Electricity Research in Public Places

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Abstract

In recent years, with the increasing demand for electric energy, the annual electricity consumption in public places has continued to increase, and the cost incurred has also increased. Studying the cost of electric energy consumption is of great significance for its conservation. In this research, we first look at the data on the consumption of China's electric energy in recent years, presenting in a line chart analysis. It is found that in the past few tears the total consumption of electricity and energy is increasing gradually. Then, by establishing a time series prediction model, it is predicted that the consumption of electric energy will continue to grow. As the increase in power demand has caused an increase in power consumption, an increase in charging equipment, and an increase in traffic in public places, according to these effects, we have categorized the increased demand in public places and the cost of energy use into fixed costs. The variable cost and the potential cost are separately studied and calculated, and the final total cost calculation model is obtained. Then, according to the characteristics of different types of public places, the model was embodied, and the energy consumption costs of three public places such as schools, cafes and airports were discussed. The model has been improved by reducing power consumption and other measures to reduce power consumption costs. Finally, combined with the findings of the full text, we put forward some reasonable suggestions for the school, thus reducing the school's electricity consumption costs.

Keywords

Power energy, Consumption time series prediction, Saving electricity.

1. Introduction

1.1 Background

We live in a mobile electronic world, and we are inseparable from electricity, whether it is school or other settings of our social life. Every day we have to charge electronic devices, from small mobile phones to electric cars. At home, we also need to buy charging equipment and pay the electricity bill on time.

Today, charging facilities such as power outlets and charging stations are constantly being added in public places. In some settings, these charging ports require a fee, but many public places offer free charging, which has a certain impact on our lives.

1.2 Restatement of the problem

1. Discuss how this type of energy consumption has changed in recent years and how it will continue to change. And analyze the impact and requirements of increased power energy and charging demand on public places.

2. Model the increased impacts and energy costs of public places using the impacts and requirements you have identified. Discuss the extent of these fees and how they are paid.

3. How does the discussion model change for different types of public places (eg, schools, cafes, airports, shopping centers, etc.)?

4. What measures are in place to reduce the cost of increasing energy use in public places? How will the implementation of these initiatives adjust your cost model?

5. Write a one-page article for your school newspaper describing your findings and recommendations.

1.3 Problem analysis

1.3.1 Analysis of Problem 1

Problem 1 requires an analysis of the consumption of electricity and energy in recent years and predicts subsequent changes. We can find the consumption of electric energy in recent years by studying the data and constructing a map. Since the research is changing based on the change of time, we can do a line chart to analyze such changes. For how the consumption situation changes, a time series prediction model can be used for prediction. At the same time, the first question also requires analysis of the impact and requirements of the increase in power energy as well as the charging demand on public places. We can discuss the types of charging equipment, the number of charging equipment, and the power consumption.

1.3.2 Analysis of Problem 2

Problem 2 requires modeling the increased demand for public places and the cost of energy use. The cost can be divided into three parts: fixed cost, variable cost, and potential cost. Combined with the impact determined in question 1, Quantify to get the total cost. For the determination of the payment method, the optimal solution can be found by comparing the impact of the charge on the public place.

1.3.3 Analysis of Problem 3

Question 3 requires that the model be improved on the basis of the second problem for different types of public places, so that the model is specifically applied and tailored to a certain public place. First, analyzing the differences between public places such as schools, cafes, airports, shopping malls, etc. For example, the school has a large flow of people and a relatively small number of people, the coffee shop has a small footprint, and the charging equipment is generally a power outlet..

1.3.4 Analysis of Question 4

Question 4 requires to find some initiatives to reduce the cost of electricity and adjust the model based on these initiatives. We can combine the cost models in questions 2 and 3 to find the main factors affecting the cost of electricity use, such as power consumption, power utilization, etc., and reduce costs by reducing power consumption.

1.3.5 Analysis of Question 5

Question 5 asks us to write an article for the school newspaper. Combined with the findings of the full text, we can make some reasonable suggestions for the school, thus reducing the school's electricity consumption costs.

