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A Study on Reasonable Energy Consumption Quota of Hotel

Zongjie Du, Shulin Sui, Chunliang Zhao
College of Mathematics & Physics, Qingdao University of Science & Technology, Qingdao 266061, China

***Corresponding Author:**
Zongjie Du
Email: 920750170@qq.com

Abstract: The study on reasonable energy consumption quota of hotel can be a hot topic in smart city. Based on the STIRPAT model, in the paper we establish the identity with the impact factors which effect the energy consumption of hotel. By calculating the correction coefficient of influencing factors, we can correct the final index of energy consumption, then we use the quartile to determine reasonable energy consumption quota of hotel. We can granulate the annual standard of the quota to smaller time period by reversing use mean value theorem for integrals. The hotel manager can carry out energy saving management and control according to the research of reasonable energy consumption quota, this study can formulate energy consumption quota for a certain area of the same star hotels, and provide the basis for the government to increase the excess fare and energy saving incentives.
Keywords: STIRPAT model, quartile, mean value theorem for integrals.

INTRODUCTION

It is a quite complex study when we evaluate the reasonable energy consumption of hotel. The study involves all aspects of energy consumption in the hotel. Up to now, individual region have introduced local standards [1]. A large number of documents show that the reasonable energy consumption quota needs to conform to the following principles [2, 3]. Firstly, taking into account the different influence between the individual energy consumption of hotel. In order to reflect the reasonableness of the requirements, we should ensure that most of the energy consumption level is under or close to the control line; Secondly, the reasonable energy consumption quota should reflect the advanced requirements. In this way we can promote the effective and sustainable development of hotel.

Based on the above principles, when we set the standard of energy consumption quota, we need to consider the different star, the different geographical, the different impact factors, and so on. So when we identify the reasonable energy consumption quota, firstly we should research the energy consumption level with the same star and the same area. Based on these statistics, we establish the corresponding mathematical model; Secondly considering the different impact factors of different hotels, we need to correct the coefficient of the main impact factors by mathematical model. Then we get the unit energy consumption which could be compared. Finally, we use the quartile to determine reasonable and advanced energy consumption of the different hotels in same area.

STUDYING THE ENERGY CONSUMPTION INDEX OF HOTEL

In order to get the reasonable energy consumption quota, we need to research the static factors which include the total construction area, parking area ratio, building layers, star, laundry room, swimming pool, and so on. We also need to research the dynamic factors which include occupancy rate, the using rate of saving equipment [4].

Assuming we have collected x impact factors data of m hotels with same star. According to the analysis method of grey correlation degree analysis and correlation analysis [5], we could get the main impact factors which can change the energy consumption of hotel.

Because of the different hotels have different impact factors; we cannot use a unified standard to measure the energy consumption of different hotels. In order to evaluate the reasonable energy consumption level of the hotel, we modify the energy consumption of hotel [6]. In this way we can get the unit energy consumption which could be regarded as the energy consumption index of hotel.

Determining unit area of energy consumption

In order to obtain the normalized indicators of energy consumption, we need to survey sample data according to energy consumption of the hotel and take effective mathematical method to establish model about the energy

consumption of hotel. Based on the main impact factors which can affect the energy consumption of hotel, using STIRPAT as the model of the energy consumption [7], we get the following formula:

$$\ln Y = \beta_0 + \sum_{k=1}^{n} \beta_k \ln x_k \tag{1}$$

Y represents unit area of energy consumption; $x_k (k = 1, 2, \cdots, n)$ is the k-th independent variable and represents main impact factors of energy consumption; β_k $(k = 1, 2, \cdots, n)$ is called the partial regression coefficient and represents coefficient of the k-th independent variable.

In generally, we use the unit area of energy consumption to represent the energy consumption level of hotel [8]. The expression is as the following:

$$EUI(x_1, \cdots, x_n) = Y \tag{2}$$

In the equation (2), when x_k is $\bar{x}_k$ which represents the average of m hotels, the $EUI(x_1, \cdots, x_n)$ corresponds to the average value $EUI(\bar{x}_1, \cdots, \bar{x}_n)$. When x_{ki} represents the statistical data x_k of the i-th hotel, the $EUI(x_1, \cdots, x_n)$ corresponds to the unit area of energy consumption $EUI(x_{1i}, \cdots, x_{ni})$ of the i-th hotel.

