

Study on the Factors of Energy Consumption of Highway Transport Passenger Station

FAN Li

School of Mechanical Engineering
Anhui University of Science and Technology
Huainan Anhui, China
fanli0815@sohu.com

TIAN Xiao-xue, WANG Sheng-chang

School of Automobile
Chang'an University
Xi'an, China
wshch@chd.edu.cn

Abstract—As the key position in the road transport, passenger depot is the enterprise of high energy consumption. Passenger depot should set the energy conservation standard, take effective measures to reduce the energy consumption. In the paper, factors related with energy conservation are extracted by analyzing the survey data and the weight of each factor can be calculated by GAHP. It provides the theoretic foundation for confirming energy-saving evaluation indicators of highway transport passenger station.

Index Terms—Energy consumption factor, GAHP, weight computing, road transport.

I. INTRODUCTION

As the economic develops constantly and rapidly, passenger transportation industry has a rapid development. Highway passenger transport plays an important role in the passenger transportation, but it has high energy consumption. Facing the increasingly strengthen resource environment, practical energy-saving measures should be taken in highway passenger transport. As the node of the highway passenger transportation, transport passenger station consumes a lot of energy and it has many influencing factors of energy consumption. In this paper, the weight of each influencing factor is calculated by analytic hierarchy process based on group decision. It provides theoretical basis for the research on the index and method of energy-saving evaluation in future.

II. ENERGY CONSUMPTION CALCULATION AND FACTOR EXTRACTION

A. Energy consumption calculation of transport passenger stations in type regions.

In this paper, three type cities are selected, they are Chang chun, Xi'an and He fei. They are belong to freezing region, cold region and hot-summer and cold-winter zone according to "China Architectural climatic zoning map". Two transport passenger stations are chose in each city. The content of the investigation includes site selection, building facilities, layout technology, hardware configuration and the type of energy and consumption.

Energy consumption of these transport passenger stations are calculated in three steps. Various kinds of

energy consumption are converted into standard fuel consumption first; second the consumption of each kind of energy per unit area should be calculated; at last the comprehensive energy consumption per unit area can be reached. In this paper, energy consumption is converted into standard coal. The consumption of each kind of energy per unit area of each transport passenger station is shown in fig.1. The comprehensive energy consumption per unit area of each transport passenger station is shown in fig.2.

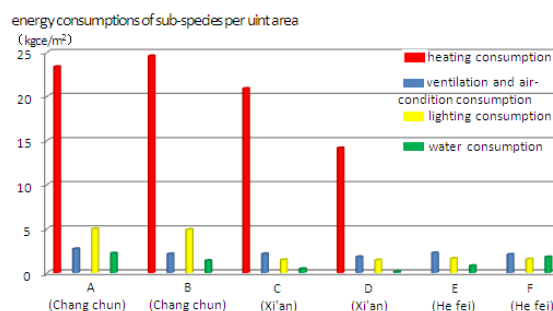


Fig.1. Energy consumptions of sub-species per unit area of passenger stations

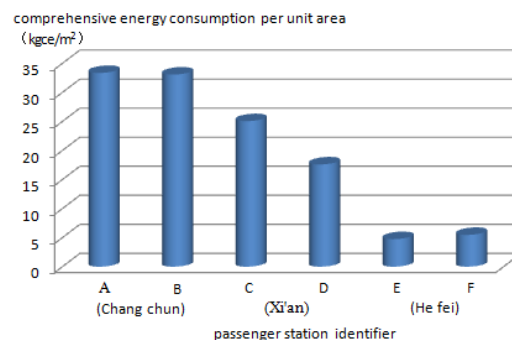


Fig.2. Comparison of the comprehensive energy consumption of passenger stations

Figure.1 shows that heating is the biggest and most important part in energy consumption of passenger station in freezing region and cold region, lighting takes second place. In hot-summer and cold-winter zone, ventilation and air-condition is the biggest part in energy consumption of

passenger station. Lighting is also in second place. In fig.2, it can be shown that energy consumption of passenger station in colder region is higher than that in warmer region. That is to say, the warmer the region is, the lower is the energy consumption of passenger station.

B. The influencing factors of energy consumption of highway transport passenger station

According to “Categorizing and construction request of bus passenger station” (JT/T 200-2004), the influencing factors of energy consumption of highway transport passenger station are selected from 4 aspects such as site selection, layout technology, building facilities and hardware configuration. Through analysis, 18 influencing factors of energy consumption can be chosen, shown in table 1. The subordinate relationships between these aspects and influencing factors are shown in table 2.