2. General Assumption

Assumption I: **Suppose a charging device can only charge one electronic device.** Due to the variety of charging devices in life, for example, the socket has a five-hole socket, a two-hole socket, etc., in order to facilitate statistical calculation, it is considered that one charging device can only charge one electronic device.

Assumption II: **Assume that the same electronic device (mobile phone, computer, electric car) has the same charging power.** The charging power of the same electronic device is not much different, and can be ignored compared with the difference between different electronic devices.

Assumption III: **The problem of different charging power due to aging of the charging device is not considered.** The aging of the charging device will cause the power to be too large during charging. Since this situation cannot be estimated, it is an uncontrollable factor and therefore will not be considered.

3. Symbols and Definitions

Here we list the symbols and their descriptions used in this article, as shown in Table 1.

Table 1 symbols and description

Symbols	Description
C	Cost

Q	Power consumption
p	Charging power
m	Number of chargers
n	Number of power outlets
P	Pedestrian volume

P.S: Other symbols will be introduced in the text.

4. Electricity consumption change forecast and impact

4.1 Changes in power energy consumption

4.1.1 Collect data and analyze

In order to understand the consumption of electricity and energy in recent years, we collected the annual electricity supply, total electricity consumption and total consumption of electricity from 2008 to 2017. The data is shown in the following table:

Table 1 China's power consumption status in 2008-2017 Unit: Million kilowatt hours

Years	Electricity availability	Total electrical energy consumption	Total consumption of electricity	Consumption of electricity consumption
2017	64821	64821	9071.6	0.1399
2016	61297.6	61297.1	8420.6	0.1374
2015	58021.3	58020	7565.2	0.1304
2014	56381.8	56383.7	7176.1	0.1273
2013	54204.1	54203.4	6989.2	0.1289
2012	49767.7	49762.6	6219	0.125
2011	47002.7	47000.9	5620.1	0.1196
2010	41936.5	41934.5	5124.6	0.1222
2009	37032.7	37032.2	4872.2	0.13157
2008	34540.8	34541.4	4396.1	0.1273

Visualize the data in Table 1, as shown in the following figure:

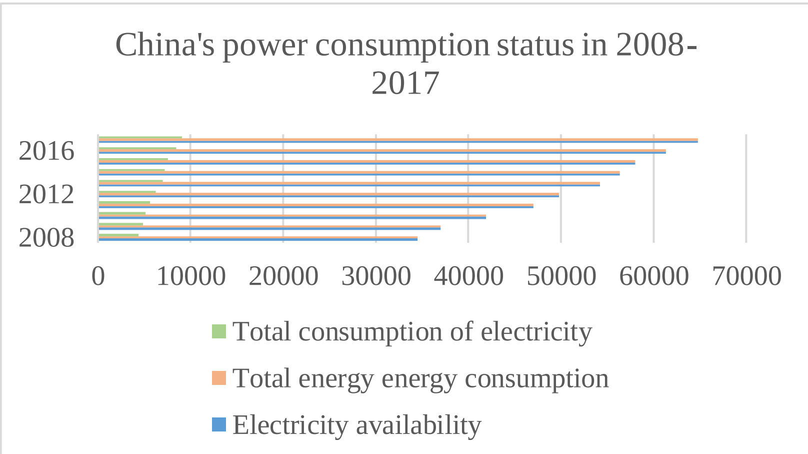

Figure 1 China's power consumption status in 2008-2017

It can be seen from Figure 1 that in recent years, the total consumption of electric energy and the total amount of electricity consumed by living are increasing year by year. Combined with the table, it is found that some countries have even had problems of insufficient power supply in some years. This is due to the continuous advancement of technology, the increasing number of electronic devices, and the emergence of new electronic products, coupled with the improvement of people's living standards, making the consumption of electric energy to grow steadily.

