Inc., a giant manufacturer of electric buses in the United States. The current performance parameters of electric buses and diesel buses, including purchase price, expected service life, energy consumption, annual mileage and other data, were obtained from the official website of Flyer Industries, the largest bus manufacturer in North America, and the electricity price and oil price in St. Louis were obtained by inquiring the United States Energy Information Administration. The relevant data table is summarized as follows:

Since we assume that each vehicle will operate normally throughout its life cycle until it exceeds its useful life, the residual value is by definition zero. In addition, as a project with huge social and ecological benefits, the federal government and the state government will adopt policy subsidies, which can cover about 50% of the entire life cycle cost of electric buses.

Table 2: Bus Performance Parameters Table

	amount	**annual mileage**	**acquisition cost**	**energy consumption**	**maintenance cost**
ebus	500	30000km	$125000	130kwh/100km	$0.05/km
diesel bus	500	30000km	$83333	50L/100km	$0.1/km

Table 3: Cost Statement

	$TC_{\text{acquisition}}$	$TC_{\text{operation}}$	$TC_{\text{maintenance}}$	**policy subsid**	**TC**
ebus	$625000000	$56160000	$15000000	50%	$343400000
diesel bus	$416666666	$180000000	$30000000	0	$626666666

We use the established life cycle cost model to calculate the cost of electric buses and diesel buses during their respective life cycles, and the calculation results are as follows:

Combined with the calculation results in the above table, we carry out the following analysis.

Due to the current high production cost of long-life batteries, the purchase cost of each electric bus is higher than that of diesel buses when other components are the same. However, the rapid development of renewable energy technology in recent years will continue to reduce the cost of new energy technology products such as long-life batteries; At present, the global demand for crude oil continues to grow, the lack of production capacity release, resulting in high diesel prices, so in terms of operating costs, electric buses are better than diesel buses. At the same time, based on the composition and maintenance difficulty of the internal parts of the electric bus, its maintenance cost is also lower than that of the diesel bus. More importantly, the federal government and the state government have greatly supported the electric bus industry, and the injection of external funds has greatly reduced the life cycle cost of electric buses. Considering the above factors, the life cycle cost of electric buses in 10 years is less than that of diesel buses, which has great market cost competitiveness and economic benefits.

5.2. Economic Benefit Analysis Based on Cost-benefit Analysis Model

5.2.1. *Establishment of Model*

In order to determine the economic value of replacing diesel buses with electric buses and gradually building an all-electric bus fleet, we establish a cost-benefit analysis model to analyze the economic benefits of gradually replacing diesel buses with electric buses, and analyze the optimal solution of the electric bus delivery plan, so as to determine whether this plan is feasible and obtain the optimal delivery plan.

We use the net income analysis method to evaluate the economic benefits of the project, and we divide the unit by year as the time of investment. Based on the above analysis of the whole life cycle cost of the two types of vehicles, we can see that the most significant cost savings of electric buses compared with diesel buses lies in their fuel costs. As can be seen from the above, the fuel cost of each electric bus compared with diesel buses is $Fuel_{\text{savings}}$about 13,860.

At the same time, the maintenance cost of electric buses is also less than the maintenance cost of diesel buses, but due to the continuous update of electric bus technology, in contrast, the maintenance cost of electric buses $Ebus_{\text{maintenance}}$will decline year by year. Diesel bus maintenance fee $Diesel_{\text{maintenance}}$will increase. Assume that the maintenance cost of electric buses $Ebus_{\text{maintenance}}$decreases by 2% annually, and the maintenance cost of diesel buses $Diesel_{\text{maintenance}}$increases by 2% annually. We can regard the maintenance cost of the two as an equal proportion series, which is convenient for later solving.

Similarly, the construction cost and purchase of charging piles for each electric bus will also decrease year by year due to technological update. Assume that the construction cost of charging piles for electric buses $Construction_{\text{cost}}$will decrease by 4% annually. The purchase cost of electric buses $Ebus_{\text{acquisition}}$will drop by 3 annually, and we will also look at the two as an equal ratio series.