TABLE I. INFLUENCING FACTORS OF ENERGY CONSUMPTION

influencing factors	influencing factors
Planning coordination (C ₁)	Exterior-protected construction (C ₁₀)
Integrated transport coordination (C ₂)	Area ratio of window to wall (C ₁₁)
Highway trunk coordination (C ₃)	External shading (C ₁₂)
Vehicle access conditions (C ₄)	Area of the windows can be opened (C ₁₃)
General layout (C ₅)	Transport and handling equipment (C ₁₄)
Station layout (C ₆)	HVAC equipment (C ₁₅)
Site layout (C ₇)	Electric accessory (C ₁₆)
Facilities scale adaptability (C ₈)	Plumbing equipment (C ₁₇)
Shape coefficient (C ₉)	Measuring equipment (C ₁₈)

TABLE II. SUBORDINATE RELATIONSHIPS BETWEEN THESE ASPECTS AND INFLUENCING FACTORS

site selection(B ₁) (C ₁ -C ₄)	building facilities(B ₃) (C ₉ -C ₁₃)
layout technology(B ₂) (C ₅ -C ₈)	hardware configuration(B ₄) (C ₁₄ -C ₁₈)

Table 1 shows that there are a lot of influencing factors of energy consumption. What’s more, the weights of the influencing factors are different. So it is necessary to calculate the weights of influencing factors before confirming energy-saving evaluation indicators.

III.CALCULATION OF THE WEIGHT OF INFLUENCING FACTORS

A. Computational method of the weight

In these influencing factors of energy consumption, some of them can be quantified; some can only be analyzed qualitatively. In this paper, analytic hierarchy process based on group decision (GAHP) is used. The basic method of analytic hierarchy process (AHP) is sequencing. That’s to say, these influencing factors should be sequenced according to their weight. AHP has the advantage of evaluating things with different levels and multiple criteria.

It disadvantage is that it is affected by personal factors easily. The evaluation can be affected by limited knowledge and subjective preference. GAHP analyze and aggregate subjective preference of group members, it can arrival at a scientific and reasonable conclusion.^[1]

B. Computational method based on GAHP

The model of hierarchical structure should be established first. In the model, there are 3 levels, target level, criterion level and layout process level. Target level is energy consumption evaluation of highway transport passenger station (A). Criterion level includes site selection (B₁), layout technology (B₂), building facilities (B₃) and hardware configuration (B₄). Layout process level includes 18 influencing factors are shown in table 2.

In this paper, 3 decision makers are all experts in station planning and evaluation on energy saving, their code names Z₁, Z₂ and Z₃. In the model, experts compare each element in B and C levels and take the upper level as the criterion. The result of comparison is quantified by index labeling method (e^{0/5}~e^{8/5}) to build judgment matrix.

Judgment matrix should be validated with the random consistency. At last, 5 judgment matrixes are constructed and validated. Eq. 1 is the formula of random consistency validation.

$$CR = \frac{CI}{RI} \tag{1}$$

In Eq.1, $RI = \frac{k - n}{n - 1}$, $CI = \frac{\lambda_{\max} - n}{n - 1}$, λ_{\max} is the biggest characteristic root of the judgment matrix.^[2]

The weight of each expert is obtained according to his professional ability, authority and familiarity. Through the analysis, the weights of Z₁, Z₂ and Z₃ are 0.4, 0.35 and 0.25. In this paper, the weighted geometric mean method (WGMM) is used to aggregate individual judgment (AIJ).

Eq. 2 is the formula of WGMM.

$$\prod_{k=1}^m (a_{ij}^k)^{w_k} \tag{2}$$

In Eq. 2, w^k is the weight of member Z_k.

Judgment matrix of criterion level is given in Table 3 and judgment matrixes of layout process level are given in Table 4, 5, 6 and 7.

