Research on Driver Model of Public Transportation Energy Consumption System Based on Computer Cloud Computing Analysis

Junhui Liu a *, Yaya Wang b and Lisha Shang c
The School of Electro Engineering, Xi’an Traffic Engineering Institute, Xi’an, China

*Corresponding author e-mail: ljhui.1986@163.com, Wangyaya21999@163.com, shanglisha313@126.com

Abstract. The urban public transportation subsystem, that is, the electric vehicle public transportation system on the ground, is an important part of the urban transportation system, and its energy consumption is increasing. However, the research on the energy consumption structure of urban public transportation subsystems is not yet mature. From a development perspective, there is an urgent need to study the energy consumption of urban public transportation subsystems. On this basis, according to actual needs, a typical public transportation energy-saving technology quantified driver model for energy-saving benefits was established, data requirements and processing methods were clarified, and relevant case analysis was carried out, which not only provided intelligence for city managers to choose transportation stand by. It can effectively analyze the energy consumption of the driver during the driving of the vehicle. On the basis of cloud computing analysis combined with public transportation energy consumption system can provide effective data support.

Keywords: Public transportation; low-carbon technology; energy-saving benefits; energy consumption model; cloud computing; driver model.

1. Introduction
With the rapid development of China’s economy and the continuous expansion of the scale of cities, the frequency and number of trips by residents are also increasing. Taking into account the impact of relevant policies and residents’ comprehensive consideration of economy, travel speed and safety, the number of people choosing to use public transportation is increasing, and the pressure on the urban public transportation system is also increasing. As the main body of the urban public transportation system, the urban public transportation subsystem will continue to increase its energy consumption. At present, China’s urban public transportation subsystem is still dominated by fuel consumption, and the development of vehicles driven by renewable energy is slow. The proportion of various buses needs to be increased. Therefore, the energy consumption structure of the urban conventional public transportation subsystem is studied on the public transportation system. Establishing a driver model and analyzing the data is of great significance to urban structural adjustment and energy saving [1].
The construction of a simulation platform for bus energy consumption and emission monitoring, dynamic monitoring of existing bus energy consumption and emissions, optimization of resource utilization, continuous improvement of bus energy consumption management and control, establishment of driver models, and data analysis and formulation of a city's social and economic development strategy for energy-saving and emission reduction programs suitable for buses. It plays an important role in ensuring the construction of an environmentally friendly public transportation system and is the basis for achieving sustainable and healthy urban social and economic development. At the same time, comprehensive monitoring of bus energy consumption and emissions can realize real-time monitoring and analysis of operating vehicle energy consumption, vehicle status and driving behavior, realize bus energy saving statistics, and establish corresponding driver models for monitoring and evaluation. Provide monitoring methods for deepening. Energy-saving management of buses provides technical support for transportation companies to carry out energy-saving refined monitoring.

2. Establish a quantitative model for energy saving and emission reduction of typical drivers

2.1. Driver Model Analysis of Bus Rapid Transit (BRT)

The road network is combined with modern public transportation technology to make full use of the advantages of rail transit. It has the characteristics of large capacity, fast speed, and has temporal and spatial priority. Its biggest advantage is that it combines the advantages of rail transit and buses, and combines technology to create a "modern, high-grade, low-cost large-capacity transportation system", which achieves energy conservation and reduces carrying capacity by reducing unit energy consumption. The purpose of the line. BRT technology mainly uses large vehicles and optimizes transportation conditions to achieve the purpose of reducing energy consumption per passenger. Therefore, when establishing the BRT public transport driver model here, the energy consumption of BRT transporting passengers was compared with the energy consumption of traditional buses. BRT The calculation method of the new energy-saving benefit $E_i$ (ton standard coal) of BRT technology in year $i$ is shown in equation (1).

$$E_i = N_{BRT} \cdot Q \cdot (k_{reg} - k_{BRT}) \cdot \rho \cdot \lambda \cdot T_{BRT} \cdot 10^{-3} \quad (1)$$