From this, we can get diesel bus maintenance cost $Diesel_{\text{maintenance}}$, electric bus maintenance cost $Ebus_{\text{maintenance}}$, Electric bus charging pile construction cost $Construction_{\text{cost}}$, electric bus acquisition cost $Ebus_{\text{acquisition}}$general expression, as follows:

$$y_i = y_{i-1} \cdot (1 + c) \tag{7}$$

We determine the total size of the bus as N, and assume that we have invested n_i electric buses by the first $i$year of the project.

To sum up, what is the benefit of our project requiring electric buses to replace diesel buses? You can do this by comparing the cost savings of electric buses in that year relative to diesel buses $Cost_{\text{savings}_\text{i}}$ with the acquisition cost already incurred in that year $Ebus_{\text{acquisition}_\text{i}}$and the charging points already generated in that year After deducting the construction cost $Construction_{\text{cost}_\text{i}}$, the total data generated during the ten years of the project can be summed to obtain the ten-year income of the project. The formula for calculating the total profit TR is as follows:

$$TR = \sum_{i=1}^{10} x_i[(\sum_{k=i}^{10} Fuel_{\text{savings}} + Diesel_{\text{maintenance}_\text{k}} - Ebus_{\text{maintenance}_\text{k}}) - Ebus_{\text{acquisition}_\text{i}} - Construction_{\text{cost}_\text{i}}] \tag{8}$$

5.2.2. *Data Analysis*

The collected and summarized data in problem 1 is substituted into the solution formula of total profit TR, and the following data can be obtained by running it.

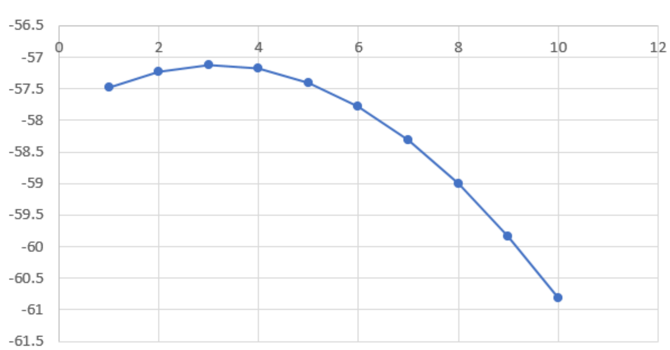

Figure 2: TR Ten Year Data Analysis Chart

Analysis of the data shows that $TR_1 > TR_2 > \ldots > TR_{10}$, that is if and only if $n_1 = N, n_2 = n_3 = \ldots = n_{10} = 0$. Takes the maximum value.

As bus is a means of public transport, it usually pays more attention to social benefits. Therefore, in order to make the public equally enjoy the public infrastructure of bus, the government usually adopts the way of lowering the ticket price to achieve the inclusiveness of infrastructure. Therefore, similar to the construction of other public infrastructure, the electric bus project will have a period of difficulty in making ends meet after it is put into use, which is called the investment payback period in economics. Therefore, when we analyze programs that are in the payback period, we tend to use investment programs with fewer initial losses. According to the above data analysis, only when the electric bus is purchased and put into use in the first year of the project will the loss of the investment payback period be minimized.

In summary, although the income of electric buses in the period of investment recovery is negative, its development potential is huge. After determining the optimal investment plan, although it is difficult to return the cost in the short term, its economic income will pick up in the long run, and drive the economic development around the bus lines.