The determination of correction coefficient

For any factors x_k that affect energy consumption of the hotel, when the other factors are the sample mean value, we need to find a x_k which belongs to the interval $[x_k^{\min}, x_k^{\max}]$ to make the $EUI(x_1, \cdots, x_n)$ value of the maximum. The correction coefficients are defined as the following [9]:

$$C_k = \frac{\max\{EUI(x_1, \cdots, x_n)\}}{EUI(\bar{x}_1, \cdots, \bar{x}_n)} - 1, \quad x_k \in [x_k^{\min}, x_k^{\max}] \tag{3}$$

Determine comparable unit comprehensive energy consumption

Because the different hotels have different internal structure and facilities configuration, when we make transverse comparison between hotels, we only use unit area of energy consumption to compare would cause errors. It makes the comparison between the hotels become meaningless. So we introduce comprehensive energy consumption of comparable unit EUI_b, which can eliminate the errors between the different internal structures, and can make the comparison result more creditable.

The correction coefficient of each factor is added together, and multiply by the average value $EUI(\bar{x}_1, \cdots, \bar{x}_n)$, we can get the result as the following:

$$EUI_b = \left[\sum_{k=1}^{n} C_k + 1\right] EUI(\bar{x}_1, \cdots, \bar{x}_n) \tag{4}$$

For the same type of construction, the level of actual energy consumption should not be higher than the maximum comparable unit area of energy consumption. Meanwhile, taking into account the implementation of the early stages with a super fixed price measures, choosing loose standard of energy consumption is useful to carry out energy saving management and control, so we choose EUI_b as the index of unit area of energy consumption.

PARTITION THE ANNUAL REASONABLE ENERGY CONSUMPTION QUOTA

There is a close relationship between energy consumption standards and the star of hotel, because different star hotels correspond with different energy consumption standards [10]. The energy consumption of different star hotels decided by a series of static and dynamic factors $x = (x_1, \cdots, x_n)$. Assuming that the reasonable value of energy consumption is $f_1(x_1, \cdots, x_n)$, the advanced value energy consumption is $f_2(x_1, \cdots, x_n)$, then reasonable range of energy consumption is:

$$f_2(x_1, \cdots, x_n) \le EUI_b \le f_1(x_1, \cdots x_n) \tag{5}$$

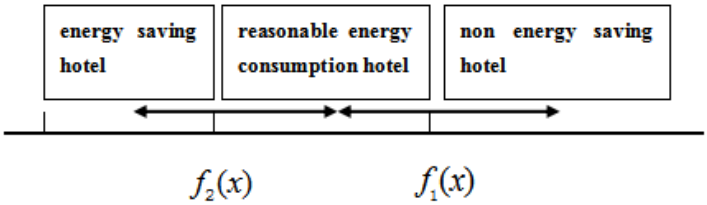

Fig-1: The range of reasonable energy consumption

Figure 1 shows that it isn't energy saving hotel, if the energy consumption of the hotel exceeds $f_1(x_1,\cdots,x_n)$. On the contrary, it is energy saving hotel, if the energy consumption below $f_2(x_1,\cdots,x_n)$ of the hotel.

The $f_1(x_1,\cdots,x_n)$ and $f_2(x_1,\cdots,x_n)$ are confirmed by a lot of statistical data from same star hotels. We collect the statistical data from same star hotels that number of the hotels is m in past n years. According to experience, in the actual execution we take upper quartile method and lower quartile method as a basis for inspecting total sample. Approximately 25% of the energy consumption exceeds the reasonable value, so these hotels need to be reformed in order to save energy.

Quartile principle in the statistics

After all the data are sorted in the order of value, the variable value in each equal position is called the quantile. Quartile is all the data which is divided into four equal portions, each section contains 25% of the data, each equal portion value is quartile [11]. Quartile has three values, the first value is called the lower quartile, the second value is the median, the third value is called upper quartile, respectively use Q_1,Q_2,Q_3 to represent. Quartile as a form of quantile, it has a very important role and significance in statistics, the calculation method of quartile is the following describes.