In the formula, $N_{BRT}$ is the number of newly added BRT lines, unit: piece; Q is the average daily passenger capacity of each BRT line, unit: 10,000 people/(day•piece); $k_{reg}$ is the diesel consumption of conventional diesel buses for transporting unit passengers Quantity, unit: liter/10,000 people; $k_{BRT}$ is the diesel consumption per passenger transported by BRT buses, unit: liter/10,000 people; $\rho$ is diesel density, unit: kg/liter, with a value of 0.84 kg/liter; $\lambda$ is Conversion coefficient between diesel quality and standard coal quality, unit: kilogram standard coal/kg; $T_{BRT}$ is the number of days of BRT vehicle operation in a year, unit: day. Cities with conditions can use more reasonable turnover data, that is, $Q'$ is the daily average passenger turnover of each BRT line, unit: ten thousand kilometers/(day • piece); $e_{reg}'$ is the passenger turnover of conventional buses per unit Diesel consumption, unit: liter/10,000-kilometer; $e_{BRT}'$ is the diesel consumption per passenger turnover of BRT buses, unit: liter/10,000-kilometer.

2.2. Public bicycle system

Public bicycles have the characteristics of low rental cost and can be freely combined with other modes of transportation. While reducing travel costs, it also reduces the number of times that cars are used, thereby optimizing the structure of urban transportation and achieving the purpose of energy saving and emission reduction. As a non-motorized travel mode, public bicycles need to be compared with motorized travel modes in the calculation of their energy saving and emission reduction benefits. In the promotion and application stage of the public bicycle system, the increase in public bicycle trips is used as the basis. At the same time, in the calculation process, bus travel and car travel were used as the
comparison objects to calculate the energy saving and emission reduction benefits of public bicycle travel. Among them, the calculation method for the newly added energy-saving benefits $E_i$ (tons of standard coal) in the i-th year is shown in equations (2) to (4).

$$E_{\text{bus}} = N_{\text{bus}} \times K_{\text{bus}}$$  \hspace{1cm} (2)

$$E_{\text{car}} = N_{\text{car}} \times K_{\text{car}}$$  \hspace{1cm} (3)

$$E_i = aE_{\text{bus}} + (1 - a)E_{\text{car}}$$  \hspace{1cm} (4)

In the formula, $N_{\text{bus}}$ is the number of new public bicycle services, unit: 10,000; $E_{\text{bus}}$ is the energy consumption of bus trips, unit: ton of standard coal; $K_{\text{bus}}$ is the energy consumption of bus trip per person, unit: ton of standard coal/10,000 Person-times; $E_{\text{car}}$ is the energy consumption of car trips, unit: ton of standard coal; $K_{\text{car}}$ is the energy consumption of car trips per unit, unit: ton of standard coal/10,000 Person-times; $a, (1 - a)$ are buses and cars respectively. The transfer ratio of travel to public bicycle travel is dimensionless [2].

2.3. Hybrid electric buses

Hybrid electric buses mainly refer to the coupling of an auxiliary power system consisting of a drive motor and a power battery on the basis of a traditional internal combustion engine vehicle, and the system performs power balance, coupling, and energy regeneration and storage. According to the degree of electromechanical coupling, control strategy and road traffic conditions, the fuel saving rate ranges from 10% to 40%.

The energy saving and emission reduction benefits of hybrid electric buses are mainly related to the number of new hybrid electric buses, the average daily operating mileage of hybrid electric buses, the fuel consumption per unit distance and the fuel saving rate of traditional diesel buses. The calculation method of the newly added energy-saving benefit $E_i$ (tons of standard oil) in year i is shown in equation (5).

$$E_i = N_{\text{HE}} \times L_{\text{HE}} \times \theta \times \gamma \times T_{\text{HE}} \times 10^{-6}$$  \hspace{1cm} (5)

In the formula, $N_{\text{HE}}$ is the number of newly added oil-electric hybrid buses, unit: vehicles; $L_{\text{HE}}$ is the average daily mileage of oil-electric hybrid buses, unit: kilometers/(day vehicle); $\epsilon_{\text{HE}}$ is 100 kilometers of traditional diesel buses Fuel consumption, unit: liter/100 kilometers; $D$ is the fuel-saving ratio of hybrid electric buses, generally valued at 10%~40%; $\gamma$ is the conversion coefficient between diesel volume and standard oil quality, unit: ton of standard oil/10,000 liters, The value is 8.568 toe/10000L (according to GB/T 2589-2008); $T_{\text{HE}}$ is the number of operating days of hybrid buses in a year, unit: day.