6. Problem 3:Optimal Roadmap Planning Problems Based on Comprehensive Evaluation Model

6.1. Optimal Roadmap Planning Based on Comprehensive Evaluation Model

The comprehensive evaluation model is a method to comprehensively evaluate a specific object by considering multiple indexes, factors or dimensions comprehensively. This model is often used in decision making, project evaluation, risk management and other fields. The comprehensive evaluation model considers multiple evaluation indicators, which can be qualitative or quantitative. This allows for a more comprehensive and objective assessment of all aspects of the object. Models often involve assigning weights to different indicators to reflect their relative importance in the overall evaluation. These weights can be determined based on expert judgment, statistical analysis, or other methods. The comprehensive evaluation model combines scores of different indicators to generate a comprehensive score. Based on this score, objects can be ranked or classified to help make decisions.

•Step 1:Determine the weight

Step 1.1:Establish the hierarchical structure model

We make the problem organized and hierarchical, and construct a hierarchical structure model. These levels can be divided into three categories: the destination level, the middle level, and the bottom level. Among them, the number of elements of the criterion layer in the hierarchical structure is related to the influencing factors of the route, which are respectively: passenger flow, charging station location, route length, service frequency and operating cost. Ridership represents the average daily ridership of each route; Charging station location represents the number and location of charging stations on each route; Route length represents the total length of each route; Service frequency represents the bus departure interval of each route; Operating costs represent the expected operating costs of each route, including maintenance, energy and personnel expenses. The hierarchy is shown below:

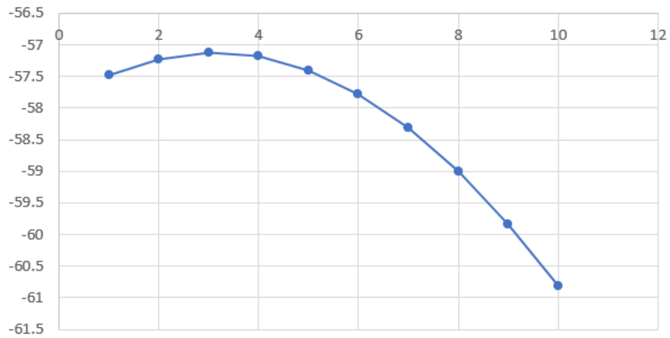

Figure 3: TR Ten Year Data Analysis Chart

Step 1.2:Construct judgment matrix

The proportion of each criterion in the target measurement is not necessarily the same, and each criterion occupies a certain proportion. We define the judgment matrix $A = (a_{ij})_{n \cdot n}$ by referring to the numbers $1 - 9$ and their reciprocal as scales.

scale	Definition
1	Both factors are of equal importance
3	Compared with the two factors, the former is slightly more important than the latter
5	Compared with the two factors, the former is significantly more important than the latter
7	Compared with the two factors, the former is more important than the latter
9	Compared with the two factors, the former is extremely important than the latter
$2, 4, 6, 8$	The median value of the above adjacency judgments
$reciprocal$	If the ratio of the importance of factor i to factor j is a_{ij}, then the ratio of the importance of factor j to factor i is $a_{\text{ji}} = \frac{1}{a_i}$

Step 1.3:Single hierarchical sort and its consistency test

Step 1.3.1:Calculate the consistency index CI

$$CI = \frac{\lambda_{\max} - n}{n - 1} \tag{9}$$

Step 1.3.2:Finds the consistency indicator RI

Step 1.3.3:Calculate the consistency ratio CR

$$CI = \frac{CI}{RI} \tag{10}$$

When $CR < 0.10$, it is considered that the consistency of the judgment matrix is acceptable, otherwise the judgment matrix should be modified appropriately

Step 1.4:Total hierarchical ranking and its consistency Test (Eigenvector method)

Multiply the weight vector W right by the weight matrix A, there is:

$$AW = \lambda_{\max} W \tag{11}$$

•Step 2:Determine the scoring criteria

Step 2.1:Passenger flow

Use the linear transformation method. Map the ridership of each route to a fixed range (for example, 0 to 100). The specific calculation formula is as follows:

$$P_i = \left(\frac{R_A - R_L}{R_H - R_L}\right) \cdot 100 \tag{12}$$

Where, P_i is the passenger flow score of route i; R_A is the daily average passenger flow of this route; R_H is the maximum daily passenger flow of the route; R_L is the minimum daily ridership of the route.

