

Analysis of functions of healthy office furniture based on analytic hierarchy process

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Abstract. In this digital information age, electronic devices can improve the work efficiency and reduce work load in business, but sedentary and long-time work style undermines the health of white-collar workers in the office. By combining qualitative and quantitative analysis, we aimed to identify the factors affecting health of white-collar workers in the office. Based on user demands, we summarized the design concepts for office furniture, pre-selected functions of the furniture, built a layered function model for healthy office furniture, and performed weight calculation on the criterion layer and the measure layers. The analytic hierarchy process method was used to sequence the functions of healthy office furniture to provide new design ideas and a basis for design of healthy office furniture.

1 Introduction

Work is an important part of people's lives. White-collar workers often sit in front of the screen and work more than half or more hours for eight hours a day. This is one of the reasons why more and more white-collar workers suffer from office syndromes. According to the prediction of the World Health Organization, more than 70% of physical diseases result from sedentary work by 2020 [1]. Office furniture, as an essential product for white-collar workers, can also play an important role in preventing occupational diseases. Therefore, our research integrates a healthy concept into the design of office furniture, so that office furniture has practical value and significance. Office furniture may play an important role in preventing

occupational diseases. Therefore, this research integrates health concepts into office furniture and make it more practical value and significance.

In the late 1990s, "Healthy Industrial Design (HID)" was proposed by Mr Alan Tye, Royal Industrial Designer [2]. Health industry design is also regarded as "health engineering" because it prioritizes health and pays attention to whether the product can help people maintain a healthy state. We found that in the office, the factors that affect the health of the office population mainly include environmental factors, man-machine factors, and work factors by using the analysis of the survey results of the office population. We analysed the mental state, work habits, behaviour habits, and office syndrome improvement measures of the office population. The office furniture design concepts oriented to the workers' health are shown in Table 1.

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Table 1. Healthy office furniture design concepts

	Concepts
Environmental factors	<ul style="list-style-type: none"> ◆ Strengthening lighting function: users can adjust the lighting according to their specific needs. ◆ Setting up air purification function: to help improve the physical environment of the office. ◆ Indoor air quality testing through the desk to facilitate users to adjust the surrounding environment. ◆ Indoor air quality testing through the desk to facilitate users to adjust the surrounding environment. ◆ According to the needs of employees for rehabilitation coaches, people should increase the function of video to guide employees to properly stretch and relax. ◆ Setting up health assessment function lets employees know their own health status at any time. ◆ The health knowledge can be transferred to employees through office furniture to raise awareness of health concern. ◆ People can combine entertainment functions with office furniture to properly entertain and relax when not working a
Man-machine factors	<ul style="list-style-type: none"> ◆ Healthy office furniture can recognize employees' bad sitting posture and correct sitting posture. ◆ Designing adjustable office furniture, and remind the user when it is at the height most suitable for the user's body to help improve the human-machine relationship in the office. ◆ The design of office furniture should meet the needs of employees for lunch break as much as possible. ◆ Desk storage function is set on the desk. ◆ Combining fitness function with office furniture, you can exercise while working out to prevent fat accumulation.
Working factors	<ul style="list-style-type: none"> ◆ File storage, file transfer and other operations can be performed through office furniture. ◆ When the user sits on the chair for a long time, the user should be reminded to carry out appropriate activities. ◆ Help users plan work tasks, improve work efficiency, and enhance work confidence. ◆ Setting up the status recognition function: when you don't want to be disturbed by others, you can set it to the busy state. ◆ Setting up a punching function on office furniture to avoid forgetting to punch in or queuing to punch in. ◆ When the user leaves, the office furniture can be set to the "leave" or "closed" state, so the rest of the people cannot use it, thus protecting user privacy. ◆ When multiple people use this office furniture, it should be able to distinguish different users, and the files stored by each user cannot be viewed with each other. ◆ Office furniture can be reminded of important events, such as anniversaries, meeting times, etc.

These concept points are converted into functions of office furniture products that are an important part of healthy office design. Through the quality function deployment (QFD), we identify research steps and seven functions based on the importance of the functions. The details are as follows.

Quality function development, called the QFD method, is a method that uses a matrix to quantify various indicators affecting the product and to meet the customer's maximum demands during the product development

process. Further, specific solutions should be proposed. QFD can not only help companies locate customer needs and choose solutions, but also break communication barriers between departments. This can reduce design period, uncertainty, and investment costs, improving product quality and user satisfaction.

There are several typical quality management tools under the QFD framework. As shown in Table 2, each tool has a different role. According to the needs of this article, the chromatographic analysis method will be adopted as a tool for functional sequencing.