2.4. Natural gas vehicles

Natural gas vehicles mainly refer to vehicles driven by natural gas, which mainly include compressed natural gas (CNG), liquefied natural gas (LNG) and unconventional natural gas (such as coal bed methane, shale gas, etc.). In addition to reducing pollutant emissions, the application of natural gas is more important to adjust the national energy structure.

The energy saving and emission reduction benefit calculation of natural gas buses is mainly reflected by replacing traditional diesel consumption. The calculation method for the newly increased fuel consumption reduction $E_i$ (tons of standard oil) in year i is shown in equation (6).

$$E_i = N_{\text{NG}} \times L_{\text{NG}} \times \epsilon_{\text{NG}} \times \gamma \times T_{\text{NG}} \times 10^{-6}$$  \hspace{1cm} (6)

In the formula, $N_{\text{NG}}$ is the number of newly-added natural gas buses, in units; $L_{\text{NG}}$ is the average daily mileage of natural gas buses, in kilometers/(day vehicle); $T_{\text{NG}}$ is the operating days of natural gas buses in a year, in days.
2.5. Pure electric taxi
A pure electric vehicle is a vehicle that uses an on-board battery as a power source and is driven by a traction motor. Its energy supplement depends on an external power source to charge the power battery. If the emissions from the power production process are not considered, the carbon emissions of pure electric vehicles are zero during driving.

The energy-saving and emission-reduction benefits of pure electric taxis are directly related to their usage, that is, operating mileage and fuel consumption per unit distance of traditional fuel taxis. The calculation method of the newly added energy-saving benefit $E_i$ (standard oil) in year $i$ is shown in equation (7).

$$E_i = N_y \times L_y \times e_{gas} \times \alpha \times T_e \times 10^{-6}$$  \hspace{1cm} (7)

In the formula, $N_y$ is the number of new pure electric taxis, unit: vehicle; $L_y$ is the average daily mileage of pure electric taxis, unit: kilometer/(day vehicle); $e_{gas}$ is the fuel consumption of traditional gasoline taxis per 100 kilometers, unit: Liter/100 kilometers; $\alpha$ is the conversion coefficient between gasoline volume and standard oil quality, unit: ton of standard oil/10,000 liters, valued at 8.652 toe/10000L (according to GB/T 2589-2008); $T_e$ is a pure electric taxi for one year Operating days, unit: day.

3. Variable prediction and calculation method
At present, the application of public bicycle technology in most cities in my country is still in its infancy. According to the statistics of relevant departments in cities with public bicycle service systems, it can be considered that with the increase in service points and the number of bicycles, the daily maximum rental amount basically shows a linear increase. As shown in Figure 1, since the operation of the public service system in City H in May 2008, with the increase in the number of service points and bicycles, the daily maximum rental usage has basically shown a linear growth trend. The average daily rental usage is positively correlated with the maximum daily rental usage, that is, the average daily rental usage is linearly related to the number of public bicycles [3].

![Fig.1 Research on Driver Model Modeling and Analysis System](image)

Therefore, it can be simplified that in the promotion stage of public bicycles, the amount of public bicycle rental will increase proportionally with the increase in the number of public bicycles, as shown in equation (8).

$$P_i = N_i \times N_0^{-1} \times P_0$$  \hspace{1cm} (8)

In the formula, $P_i$ is the number of public bicycles rented in the i-th year, unit: 10,000 times/year; $N_i$ is the number of public bicycles in the i-th year, unit: 10,000; $N_0^{-1}$ is the number of public bicycles in the base year, unit: 10,000; $P_0$ is the amount of public bicycle rental in the base year, unit: 10,000 times/year. Taking the fuel consumption per 100 kilometers of a traditional...
diesel bus as an example, it is necessary to consider the fuel consumption of various models of the same length and class powered by diesel, as shown in equation (9).

$$e_{buv} = \frac{\sum_{i} C_i \times 100}{\sum_{i} L_d}$$  \hspace{1cm} (9)

In the formula, $C_i$ is the total fuel consumption of the b-th model, in ten thousand liters; $m$ is the number of cars of the same length, in units; $L_d$ is the total mileage of the d-th model, in ten thousand kilometers.

For example, the energy consumption statistics of large (12 meters ≥ vehicle length > 6 meters) traditional diesel buses in City H are shown in Table 1. According to (9), the fuel consumption per hundred kilometers of the large traditional diesel bus in H city is 39 liters.