Step 2.2:Location of charging station The score is based on the number of charging stations on each route. The specific calculation formula is as follows:

$$C_i = \frac{N_i}{N_{\max}} \cdot 100 \tag{13}$$

Where, C_i is the score of the charging station location of route i; N_i is the number of charging stations on the route; $N_{textmax}$ is the number of charging stations on the route with the most charging stations of all routes.

Step 2.3:Route length

Consider the length of the route and the endurance of the electric bus. Using the normal distribution method, a longer route may require a higher score, provided the electric bus can cover that length. Only the length of a single trip is considered here. The specific calculation formula and image are as follows:

$$L_i = 100 \cdot e^{\left(-\frac{(x-20)^2}{98/(\ln 2)}\right)} \tag{14}$$

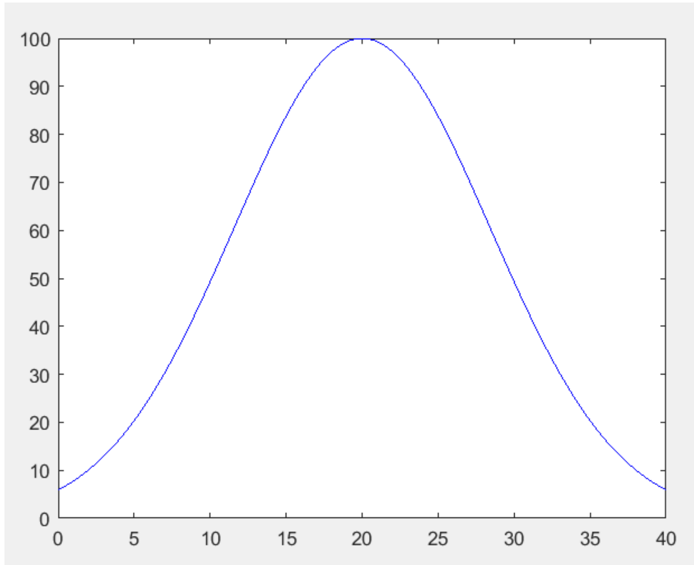

Figure 4: TR Ten Year Data Analysis Chart

Where, L_i is the route length score of route i; x is the length of route i. As shown in the figure, the figure shows the score obtained by the route length with the value range of $0 - 40$ km according to the rule of normal distribution. If the route length is too low, it indicates that the tram has not completed the maximum mileage, and the cost performance of the route is low. If the length of the route exceeds the maximum mileage, the benefit of the route is low. When the distance is moderate and just the mileage, the cost performance and benefit are the best, and the highest score is accordingly.

Step 2.4:Service frequency

Use linear conversion or categorical scoring methods. Routes with more frequent service receive higher ratings. The specific calculation formula is as follows:

$$F_i = \begin{cases} 50 & t = 0.5h \\ 100 & t = 1h \end{cases} \tag{15}$$

Among them, F_i is the service frequency score of route i; t is the service frequency for this route. After numerical preprocessing, we find that the service frequency is roughly one every hour and one every half hour, so the two service frequencies are assigned 100 and 50 points respectively.

Step 2.5: Operating costs:

Use the linear conversion method. Lower cost routes receive higher ratings. The specific calculation formula and image are as follows:

