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Comfort Evaluation and Application of Office Chair Based on FAHP

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Abstract. In order to establish an evaluation system of office chair comfort, this paper comprehensively and quantitatively analyzed the qualitative problem of comfort. Typical office chair samples were selected through cluster analysis and multi-dimensional scale analysis methods, and FAHP was used to establish the evaluation model from four aspects: physical scale, adjustability, support and synergy. Then, the model was used to evaluate the comfort of three office chair types. The results showed that it is feasible to apply FAHP to product evaluation of office chairs, and this evaluation model can provide a quantitative indicators system of seat products.

1. Introduction

Comfort is a subjective feeling that comes from people's reactions to the environment. It is affected by many factors and is difficult to compare[1]. With the advancement of industrialization and the development of office automation, sitting work has become a common way of working[2]. The ergonomic office chair can transfer the weight of the body through the seat, backrest and handrails, reducing the physical energy consumption of the limbs and muscles, helping the staff to maintain a comfortable sitting posture and improve their working efficiency. On the contrary, it will aggravate the user's fatigue and even cause the deformation of the cervical and lumbar spine[3]. Therefore, based on Fuzzy analytic hierarchy process (FAHP), this paper comprehensively and quantitatively analyzed the comfort of office chairs and established an evaluation system to promote product performance.

2. FAHP

AHP was proposed by Professor Thomas L. Saaty of the University of Pittsburgh in 1971. It can turn complex problems into system-level problems and compare the importance of each element[4]. However, this method tends to be subjective in the establishment of hierarchical relationships, and is susceptible to extreme values in data analysis. Therefore, scholars introduce the fuzzy number theory into AHP to form FAHP to solve the problem[5]. The procedure for applying FAHP to the evaluation of office chair comfort is shown in Figure 1.

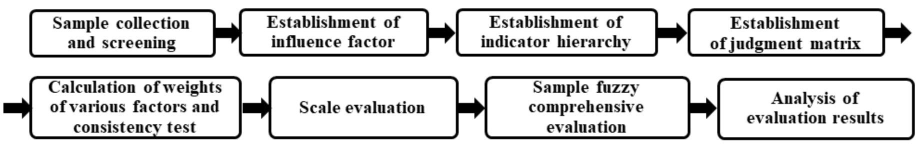

Figure 1. Office chair comfort evaluation process based on FAHP

3. Construction of the influence factor set of office chair comfort

3.1. Office chair samples collection and selection

100 office chair samples were collected from the store, product brochures, and the official website. Try to select images at a 45° perspective and classify the samples by multidimensional scaling. In order to anticipate the problems that may exist in the classification process, 4 people were asked to classify the samples for pre-experiment. The results showed that when the number of classifications was 7~8, the experiment would be easier to carry out. Therefore, in the formal classification experiment, 7~8 categories were used as standard. 30 people were asked to observe the samples, and the samples they thought were similar were filled in the same column, and the number of each type could be different. According to the distance between the sample and the category center, 8 representative samples such as D_4, D_{19}, D_{24}, D_{37} and D_{56} were selected for further research. (Table 1)

Table 1. Representative sample of office chair products

D_4	D_{19}	D_{24}	D_{27}	D_{35}	D_{44}	D_{56}	D_{75}
							

3.2. Analysis of design factors for office chair comfort

The most basic function of the office chair is to provide support for sitting. The basic components of the office chair include the chair legs, the seat surface, the backrest or a seat backrest integrated structure, and the functional extension components include the armrest, the lumbar support, the headrest and the like[6]. According to the principle of morphological analysis, the above eight office chair samples were decomposed into several independent design projects to analyze the comfort design elements involved. (Table 2)

Table 2. Decomposition of office chair comfort design elements

Design project	Office chair comfort core design elements
Backrest	Height, width, inclination, support, adjustability, material
Armrest	Height, width, adjustability
Cushion	Height, width, depth, fit, material
Chair leg	Adjustability, support, safety

4. Construction of comprehensive evaluation model for office chair comfort

4.1. Establishment of indicator evaluation level model

The indicators of the index set U= {u1, u2, ..., u_n} were divided hierarchically according to the target and the relationship between various factors. Through the analysis of office chair research and comfort design elements, combined with expert opinions and related literature, 16 items were summarized. The office chair comfort index was divided into three levels, including target layer A, criterion layer B and indicator layer C[7]. As shown in Figure 2, the 16 items were attributed to the indicator layer, and the four criteria level standards were obtained through classification, which were physical scale, adjustability, support and synergy.

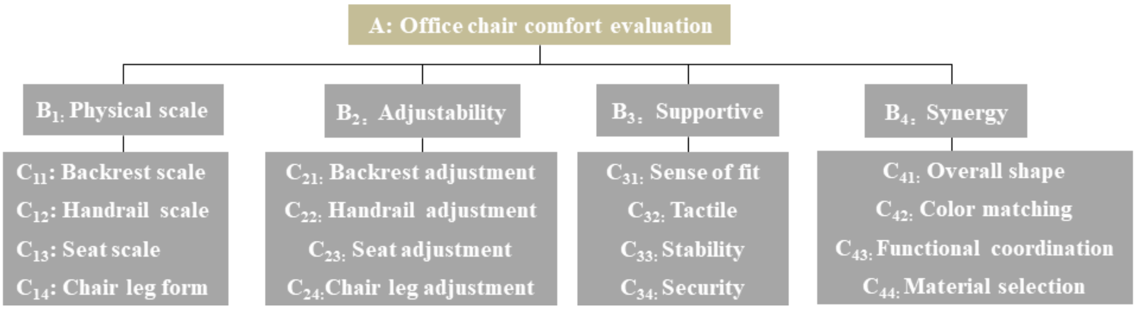

Figure 2. Evaluation index model of office chair

4.2. Construction of judgment matrix

In order to calculate the weight value of each layer index, the judgment matrix was constructed by pairwise comparison, and the importance between the evaluation items was expressed according to the comparison scale of 1-9[8]. Taking the comfort of the office chair as the evaluation object, 20 people were subjected to conduct the analytic questionnaire survey. The criterion layer judgment matrix is shown in Table 3, and the indicator layer judgment matrix is shown in Tables 4-7.