In addition, according to the consumption of electricity and total electricity consumption, you can get the percentage of electricity consumption in your life and plot it:

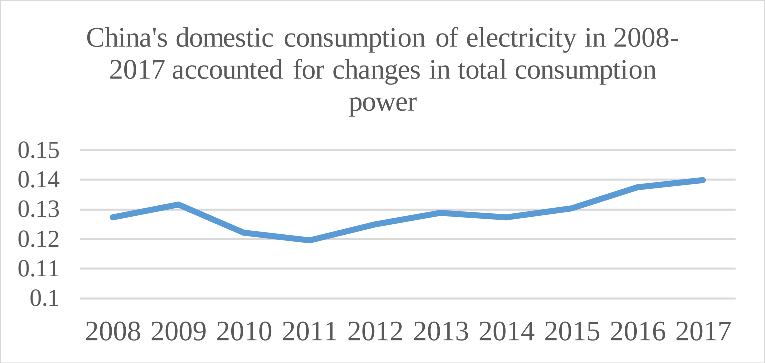

Figure 2 China's domestic consumption of electricity in 2008-2017 accounted for changes in total consumption power

It can be seen from Figure 2 that in 2010 and 2011, the proportion of domestic consumption of electricity has declined, but in recent years it has been on the rise, indicating that people are increasingly demanding electricity and energy in their lives.

4.1.2 Time series quadratic smoothing method predicts the trend

It can be roughly inferred from Fig. 1 and Fig. 2 that the power consumption will continue to increase afterwards, and in order to make the predicted results more convincing, a model is established for explanation. Since the national electricity consumption total and time function lines are on an increasing trend, and the electricity consumption shows dynamic changes with time, we use the time series model to solve this problem. In order to avoid large forecasting errors, based on the 2008-2017 national total electricity consumption data, the time series model is used to predict the national power consumption in 2018 and compare with the real situation.

The solution of the time series model can be: moving average method, primary exponential smoothing method, second exponential smoothing method and cubic exponential smoothing method. The moving average method is only suitable for recent predictions, so it is not suitable for solving with the smoothing method. Because the total national power supply is limited, the total electricity consumption in the country is unlikely to grow exponentially with time, so we did not use the three-exponential smoothing method to solve the time series model. If only one exponential smoothing method is used, there will be a large hysteresis deviation, and the second exponential smoothing method solves this problem by comparing the exponential deviation with the second exponential smoothing method by one exponential smoothing method. It is obviously more appropriate.

Let the time series be $y_1, y_2, \cdots, y_t, \cdots$, α is the weighting coefficient, $0 < \alpha < 1$. An exponential smoothing formula is:

$$S_t^{(1)} = \alpha y_t + (1-\alpha) S_{t-1}^{(1)} = S_{t-1}^{(1)} + \alpha (y_t - S_{t-1}^{(1)})$$

The prediction model is:

$$\hat{y}_{t+1} = S_t^{(1)}$$

Therefore:

$$\hat{y}_{t+1} = \alpha y_t + (1-\alpha) \hat{y}_t$$

The range of α is generally 0.1-0.3, and the larger the value of α, the faster the decay rate of the weighting coefficient sequence. The basic trend of the time series in this question is not stable enough and the data is less selected. A large correction to the original model to adapt the prediction model to the new changes in the prediction target, we take $\alpha = 0.3$.

The formula for calculating the second exponential smoothing method is:

$$\begin{cases} S_t^{(1)} = \alpha y_t + (1-\alpha) S_{t-1}^{(1)} \\ S_t^{(2)} = \alpha S_t^{(1)} + (1-\alpha) S_{t-1}^{(2)} \end{cases}$$

Where: $S_t^{(1)}$ is the smoothed value of the primary exponent; $S_t^{(2)}$ is the smoothed value of the quadratic exponent.