$$O_i = \frac{214}{\pi} \cdot \arctan\left(\frac{20 - x}{2}\right) \tag{16}$$

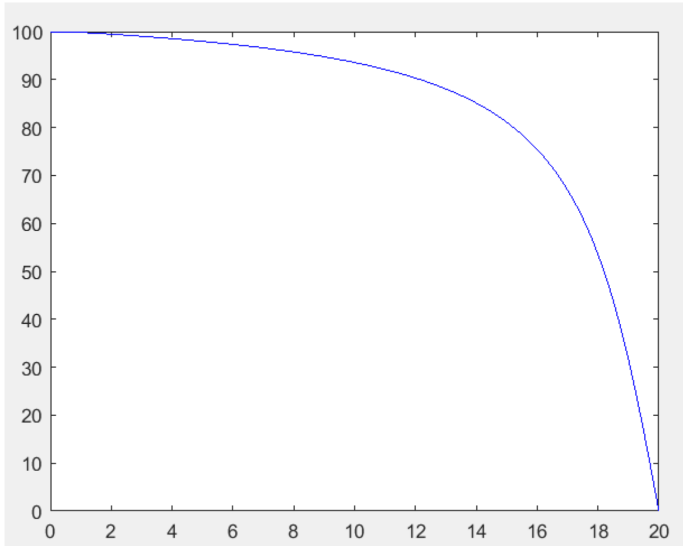

Figure 5: TR Ten Year Data Analysis Chart

Where, O_i is the operating cost score of route i; x is the operating cost of the route. As shown in the figure, this graph represents the operating cost in the range of \$0 to \$20 as scored according to the law of the arc-tangent function. The lower the operating cost, the higher the score; The reverse is also true.

•Step 3:Allotment score

Each factor data of each route is brought into the scoring standard of each data and the corresponding score is obtained.

•Step 4:Comprehensive score

Ri is set as the total score of route i, and the specific calculation formula is as follows:

$$R_i = w_1 \cdot P_i + w_2 \cdot C_i + w_3 \cdot L_i + w_4 \cdot F_i + w_5 \cdot O_i \tag{17}$$

Where P_i is the ridership score of Route i. C_i: Charging station location score for Route i. L_i: The length score of route i. F_i: Service frequency score for Route i. O_i: Operating cost score for Route i. w_1, w_2, w_3, w_4, w_5: The weights of ridership, charging station location, route length, service frequency, and operating cost, respectively.

6.2. Data Analysis

We inquired the official website of Bureau of Transportation Statistics and collected the relevant data of passenger flow, route length, charging station location, service frequency and operating cost. The judgment matrix A and its weight coefficient based on the analytic hierarchy process are shown as follows: $W = \begin{bmatrix} 0.26042254 \\ 0.06099529 \\ 0.12457606 \\ 0.11164655 \\ 0.44235955 \end{bmatrix}$

$$A = \begin{bmatrix} 1 & 3 & 5 & 2 & \frac{1}{2} \\ \frac{1}{3} & 1 & \frac{1}{3} & \frac{1}{3} & \frac{1}{5} \\ \frac{1}{5} & 3 & 1 & 2 & \frac{1}{5} \\ \frac{1}{2} & 3 & \frac{1}{2} & 1 & \frac{1}{5} \\ 2 & 5 & 5 & 5 & 1 \end{bmatrix}$$

$RI = 1.12$

$lambda_{max}$: 5.409565256771517

$Weights =$ [0.260422540.060995290.124576060.111646550.44235955]

$CR =$ 0.09142081624364211

Among them,$CR < 0.1$ is obtained by calculation, indicating that the consistency of the judgment matrix is acceptable. In the W matrix, $w_1, w_2, w_3, w_4 and w_5$ from top to bottom are respectively the weights of passenger flow, charging station location, route length, service frequency and operating cost.

After the above weights and the data processed by the scoring criteria are put into the comprehensive scoring formula, the scoring results and the routes obtained based on the scoring results are shown in the frequency distribution histogram and road map below:

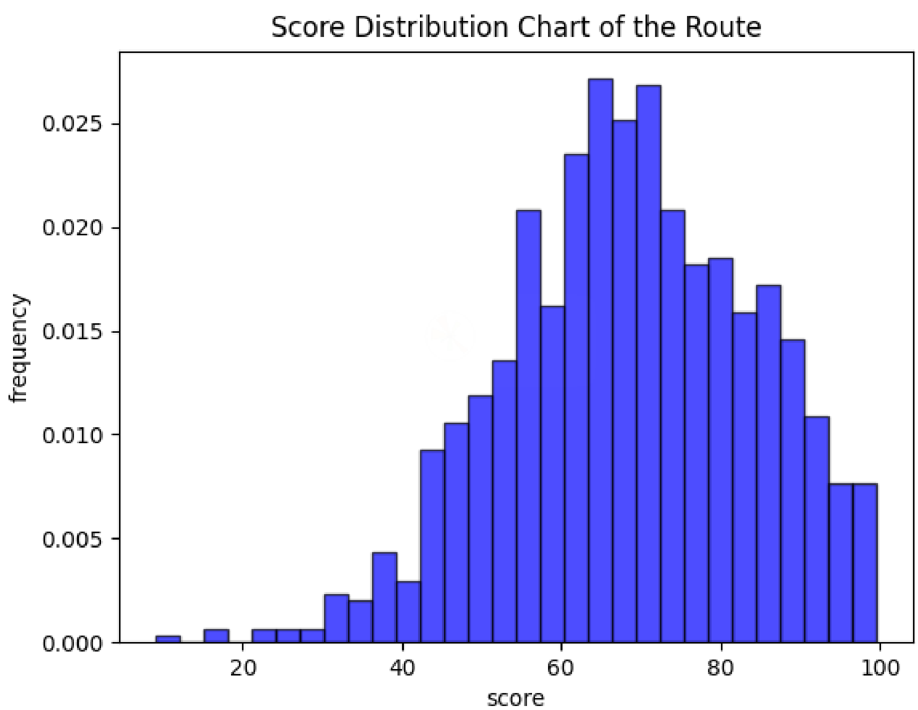

Figure 6: Score distribution Chart of the Route

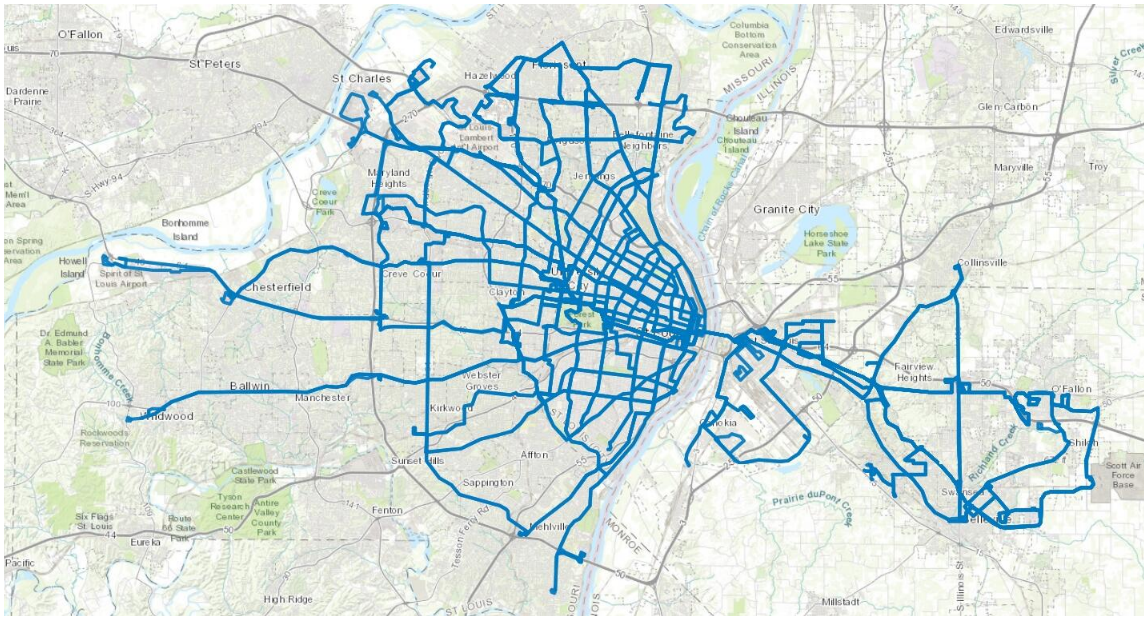

Figure 7: St. Louis Streetcar map

Among them, the route score map contains scores of many routes, so it is expressed in the form of frequency distribution histogram. The sample size is 1000, and the number of routes for each score is the product of the score frequency and sample size. The number and distribution of routes with different scores are shown in Figure 6. It can be found that the routes with medium and high scores are mostly the routes with low scores, and the routes with medium and high scores are relatively similar to the original bus routes. Therefore, we can make adjustments on the basis of the original bus routes, and the adjusted road map is shown in Figure 7.

6.3. Model application

After applying the comprehensive evaluation model established above to two electric bus cities similar to St. Louis, Cincinnati and Houston, which are also in the initial stage, the following route scores and trolley road maps can be obtained:

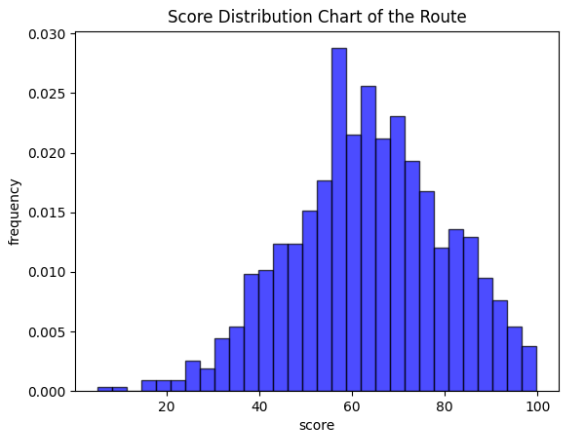

Figure 8: core distribution Chart of the Route

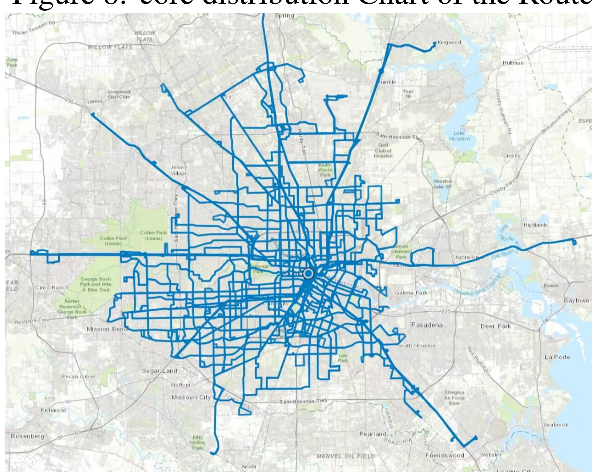

Figure 9: Houston Roadmap

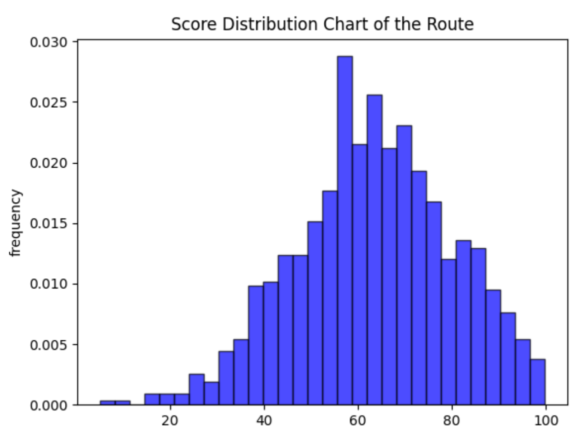

Figure 10: Score distribution Chart of the Route

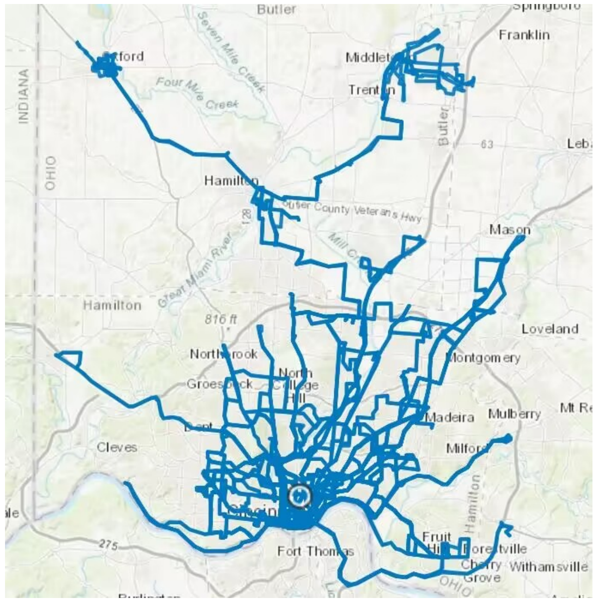

Figure 11: Cincinnati Road Map

Among them, the analysis result of the route is roughly the same as that of St. Louis, so we can make adjustments according to the planning method of St. Louis, and the adjusted road map is shown in the above figure

7. A Letter to the Transportation Officials

Dear Transportation Officials,

We conducted an in-depth analysis of St. Louis' public transit system, with a particular focus on the potential benefits of transitioning from traditional internal combustion engine buses to electric buses. The research shows that the popularization of electric buses will bring many advantages to St. Louis, including environmental quality improvement, economic benefit improvement, and significant social impact.

First, the adoption of electric buses will help improve local air quality and reduce emissions of greenhouse gases and air pollutants. This is essential to improve the quality of the urban environment, thereby protecting the health of citizens and enhancing the sustainability of cities. Our model analysis shows that the adoption of electric buses will reduce emissions of pollutants and greenhouse gases, contribute to the mitigation of the greenhouse effect, reduce human respiratory diseases and improve quality of life.

Second, our research finds that despite the higher initial investment cost of electric buses, the net present value benefits of electric buses are greater in the long run. With the continuous progress of new energy technology and the continuous improvement of charging infrastructure, the life cycle cost of electric buses will continue to decrease. In addition, strong policy support and the government's funding subsidy program will help ease the burden of initial investment.