Table 3. Criteria layer judgment matrix

A	B_1	B_2	B_3	B_4
B_1	1	3	2	3
B_2	1/3	1	1/2	2
B_3	1/2	2	1	3
B_4	1/3	1/2	1/3	1

Table 4. Physical scale indicator layer judgment matrix

B_1	C_{11}	C_{12}	C_{13}	C_{14}
C_{11}	1	3	2	4
C_{12}	1/3	1	1/3	1/2
C_{13}	1/2	3	1	4
C_{14}	1/4	2	1/4	1

Table 5. Adjustable index layer segment matrix

B_2	C_{21}	C_{22}	C_{23}	C_{24}
C_{21}	1	3	2	2
C_{22}	1/3	1	1/4	1/2
C_{23}	1/2	4	1	2
C_{24}	1/2	2	1/2	1

Table 6. Supportive index layer segment matrix

B_3	C_{31}	C_{32}	C_{33}	C_{34}
C_{31}	1	4	3	1

C_{32}	1/4	1	1/2	1/2
C_{33}	1/3	2	1	1
C_{34}	1	2	1	1

Table 7. Synergistic index layer segment matrix

B_4	C_{41}	C_{42}	C_{43}	C_{44}
C_{41}	1	2	3	2
C_{42}	1/2	1	4	3
C_{43}	1/3	1/4	1	1/2
C_{44}	1/2	1/3	2	1

4.3. Weight calculation and consistency test of various factors

Solve the weight vector of each judgment matrix and check the consistency. The formulas included in the calculation steps are as follows:

$$\mathrm{M_i}=\prod_{j=1}^{m} a_{ij}\ (\mathrm{i}=1{,}2,\cdots,\mathrm{m}) \tag{1}$$

$$w_i=\sqrt[m]{M_i} \tag{2}$$

$$W_i=w_i/\sum_{i=1}^{m} w_i \tag{3}$$

$$\mathrm{CI}=\lambda_{max}-n/n-1 \tag{4}$$

$$\mathrm{CR}=CI/RI \tag{5}$$

According to the method, weight vectors of the criterion layer and the relative indicator layer were calculated. As shown in Table 8, the fuzzy judgment matrix for evaluating the comfort of office chair is A= [0.44 0.16 0.28 0.10].

Table 8. Calculation Results and Consistency test of Office Chair Comfort Evaluation Index

Criteria layer		Indicator layer		Consistency test	Criteria layer		Indicator layer		Consistency test
Index	Weight	Index	Weight		Index	Weight	Index	Weight	
B_1	0.44	C_{11}	0.46	$\lambda_{max}=4.17$	B_3	0.28	C_{31}	0.42	$\lambda_{max}=4.09$
		C_{12}	0.10	CI=0.06			C_{32}	0.11	CI=0.03
		C_{13}	0.32	CR=0.06			C_{33}	0.20	CR=0.04
		C_{14}	0.12	CR<0.1			C_{34}	0.27	CR<0.1
B_2	0.16	C_{21}	0.41	$\lambda_{max}=4.09$	B_4	0.10	C_{41}	0.38	$\lambda_{max}=4.14$
		C_{22}	0.10	CI=0.03			C_{42}	0.32	CI=0.05
		C_{23}	0.31	CR=0.04			C_{43}	0.09	CR=0.05
		C_{24}	0.18	CR<0.1			C_{44}	0.15	CR<0.1

4.4 Fuzzy comprehensive evaluation

Comment set E= {satisfied, general, dissatisfied, very dissatisfied} was used to express perception, the corresponding score levels were 80, 60, 45, and 30. More than 80 points were considered satisfied, 60~80 was general, 45~60 was dissatisfied, and 30~45 was very dissatisfied[8]. As shown in Table 9, the results of fuzzy comprehensive evaluation were transformed, according to the principle of maximum membership degree.

Table 9. Fuzzy comprehensive evaluation result of office chair comfort

Evaluation factor	D_4	D_{35}	D_{44}
Physical scale	80.42	47.83	75.22
Adjustability	82.11	36.00	60.00
Supportive	74.56	55.62	65.54
Synergy	75.62	46.50	72.34
Comprehensive comfort	80.23	48.80	71.20

According to Table 9, the comfort evaluation score of D_4 is the highest, corresponding to the satisfied level of the comment set. D_{35} and D_{44} correspond to the dissatisfied and general levels respectively. D_4 is higher than D_{35} and D_{44} in each score, and the adjustable index score is much larger than D_{35} and D_{44}, indicating that D_{35} and D_{44} need to be improved in seat adjustability. The synergy indicators and physical scale indicators of D_{35} are dissatisfied, indicating that the office chair is insufficient in aesthetics and ergonomics.

5. Conclusion

Seat comfort evaluation is to find out the influencing factors and the relationship between them, then calculate the degree of influence on comfort, and finally establish an evaluation index system[9]. Based on FAHP, this paper established a comprehensive evaluation model that affected the comfort of office chairs, including physical scale, adjustability, support and synergy, and used the model for comfort assessment. The results indicated that it was feasible to apply FAHP to seat comfort evaluation. In the future, research in this field should combine subjective and objective evaluation methods, and rely on big data resources to enrich human parameters, analyze the influencing factors of seat comfort based on ergonomics, and quantify the weight of factors.

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