Table 2. Typical quality management tools under the QFD framework

Title	Features
Affinity diagram KJ	Identifying the essence of complex problems and collect different opinions, ideas and experiences, more suitable for unknown fields

Relation diagram	Finding the problem that affects the quality from the horizontal causal relationship between the problems, suitable for analyzing complex problems intertwined by multiple factors
System diagram (tree diagram)	Systematical identifying the problem, looking for specific means that can solve the problem, and form a "purpose-means" diagram
Matrix diagram	Looking for paired factors to construct a matrix diagram, comprehensively analyze multi-factor associations, and find key points
Process decision procedure diagram	Anticipating obstacles and possible outcomes during development and design, avoid major mistakes
Analytic hierarchy process	It can handle complex decision-making problems, suitable for prioritizing subjective information
Blueprint	Describing the service process in detail, and transforming the invisible service into specific steps and methods
The House of Quality	In the process of product design and development, it is used to connect user needs and corresponding product functions or services

2 Analytic hierarchy process

Analytical Hierarchy Process (AHP) was proposed by American operations researcher T.L. Saaty in the mid-1970s. AHP is competent to deal with complex decision-making problems. It can implement system analysis by assigning values to certain qualitative factors [3]. It is suitable for subjective problems and situations with uncertain factors, and it has a logical layering of complex problems. The method also has the advantages of organization, which can make the selection process more visual and concise. This method is not only can resolve subjective problems and situations with uncertain factors, but also can make complex problems logical, hierarchical and organized, making the selection process more concise and clearer.

As a mixed method of qualitative analysis and quantitative analysis, AHP can not only avoid the limitations of qualitative analysis but also have the scientific reliability of quantitative analysis [4]. The analytic hierarchy process analyzes the weights of the selected functions and optimizes the order of core functions, main functions, secondary functions and auxiliary functions of the product. The purpose is to understand the needs of customers and distinguish primary

and secondary. Then, designers can allocate their work. Finally, we hope to achieve the maximum users' satisfaction at the least cost.

3 Apply AHP can determine the functional weighted ranking of healthy office furniture

3.1 Product function preselection

Although the above summarizes the design concepts of 20 healthy office furniture, when we try to design furniture, it is unlikely to use all the conceptual functions on one product.

Therefore, if we would like to design a kind of office furniture that can be deeply liked by office workers and really resolve their difficulties, we first upgrade the concepts into conceptual functions and then we need to screen the conceptual functions. During this process, there may be several concepts combining into a conceptual function. The process of function selection is in the form of a questionnaire. It requires opinions from white-collar workers with a sedentary job. Employees are asked to choose the three functions they most expect from all the conceptual functions. The conceptual function and questionnaire form is shown in Figure 1:

Voting for Functions of Healthy Office Furniture

Hi, this is a vote for the functional screening of healthy office furniture. Healthy office furniture aims to promote healthy working methods and improve work efficiency in the office. To identify the most suitable functions, we invite you to take part in this vote. Thank you for your support. ↵

Please select the three product functions you expect the most:↵

Update health knowledge↵ Health assessment↵ File transfer↵
 Storage function↵ Lighting adjustment↵ Fitness equipment↵
 Sitting posture correction↵ Height adjustment↵ Convenience for lunch breaks↵
 Sedentary reminder↵ Work planning↵ Air purification↵
 Air quality inspection↵ Separation between leisure and busy state↵ Entertainment↵
 Privacy protection↵ Important event reminder↵ Event logging↵

Figure 1. Questionnaire for functions of healthy office furniture

In this survey, there are 120 participants in the voting. As survey results in Figure 2 show, the seven functions with the most votes are sedentary reminder, height

adjustment, lighting adjustment, work planning, sitting posture correction, air purification function and state separation.