Supposing energy consumption of same star hotels is discrete and is not packet processing, then quartile calculated by the following method:

First step: determine position of quartile.

$$Q_i = \frac{i(n+1)}{4} \quad i=1,2,3 \tag{6}$$

The n is the number of data.

Step two: according to the position of the first step and calculating the corresponding quartile.

If (n+1) is not the integral multiples of 4 in the equation (6), so position of quartile with a decimal, then we need further research. There is a certain relationship between the value before and after position and the decimal position: quartile is the average of two adjacent integers, weight depends on the distance of two integers, the closer distance, the greater the weight, the farther the distance, the smaller the weight, and weight should be equal to the sum of 1.

Setting the decimal part of Q_i is q, the location before and after the value is respectively by α,β, then the quartile is

$$Q_i = \alpha(1-q)+\beta\times q \tag{7}$$

Reasonable value and advanced value of the energy consumption

Based on the statistical data of energy consumption from many hotels, we start to sort after data processing, and we determine the reasonable and advanced value of energy consumption by quartile [12].

In order to determine order index, we get EUI_b of m hotels according to the equation (4). Then we sort from small to large order according to the above described the method of quartile. We take the lower quartile as advanced value of the energy consumption, following:

$$f_2(x) = EUI_{b,\frac{1}{4}} \tag{8}$$

The energy consumption of such hotels is quite energy saving, then we ensure this type of hotels is energy saving advanced hotel;

We take the upper quartile as reasonable value of the hotel energy consumption, following:

$$f_1(x) = EUI_{b,\frac{3}{4}} \tag{9}$$

The energy consumption of such hotels is reasonable, then we ensure this type of hotels is energy saving reasonable hotel.

ENERGY CONSUMPTION STANDARD FOR GRANULATION

Last section we put forward the division of reasonable annual energy consumption quota, and we can get the reasonable value and advanced value by the dividing. But we do not granulate the reasonable energy consumption quota by quarter, months, weeks, days, etc. Based on the mean value theorem for integrals, the energy consumption can be granulated to smaller time period. In order to explain the basic principles of the granulation, we only use the reasonable monthly energy consumption quota to granulate the energy consumption standard.

Mean value theorem for integrals

The mean value theorem for integrals is defined as following:

If the function $f(x)$ is continuous on the integration interval $[a,b]$, there is at least one point ξ in the interval $[a,b]$. The following formation is established as following.

$$\int_a^b f(x)dx = f(\xi)(b-a) \quad (a \le \xi \le b) \tag{10}$$

Formula (10) is called the mean value theorem for integrals [13].

Reasonable annual energy consumption index curve

Based on a large number of statistical data about energy consumption of hotels, we get the unit annual energy consumption which is as the reasonable energy consumption value by the quartile method. As shown in the following figure:

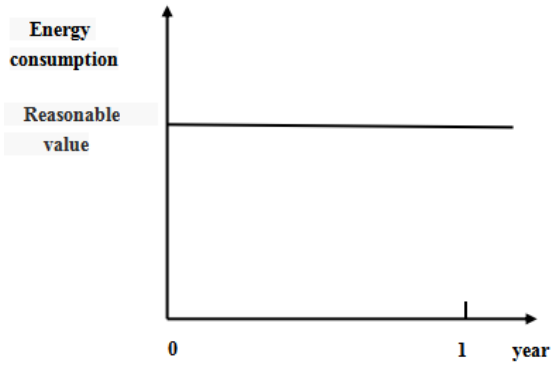

Fig-2: Reasonable value of annual energy consumption

The annual energy consumption curve

Based statistical data about energy consumption of a certain hotel, using STIRPAT model get the annual energy consumption curve $f(x)$, as shown in the following figure:

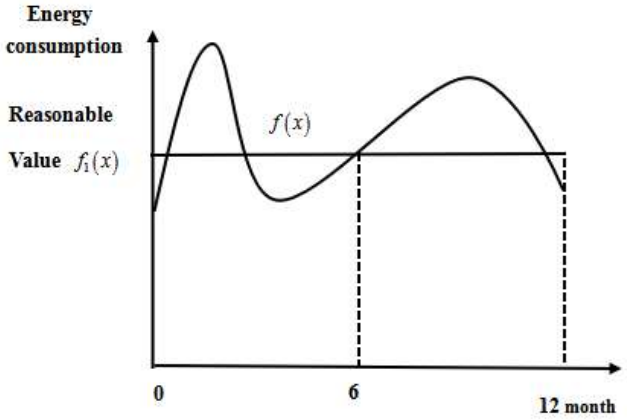

Fig-3: Annual energy curve and reasonable value

We reverse use the mean value theorem for integrals in figure 3, the annual energy consumption curve could be equal to the reasonable energy consumption value curve for the integral interval in one year.

$$\int_0^{12} f(x)dx = \int_0^{12} f_1(x)dx \tag{11}$$

Granulation of monthly energy consumption

On the basis of the last step, we take July as an example, using the mean value theorem for integrals to calculate the reasonable value of energy consumption. As shown in the following figure:

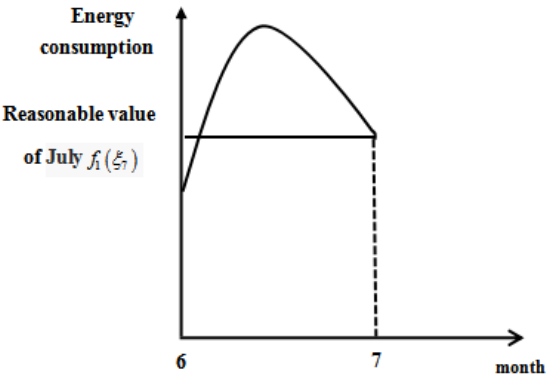

Fig-4: Reasonable value of energy consumption for July

As shown in Figure 4, based on the energy consumption value in July, according to the mean value theorem for integrals, we can get the following formula

$$\int_6^7 f(\xi_7)dx = \int_6^7 f(x)dx \tag{12}$$

The $f(\xi)$ is regarded as the reasonable energy consumption value in July. In same way, we can get the monthly energy consumption at the following figure.

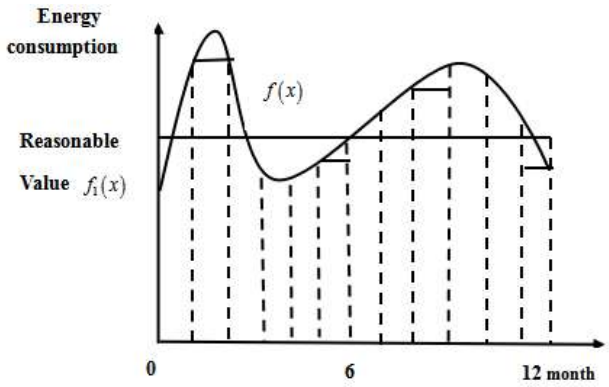

Fig-5: The monthly energy consumption quota

Similarly, we can granulate the reasonable energy consumption quota by quarter, months, weeks, days, etc.

SUMMARY

In this paper we put forward the research method of reasonable energy consumption quota. Firstly, we set up the energy consumption index model which is based on the theory of STIRPAT. Considering that lots of factors can affect the energy consumption of hotel, in order to evaluate the reasonable energy consumption level of hotel, We need to put the impact factors which effect the energy consumption of hotel at the same level in the ideal situation. A method for calculating the correction coefficient of each impact factor is proposed. Then we get the unit energy consumption which could be compared. The unit energy consumption is used as an indicator of energy consumption.

We apply the concept of the quartile in statistics. Upper quartile and lower quartile are used as a reference. As a result, we determinate the reasonable value and advanced value of the energy consumption.

Based on the above analysis, finally we granulate reasonable energy consumption quota of annual cycle into smaller time period by using mean value theorem for integrals. We formulate a more accurate energy consumption index. Our study is based on history of statistical energy consumption data which the data come from the same area and the same star hotels. The hotel managers can carry out energy saving management and control according to this paper study.

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