**Table 1.** Fuel consumption statistics of traditional diesel buses per 100 kilometers

| vehicle                | Total mileage (10,000 kilometers) | Total fuel consumption (ten thousand liters) | Unit fuel consumption (L/100km) |
|------------------------|-----------------------------------|---------------------------------------------|---------------------------------|
| 10m and below (manual) buses | 8229                             | 2607.06                                     | 31.68                           |
| 10m and below (automatic) buses | 3896                             | 1650.65                                     | 42.37                           |
| 12m (manual) bus        | 7598                             | 3181.45                                     | 41.87                           |
| 12m (automatic) bus     | 2645                             | 1286.02                                     | 48.62                           |
| total                  | 22368                            | 8725.18                                     | 39.01                           |

4. Urban public transportation energy management and control system design

4.1. Overall system framework
The overall framework of the bus energy consumption and emission monitoring and simulation system is shown in Figure 2. The system collects dynamic vehicle CAN bus data from the bus, including vehicle basic data, vehicle energy consumption, gas or electricity consumption data, GPS data and IC card data. Vehicle routes, schedules, and manual entry of bus energy consumption, GIS data and other information input systems. After transmission and processing, the data is stored in the basic database of the data center. The data center monitors the energy consumption and emission of public transportation vehicles within its jurisdiction and aggregates various energy consumption and emission data. In addition, according to the established bus energy consumption and emission model, it provides simulation analysis of bus energy consumption and emission, and provides simulation analysis for the competent authorities and public transportation enterprises to provide energy-saving and emission reduction measures [4].
4.2. Network Transmission Framework

The network transmission framework is shown in Figure 3, which is generally divided into three levels: the internal network of the data center, the external INTERNET network and the vehicle terminal APN network. Users in the data center access the system through the intranet to improve access and processing speed, and exchange data with the internal system of the data center in the intranet to improve data security. The external INTERNET network is mainly used for external data exchange, providing corresponding system functions according to the distribution of permissions; and obtaining relevant data of the enterprise application system through the INTERNET network. In order to ensure data quality and real-time performance, the on-board terminal of the bus can be directly connected to the data center through the APN network.

4.3. System function design

The system mainly completes four functions: basic data collection, bus energy consumption and emission query, bus energy consumption and emission dynamic monitoring, and bus energy consumption and emission simulation analysis. The public transportation basic data collection and processing module collects various basic road network data and dynamic public transportation data in different ways, performs preliminary processing, and provides it to the bus energy consumption and emission monitoring platform. Using GPS, GPRS and other methods to collect the dynamic information of public transportation, and make full use of the static data of the existing public transportation network to provide the necessary data for the monitoring platform, complete system verification and verification, and improve the accuracy of monitoring, To meet the accuracy requirements of system applications. The main collected data includes: basic geographic data of the road network, bus line network, basic information of public buses, GPS information of buses, IC card information, bus dispatching information, and bus energy consumption information [5].
The bus energy consumption and emission query module provide bus energy consumption and emission query functions for bus companies and traffic management departments. The status of energy consumption and emissions of bus operation is a city issue that the public transportation management department pays close attention to. The perception of energy consumption and emissions of buses can help determine the status of energy consumption and emissions of buses, find the causes of problems in time, and develop buses for the city. Energy consumption and emission management measures provide a scientific basis. The bus energy consumption and emission query module provide the following functions:

1) Basic data management functions: including the input and update of bus energy types, measurement units, energy consumption equipment parameters, etc.; energy consumption indicators, parameters, and national and local standards and specifications.

2) Energy consumption and emission statistics analysis function: energy consumption and emission statistics, real-time upload of energy consumption, IC card, GPS and other relevant information of vehicles, and statistical analysis according to conditions such as road sections, routes, regions, dates and enterprises to form the whole city The total energy consumption and emissions of buses within the scope, and the energy consumption emissions of a single vehicle per 100 kilometers provide decision-making support for the transportation management department; analyze the status of vehicle energy consumption and emissions by comparing with historical averages, limit standards, and enterprise-set indicators. Comparative analysis, timely warning of vehicles outside the deviation range to notify users; energy consumption and emission analysis and prediction, based on passenger flow growth rate, vehicle growth rate, route arrangement and other data, combined with energy consumption statistics to establish energy consumption and emission forecasts Model, establish the statistics, monitoring and assessment system of bus energy consumption and emissions, and provide accurate, timely and comprehensive data support for the formulation of industry energy-saving development plans.