Finally, the adoption of electric buses will help improve the local public transport system and the surrounding infrastructure construction, so as to beautify the city, promote technological innovation, create job opportunities, strengthen the public's transportation convenience, better gain the trust of the public and enhance the urban happiness index, and bring a positive impact on the local economic and social development.

Based on the above benefits, we strongly recommend that the transport authorities in your city consider designating a reasonable plan for the introduction of electric buses and develop relevant policies around this plan to ensure the smooth implementation of the plan and complete the transition from traditional internal combustion engine buses to electric buses. We are ready to provide further support, including a detailed roadmap and implementation recommendations, to help your city achieve a successful transition to electric buses.

On behalf of the research team, we sincerely hope that our proposal will contribute to the sustainable transportation development of your city. If you have any questions or need further information, we will be more than happy to assist.

8. Model Evaluation

8.1. Advantages of Model

In analyzing the model of the city's replacement with electric buses, we adopted the method of integrating environmental and economic factors to ensure the comprehensiveness and practicability of the model. We considered the improvements in urban air quality, the reduction in energy consumption, and the long-term cost-effectiveness of electric buses. By simulating different scenarios, we are able to predict the effects of different policy and infrastructure changes, thus providing strong support for decision makers.

8.2. Disadvantages of Model

However, our model is limited in some ways. First, due to the lack of detailed city-specific data, our model must rely on a number of assumptions and generic data, which can affect its accuracy in specific situations. Second, while we took environmental and economic factors into account, we failed to adequately consider social and policy factors, such as changing public acceptance of electric buses or uncertainty over government policy. In addition, our model does not fully consider the potential impact of technological advances on the performance and cost of electric buses.

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