When the time series {yt} has a linear trend from a certain moment, the linear trend model can be used for prediction:

$$\hat{y}_{t+m} = a_t + b_t m, m = 1, 2, \cdots$$

$$\begin{cases} a_t = 2S_t^{(1)} - S_t^{(2)} \\ b_t = \dfrac{\alpha}{1-\alpha}(S_t^{(1)} - S_t^{(2)}) \end{cases}$$

Take α = 0.3, the initial values $S_0^{(1)}$ and $S_0^{(2)}$ take the first value of the sequence, that is, $S_0^{(1)} = S_0^{(2)} =$ 64821, calculate $S_t^{(1)}$ and $S_t^{(2)}$, and predict the power consumption of the next few years.

After calculation, the total energy and energy consumption in 2018 is 679.26 billion kWh, which is not much different from the actual total consumption of power resources of 684.9 billion kWh in 2018. Therefore, this method is used to predict the power consumption of the next six years as shown in the following figure:

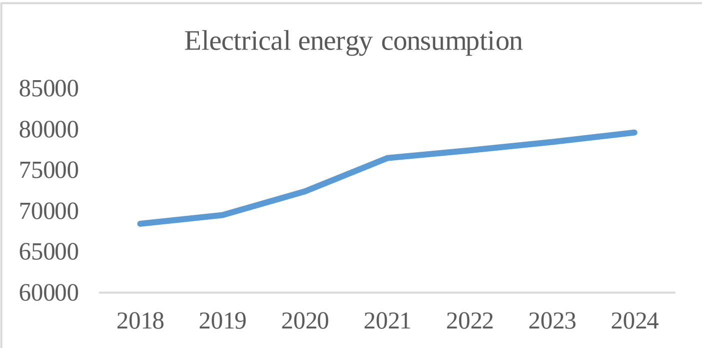

Figure 3 The power consumption of the next six years

It can be seen from the figure that the consumption of power resources will become larger and larger.

4.2 Impact of increased demand for electrical energy on public places

According to the increase in power energy and charging demand, and considering the possible multi-faceted impact on public places, the following indicators are established and discussed separately from these aspects.

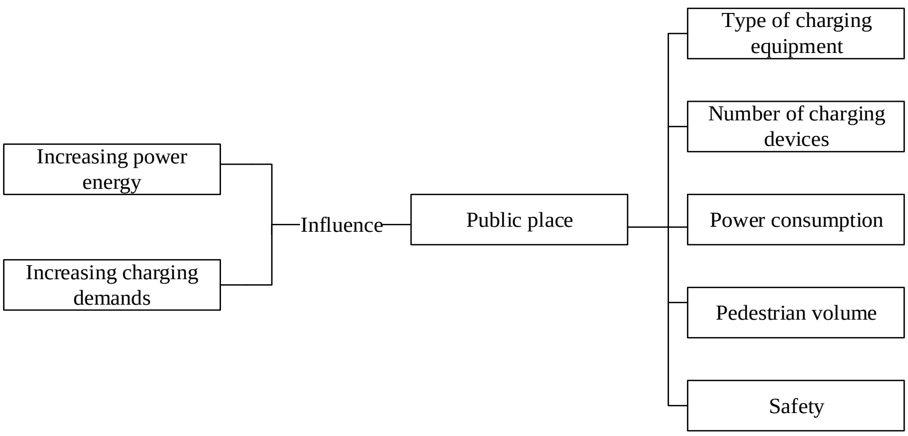

Figure 4 Impact of increased power energy and charging demand on public spaces

4.2.1 The type of charging equipment

The charging device is divided into two types of large charging devices and small charging devices. Large-scale charging equipment, including charging stations, is used to charge electric vehicles, which consumes a large amount of electricity and has a high construction cost. Small-sized charging equipment, including sockets, is used to charge electronic products such as mobile phones and computers, and consumes less power and costs are also lower.

As the demand for charging increases, some public places need to build large charging devices to meet people's charging needs.

4.2.2 The number of charging equipment

When the demand for electric energy and charging increases, public places need to build more charging equipment, otherwise there will be a shortage of supply thus being unable tobetter service the public.

4.2.3 Power consumption

Power consumption refers to the total amount of electrical energy consumed by the public place within a certain period of time. As people's charging demands increase, the frequency with which charging devices are used also increases. The power consumption of public places will increase due to the multiple use of charging devices.