TABLE III. MATRIX B CONCENTRATED AIJ BY WGMM

A	B ₁	B ₂	B ₃	B ₄	Weight(W _i)
B ₁	1.0000	1.0618	1.2840	1.3498	0.2883
B ₂	0.9417	1.0000	1.2840	1.3771	0.2811
B ₃	0.7788	0.7788	1.0000	1.1052	0.2239
B ₄	0.7408	0.7261	0.9048	1.0000	0.2067
CR=CI/RI= 0.0143<0.10					

TABLE IV. MATRIX C CONCENTRATED AIJ BY WGMM (C1-C4)

B _i	C ₁	C ₂	C ₃	C ₄	W _i
C ₁	1.0000	1.1052	1.1972	1.2214	0.2796
C ₂	0.9048	1.0000	1.2214	1.2840	0.2707

C_3	0.8352	0.8187	1.0000	1.4918	0.2492
C_4	0.8187	0.7788	0.6703	1.0000	0.2005
$\lambda_{\max} = 4.0502, CR=CI/RI= 0.0188<0.10$					

TABLE V. MATRIX C CONCENTRATED AIJ BY WGMM (C5-C8)

B_2	C_5	C_6	C_7	C_8	W_i
C_5	1.0000	1.2214	1.2840	1.0000	0.2777
C_6	0.8187	1.0000	1.4918	1.0618	0.2648
C_7	0.7788	0.6703	1.0000	0.8269	0.2012
C_8	1.0000	0.9417	1.2092	1.0000	0.2563
$\lambda_{\max}=4.0301, CR=CI/RI= 0.0113<0.10$					

TABLE VI. MATRIX C CONCENTRATED AIJ BY WGMM (C9-C13)

B_3	C_9	C_{10}	C_{11}	C_{12}	C_{13}	W_i
C_9	1.0000	1.4770	1.5683	1.8964	2.0544	0.2986
C_{10}	0.6770	1.0000	1.4477	1.6000	1.7682	0.2358
C_{11}	0.6376	0.6907	1.0000	1.1735	1.4918	0.1826
C_{12}	0.5273	0.6250	0.8521	1.0000	1.3910	0.1593
C_{13}	0.4867	0.5655	0.6703	0.7189	1.0000	0.1237
$CR=CI/RI= 0.0100<0.10$						

TABLE VII. MATRIX C CONCENTRATED AIJ BY WGMM (C14-C18)

B_4	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}	W_i
C_{14}	1.0000	1.6487	2.0137	2.5345	3.3201	0.3499
C_{15}	0.6065	1.0000	1.3771	2.1170	2.5857	0.2436
C_{16}	0.4966	0.7261	1.0000	1.6000	1.9542	0.1842
C_{17}	0.3946	0.4723	0.6250	1.0000	1.7506	0.1308
C_{18}	0.3012	0.3868	0.5117	0.5712	1.0000	0.0915
$\lambda_{\max} = 5.0353, CR=CI/RI= 0.0079<0.10$						

The weight of each influencing factor is the product of element of matrix B and element of matrix C. The sequence list of the influencing factors is given in table 8.

TABLE VIII. INFLUENCING FACTORS OF ENERGY CONSUMPTION SIZED DOWN WITH THE BIGGEST IN FRONT

Influence factor	Weight	Influence factor	Weight
Planning coordination C_1	0.0806	Site layout C_7	0.0566
General layout C_5	0.0781	Exterior-protected construction C_{10}	0.0528
Integrated transport coordination C_2	0.078	HVAC equipment C_{15}	0.0504
General layout C_5	0.0744	Area ratio of window to	0.0409

		wall C_{11}	
Transport and Handling equipment C_{14}	0.0723	Electric accessory C_{16}	0.0381
Facilities scale adaptability C_8	0.0721	External shading C_{12}	0.0357
Highway trunk coordination C_3	0.0718	Area of the windows can be opened C_{13}	0.0277
Shape coefficient C_9	0.0669	Plumbing equipment C_{17}	0.027
Vehicle access conditions C_4	0.0578	Measuring equipment C_{18}	0.0189

In table 8, influencing factors were sized down with the biggest in front. It shows that the weight of planning coordination is the biggest, while the weight of measuring equipment is the smallest.^[3] Energy-saving evaluation criteria is set according to the weight of influencing factors and relative standards should be take into consideration, such as “Construction design standard of highway transportation station” and “National work requirements about energy saving design and assessment of engineering construction project” etc.

IV.CONCLUSION

In this paper, 6 passenger stations in 3 climatic zoning are surveyed, the data are standardized to analyze comprehensive energy consumption and energy consumption of sub-species. 18 influencing factors are chosen from 4 aspects as site selection, building facilities, layout technology and hardware configuration according to the research results. The weights of these influencing factors are calculated by GAHP. Influencing factors were sized down with the biggest in front. It provides theoretical basis for confirming energy-saving evaluation indicators of highway transport passenger station. It has the important practical significance.

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