3) GIS data display, monitoring and output function: establish a data interface between the bus energy consumption and emission monitoring platform and the GIS-T system, support the monitoring platform to use the data of the GIS-T subsystem, and call the GIS- according to its own business needs. The map service of the T subsystem reflects energy consumption and emissions data on the GIS map.

The dynamic monitoring module of bus energy consumption and emission completes the analysis of energy consumption and emission of vehicles, routes, and sections through dynamic monitoring of public transportation vehicles, and reflects the energy consumption and emission status of the bus network. Specific functions include:

1) Dynamic monitoring of vehicle energy consumption and emissions. Public transportation vehicles are the basis of the operation of the public transportation system and directly determine the overall energy consumption and emission level of the public transportation system. By dynamically monitoring the energy consumption and emissions of vehicles, it can intuitively reflect the use efficiency of vehicle energy consumption. The system provides vehicle energy consumption and emission inquiries in different dimensions: full-day, morning peak, evening peak, and flat peak conditions; summer and winter weather conditions; high temperature and low temperature conditions; statistics of total vehicle energy consumption under rainy and sunny weather conditions Emissions. The transportation efficiency of vehicle unit energy consumption and the transportation efficiency of vehicle unit emission.

2) Line energy consumption and emission monitoring. Accurately grasp the energy consumption and emissions of the line by the traffic management department, plan and manage the bus line in a targeted manner, and achieve the desired effect. Through the analysis of the energy consumption and emissions of the existing lines, determine the energy consumption efficiency of the lines, potential routes or vehicle arrangements.

3) Energy consumption and emission monitoring of road sections. The line energy consumption and emission monitoring module reflect the energy consumption and emission status of the road section. Due to differences in road grades, traffic flow, number of intersections, bus station settings, and passenger flow, each bus on a bus route has different energy consumption and emissions. Through the analysis and determination of the energy consumption and emissions of the existing road sections, the
energy consumption efficiency of the road sections and the potential route or vehicle arrangement problems are determined.

Simulation analysis of bus energy consumption and emissions is helpful to analyze complex problems and provide strong technical support for optimizing the bus system. The simulation analysis of bus energy consumption and emissions requires the completion of functional modules such as driver behavior simulation, vehicle adjustment plan analysis, and bus route adjustment plan evaluation.

1) Driver behavior simulation. Through the simulation analysis platform, complete the monitoring and simulation of energy-saving driving behavior (gear, clutch, throttle, etc.). Statistics of energy consumption and emissions under different driving behaviors according to drivers; comparative analysis of vehicle operating conditions and driving behaviors, reminding of bad driving behaviors; providing energy consumption and emission assessments under different driving behaviors [6].

2) Analysis of vehicle adjustment plan. Through the simulation analysis platform, the energy consumption and emission monitoring and simulation of different types of vehicles are completed. By loading basic data such as line passenger flow scale and road conditions, evaluate and adjust the unit energy consumption and emission status of vehicle types.

3) Evaluation of bus line adjustment plan. Through the establishment of a simulation platform, the energy consumption and emissions of different bus line planning methods are simulated, and the impact of bus line adjustment on the energy consumption and emissions of the bus system is analyzed and evaluated.

5. Analysis of simulation results
Carrying out a life cycle cost analysis of the existing bus models. According to the calculation results, it can be seen that the purchase cost of diesel vehicles is lower, other costs are lower, but the operating costs are relatively high; the overall situation of natural gas vehicles is similar to diesel vehicles, but the cost of each part is relatively small; the purchase cost and operating cost of hybrid vehicles are relatively high; the purchase cost and other costs of trolley buses are relatively high; the main limitation of pure electric vehicles is that the purchase cost and battery lease and replacement costs are too high. The lowest life-time cost Natural gas vehicles, followed by trolleybuses. Diesel vehicles cost 362,000 yuan and hybrid vehicles cost 336,100 yuan; pure electric vehicles have the highest lifetime cost of 589,900 yuan, mainly due to the purchase cost of pure electric vehicles and others. The cost (supporting settings, mainly battery replacement and leasing) is relatively high, accounting for 54.7% and 33.9% of the total life cost, respectively, accounting for 88.6% of the total life cost, which is a major obstacle to the popularization of electric vehicles. The full life of public buses the cycle cost is substituted into equation (10) to calculate the energy rate of various buses.