4.2.4 Pedestrian volume

When people have a charging demand, they will go to a public place with charging equipment to charge, and bring a certain amount of pedestrian volume to the public place. When the demand increases, the flow of people will increase accordingly.

4.2.5 Security

The increase in traffic and the increase in the use of electricity facilities will certainly bring certain security problems to public places. If the charging socket is too dense, the wiring will be unloaded. The increase in charging demand may cause some people to arbitrarily connect to the socket, the power supply wire is not set properly, and it is easy to cause a short circuit of the power supply and cause a fire.

5. Cost calculation and charging method

5.1 Cost calculation

In order to calculate the increased demand for public places and the cost of energy use, according to the impact of problem 1, the cost is divided into fixed cost, variable cost and potential cost, so:

$$C = C_f + C_v + C_p$$

Of which: C—— total cost;

C_f —— fixed costs;

C_v ——Variable costs;

C_p ——potential costs.

5.1.1 Fixed costs C_f

Fixed cost refers to the construction cost required to build charging equipment in public places. This part of the cost is related to the type and quantity of charging equipment in the site. According to the investigation, the infrastructure cost of the charging station is directly related to the number of configured charging machines. The construction cost required to build a charger is about 240,000 *yuan*. The cost of building a power outlet is divided into labor costs and material costs, which is about 26 *yuan*.

Assuming that the number of chargers in the public place is m and the number of power outlets is n, then:

$$C_f = 240000m + 26n$$

5.1.2 Variable cost C_v

Variable cost refers to the amount of electricity consumed by people when charging, and is related to power consumption. According to the information, the power cost of 1 kW·h is about 0.56 *yuan*. therefore:

$$C_v = 0.56Q$$

Where Q is the power consumption.

The power consumption of the charging device in public places is related to the average length of use of the charging device t and the average power p of the charging product:

$$Q = pt(m+n)$$

5.1.3 Potential cost C_p

The potential cost refers to the cost of maintaining the charging equipment and the cost of safety, which is related to the flow of people in public places and the degree of safety. The maintenance cost of the charging station facility is about 6,000 *yuan* per year for a charger. The life of the socket is generally 12 years. The higher the frequency of socket usage, the shorter the life. The frequency of use of the socket is related to the flow of people. Where the flow of people is large, the frequency of use of the socket is higher. therefore:

$$C_p = 6000mY + f(P, m, n)$$

Where Y is the number of years the charger is used and P is the flow of people.

Therefore:

$$C = 240000m + 26n + 0.56pt + 6000mY + f(P, m, n, \mu)$$

5.2 Charging method

According to the title, charging equipment in public places is divided into two types: charging and no charging. In general, large charging devices such as charging stations are charged, while small outlets are non-charging devices. Charges have less impact on the use of large charging equipment. This is because electric vehicles need to be charged immediately when there is no electricity. People have more demand for charging stations and are less sensitive to price. Charges have a greater impact on the use of power outlets. The reason is that when the mobile phone or computer is out of power, most people are more willing to go home to charge than the charging sockets that need to pay. People are more sensitive to price. Therefore, the classification of the charging methods of the two devices is discussed.

5.2.1 Large charging equipment

There are two ways to charge large charging devices:

Cost-benefit pricing method: The basic idea of the cost-benefit pricing method is to charge all types of vehicles based on the battery capacity and charging method based on the battery capacity and charging method to ensure that the charging facilities recover the cost during the operation period and obtain a reasonable profit. The price of charging service, the loss of business operation is partly compensated by the government's compensation and tax incentives.

Alternative Energy Law: The basic idea of the alternative energy pricing method is to price the charging service price according to a certain proportion according to the energy consumption characteristics of the electric vehicle and the energy consumption cost of the same type of fuel or gas vehicle. In the alternative energy law, it is only necessary to calculate the charging price of the electric vehicle based on the fuel consumption of the fuel vehicle, and the operability is strong, and the charging cost paid by the user is not higher than the fuel consumption of the conventional fuel vehicle.

We use the first method to price, according to the total amount of electricity consumed by people's charging, the more electricity, the more the corresponding cost.

5.2.2 Small charging equipment

Small charging devices consume less power. If they are priced according to the charging standards of large charging devices, they are not easy to calculate and inconvenient. On the other hand, the pricing of charging needs to take into account the public service policy. Therefore, a segmentation charge is charged for the power outlet charging.

When people charge for a short time, they can charge for free, which brings convenience to people who need emergency charging. When the charging exceeds a certain period of time, it is necessary to appropriately charge a certain fee to prevent some people from saving electricity and causing a certain waste of electric energy.

6. Improvements to models for different public places

6.1 School

Schools use electricity differently than other public places. In schools, the population is large and the demand for electricity is relatively large.

Next, take a university in Beijing as an example for specific analysis. First, we collected the changes in the use of electricity in the university within one year, as shown in the following figure:

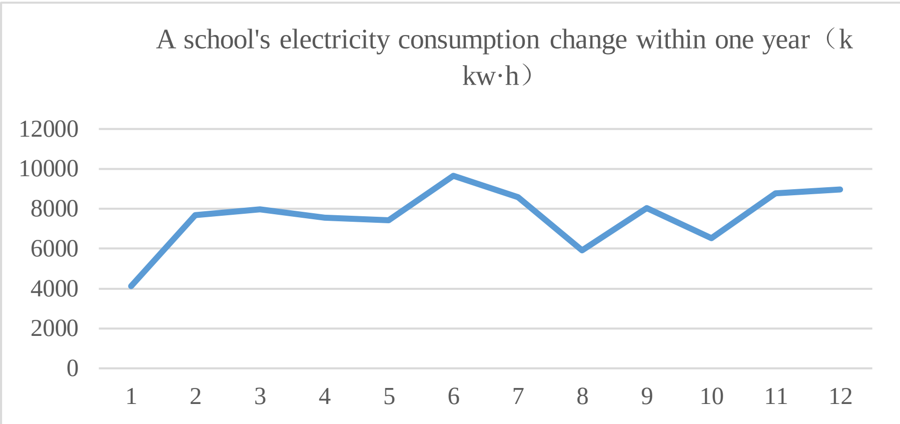

Figure 5. A school's electricity consumption change within one year

It can be seen from the figure that the electricity consumption is the lowest in January, followed by August, and the maximum electricity consumption in summer is higher than the maximum load in winter. In addition, there are two factors that are more obvious for the power consumption. On one hand, it is the cooling load in summer such as the heavy usage of air conditioning equipment. Since the school started summer vacation from mid-July in July, the peak electricity consumption in summer appeared in June-July and remained stable; on the other hand, in the two school days of the school, March and Electricity consumption increased slightly in September. In addition, electricity consumption remained high in November-December.

School electricity can be divided into dormitory electricity, classroom electricity, library electricity, experimental electricity, teacher electricity, other electricity, etc. The main charging facilities are power sockets, and electronic products that need to be charged also have Diversity. Due to the fixed staff, the daily electricity consumption has not changed much except for holidays.

Due to the excessive number of school outlets, the power outlet loss rate α is introduced, which indicates the proportion of the number of power outlets that need to be repaired in one year to the total number of outlets. The rate of wastage is related to the number of schools. Since the number of schools varies little, the rate of loss can be approximated as a fixed value.

Therefore, the total cost calculation model of the school within one year can be modified to:

$$C = 0.56Q + 26\alpha nY$$

Where Q refers to the total electricity consumption of the school for one year, and n refers to the total number of outlets in the school.