From the comparison results of the energy rates of different types of buses (as shown in Figure 4), it can be seen that the energy rates of natural gas vehicles are the lowest, only 457.46 yuan/100 kilometers; pure electric vehicles are the worst economical, at 1565.47 yuan/km. About 3.4 times that of natural gas vehicles; energy rates for other types of buses are not much different, basically maintaining at 600 yuan/100 kilometers [7].
According to the energy consumption model of urban public transportation subsystem (9), using the above data, it can be calculated that the energy consumption of diesel vehicles, natural gas vehicles, hybrid vehicles, trolley buses and pure electric vehicles are 6.024 billion yuan, 835 million yuan, and 289 million yuan, respectively. 179 million yuan, 179 million yuan and 59 million yuan, the proportion of their expenses: diesel vehicles 81.56%; natural gas vehicles 11.32%; hybrid vehicles 3.91%; trolley buses 2.12%; pure electric vehicles 0.79%. It can be seen that diesel vehicles are still public transportation The backbone of the system's energy consumption costs, accounting for about 81.56% of the total energy consumption costs; pure electric vehicles have the least energy consumption costs; the energy consumption costs of natural gas vehicles, hybrid vehicles, and trolley buses are relatively small compared with diesel vehicles. In the future for a period of time, automobile energy will still be fuel oil. The development of new energy buses has just started, and the effect of replacing petroleum is not obvious. The technology needs to be improved. Vigorously adjust the proportion of new energy vehicles in the public transportation system and give full play to Electricity and natural gas have the effect of replacing fuel oil. The number of pure electric vehicles is small, and the technology needs to be improved. Vigorously promoting pure electric vehicles needs to break through the bottleneck of the battery.

6. Conclusion

Through the above analysis, it can be concluded that the establishment of an energy consumption driver model for urban public transport subsystems based on energy consumption can conveniently and effectively calculate the energy consumption of various buses. It plays an active role in assisting the driver's vehicle driving. So far, China's urban public transportation has developed rapidly and its scale has continued to expand. However, there are few studies on the energy consumption of urban public transportation systems. The driver energy consumption model of the urban public transportation subsystem researched and established in this paper has certain practical significance and can provide reference for relevant public transportation energy evaluation research and decision-making departments.

Acknowledgements

Scientific Research Program Funded by Shaanxi Provincial Education Department (Program No.20JK0747).

References
[1] Cheng, Y. H., Chang, Y. H., & Lu, I. J. Urban transportation energy and carbon dioxide emission reduction strategies. Applied Energy, vol. 157, pp. 953-973, November 2015.
[2] Millo, F., Rolando, L., Fuso, R., & Zhao, J. Development of a new hybrid bus for urban public transportation. Applied Energy, vol. 157, pp. 583-594, January 2015.
[3] Ortenzi, F., Pasquali, M., Prosini, P. P., Lidozzi, A., & Benedetto, M. D. Design and validation
of ultra-fast charging infrastructures based on supercapacitors for urban public transportation applications. Energies, vol. 12, pp. 2348-2356, December 2019.

[4] Uittenbroek, C. J. Janssen-Jansen, L. B. & Runhaar, H. A. C. Mainstreaming climate adaptation into urban planning: overcoming barriers, seizing opportunities and evaluating the results in two dutch case studies. Regional Environmental Change, vol. 13, pp. 399-411, February 2013.

[5] Vishwanath, A., Gan, H. S., Kalyanaraman, S., Winter, S., & Mareels, I. Personalized public transportation: a mobility model and its application to melbourne. IEEE Intelligent Transportation Systems Magazine, vol. 7, pp. 37-48, April 2015.

[6] An, S., Leng, J. Q., Wang, J., Li, W., & He, Y. Vulnerability of road network based on generalised travel time. Transport, vol. 168, pp. 425-433, May 2015.

[7] Manville, M., & Cummins, B. Why do voters support public transportation? public choices and private behavior. Transportation, vol. 42, pp. 303-332, February 2015.