6.2 Cafe

For coffee shops, which are small in size and have unfixed public places, the number of charging devices is small and is basically used for charging mobile phones and computers. The change in passenger flow from the day of the cafe to the closing of the cafe can be approximated as a Poisson distribution:

$$P(X=k)=\frac{\lambda^k}{k!}e^{-\lambda}$$

The trend of the number of people is shown in the following figure:

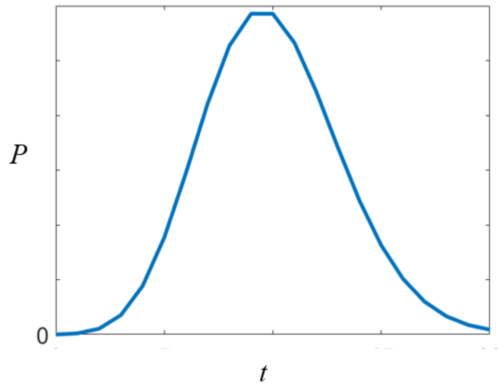

Figure 6 The trend of the number of people

Electricity consumption will also change with the flow of people, assuming that the number of people who need to charge accounts for β of all customers, because the products that need to be charged are mainly mobile phones and computers, use mobile phones and computers in surveys in coffee shops. The number of customers found that the ratio is approximately 7:3, so the cost of electricity consumption from time i to time j in a coffee shop in one day is:

$$C=0.56(\frac{3}{10}p_c+\frac{7}{10}p_m)(t_j-t_i)\cdot\beta\frac{P_i+P_j}{2}$$

Among them: p_c is the charging power of the computer, p_m is the charging power of the mobile phone, P_i is the number of coffee shops at i time, and P_j is the number of coffee shops at j time.

6.3 Airport

The airport is a large public place with a large turnover. First, we investigated the changes in passenger flow in an airport in China within one year, as shown in the following figure:

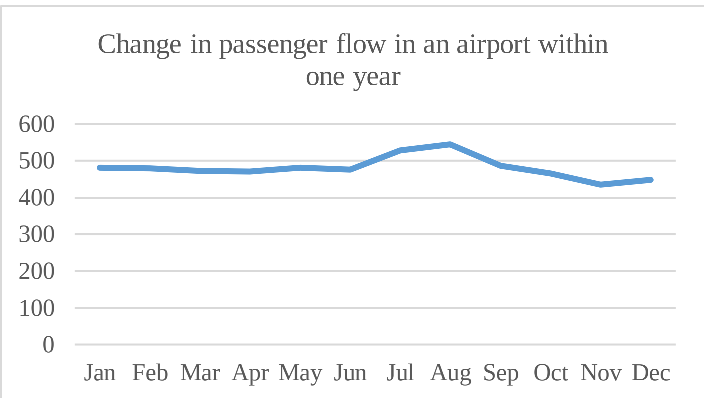

Figure 7 Change in passenger flow in an airport within one year

Unit: 10,000 people

As can be seen from the above figure, the month with the most passenger traffic in the year is July and August, and the month with the least passenger traffic is November and December. The passenger flow in other months has not changed much.

The charging equipment in the airport includes two types of sockets and charging piles, which are used for charging electric vehicles and charging of mobile phones respectively. The power consumption of electric vehicle charging is far greater than the power consumption of mobile phone charging.

Therefore, the calculation model of the total energy consumption cost of the airport within one year can be modified to:

$$C = 0.56(mp_s t_s + np_m t_m) + 6000m$$

Where p_s is the charging power of the electric vehicle, t_s is the average usage time of the charging station, and t_m is the average length of time for charging the mobile phone using the charging socket.

7. Model adjustment

7.1 Measures to reduce the cost of energy use in public places

In order to reduce the cost of energy use in public places, we propose the following measures:

1. Reduce safety costs. The installation and maintenance of power lines in all public places must be sent by a dedicated electrician to properly design the circuit and conduct regular inspections to prevent potential safety hazards.

2. For public places such as cafes and schools, it is forbidden to privately pull the power supply. It is strictly forbidden to use illegal and illegal electrical appliances. It is strictly forbidden to use the power line overload.

3. Improve power utilization. The energy utilization rate is the ratio of the total amount of effective energy available to the user to the total amount of consumed energy. The difference between the two is the loss of electrical energy, which includes equipment losses and management losses. Poor performance of electrical equipment, conversion of electrical energy and other energy, and low efficiency will increase equipment losses. The low level of operation of the electricity process, unreasonable process parameters, uncoordinated processes, and poor management will increase management losses. The power loss of the power supply network includes the power loss on the power supply line and the power loss of the transformer.

4. Reduce electricity consumption. Cultivate people's awareness of saving electricity, and turn off the power in time when there is no need to use electricity, such as turning off the lights.

5. Reduce unnecessary power consumption. For example, do not turn on the light in the case of natural lighting, or turn on the light when a light is enough.

7.2 Adjust the model according to the measures

The several measures proposed above reduce the cost of electricity from the aspects of safety cost, total power, power utilization and duration of electricity consumption, and then discuss them separately:

7.2.1 Energy utilization rate

The energy utilization rate is the ratio of the total amount of available electric energy available to the user and the total amount of consumed electric energy. Assuming that the original electric energy utilization rate is x and the electric energy utilization rate is increased by λ, the electric energy consumed is increased after:

$$Q' = \frac{x}{x+\lambda} Q$$

Q is the original power consumption, and $Q^{'}$ is the power consumption after the energy utilization rate is increased.

7.2.2 Total power and duration of electricity consumption

After controlling the power consumption, it is assumed that the total power and the duration of power consumption are reduced, and the power consumption is ε times.

7.2.3 Security costs

The safety factor ρ is introduced to indicate the safety degree of the circuit. The larger the value of ρ, the safer the circuit system, the lower the cost, and the smaller the value of ρ, indicating that the circuit system is dangerous and the cost is higher.

Thus, the model of the energy consumption cost can be changed to:

$$C=24000m+26n+0.56\rho\frac{x}{x+\lambda}+6000mY+\varepsilon f(P,m,n,\mu)$$

8. Strengths and Weaknesses

8.1 Strengths

1. The model can be applied to the calculation of electric energy costs in public places, and can be adjusted according to the characteristics of different public places, and has universality.

2. In this paper, the time series quadratic smoothing method is used to predict the model, which is more reasonable and appropriate, and the time series model can be applied to other energy prediction problems.

3. In calculating the power consumption cost, this paper considers the loss cost of the charging equipment caused by multiple charging.

8.2 Weaknesses

Due to the lack of data, the loss of electrical energy during transportation during charging is not taken into account.

9. Report

Energy management is managed through data collection, comparative analysis, and implementation of relevant energy-saving work in schools to reduce waste and ensure the rational use of energy in schools.

In recent years, as people's demand for electric energy has increased, the annual electricity consumption of schools has continued to increase, and the costs incurred have also increased. Therefore, safe use of electricity and energy conservation are important components of school safety and energy conservation, and are necessary guarantees for the healthy and sustainable development of schools.

In order to better implement energy conservation and reduce the cost of using electricity, you can consider the following aspects:

1. All lighting and electrical equipment in the public places of the campus are managed by the class in the Baogan District. The first responsible person is the class teacher. The lighting and electrical equipment of the office (fans, computers, air conditioners, etc.) are managed by the directors of the offices. The first person responsible is the director of the office.

2. The office turns on the lights when the lighting is insufficient. It is strictly forbidden to turn on the curtains with natural lighting. All power sources (lights, fans, computers, air conditioners, etc.) must be cut off when leaving school. The director of the office is responsible for inspections, and the results of the school safety team are included in the teacher's monthly assessment.

3. It is forbidden to use high-power power-consuming equipment such as electric heaters (heaters, electric blankets) in the office and dormitory; it is forbidden to use unsafe equipment such as money boards.

4.Classroom lighting, water dispensers, televisions, computers, etc., should be dedicated to others, other people can not open casually, should turn off the power in time after school. The classrooms use lighting to keep on and off, students can't rest during the break, and no drone lights can appear.

It is everyone's responsibility to save electricity, and we need everyone to start from scratch and contribute to building a more energy-efficient and environmentally friendly campus.

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