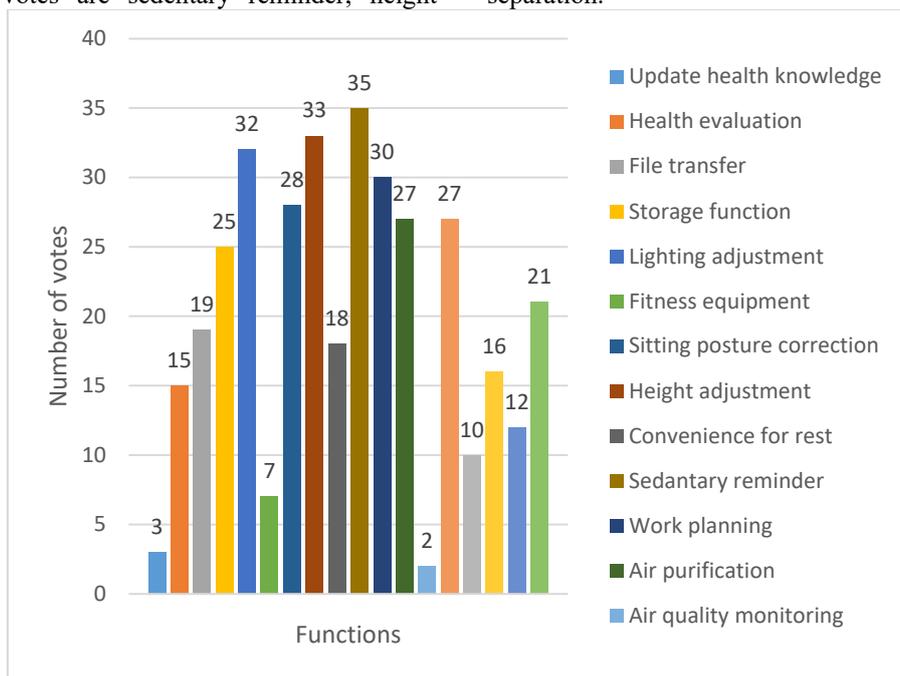


Figure 2. Survey result for functions of healthy office furniture

3.2 Building a hierarchy model of healthy office furniture
 The goal of the design of healthy office furniture is to design a way to guide office workers to have healthy work, which can help users efficiently complete heavy work tasks. Therefore, the target layer of the constructed hierarchical structure model is "healthy and efficient work". Through the analysis of the survey results, it is concluded that there are three factors that affect the health of office workers, including environmental factors, human-machine factors, and work factors. Therefore, we take these three factors as the criterion level indicators of

the hierarchical structure model. From the results of product function screening, seven product functions most anticipated by the target user can be drawn, including lighting adjustment, air purification, desktop adjustment, sitting posture correction, status differentiation, sedentary reminder, and planning work tasks. We classify these 7 functions according to their respective properties and use them as the measure level indicators of the hierarchical structure model. The hierarchical structure model can be built from top to bottom by the AHP method, as shown in Figure 3.

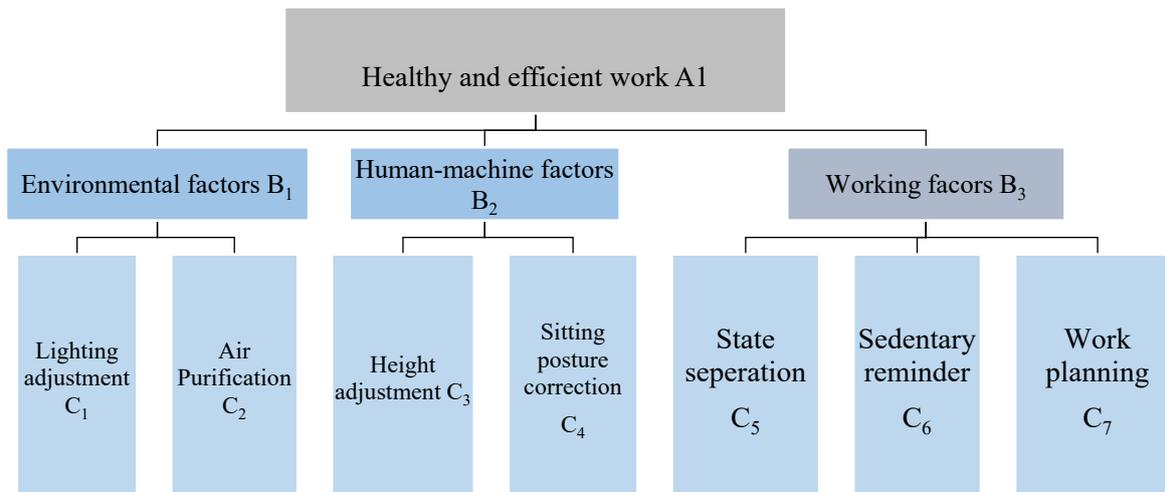


Figure 3 Layered structure model for functions of healthy furniture

3.3 Criteria-layer weight calculation

3.3.1 Constructing a judgment matrix

After establishing the hierarchical structure model, the importance of each level index in the model can be investigated, and then the judgment matrix can be constructed. The method of pairing comparison is used to judge the importance degree. For the assignment criteria, we can refer to Saaty’s 1-9 comparison scale (Table 3) [5].

Table 3. Comparison Scale

Importance scale	Meaning
1	Two elements are equally important
3	The former element is slightly more important than the latter
5	The former ELEMENT is obviously more important than the latter
7	The former element is more important than the latter
9	The former element is more important than the latter
2,4,6,8	Median
Reciprocal	If the ratio of the importance of element <i>i</i> to element <i>j</i> is <i>a</i> , then the ratio of the importance of element <i>j</i> to element <i>i</i> is <i>1/a</i>

Because this layer of indicators is not accurate to specific functions, the expert evaluation method is used. We selected 10 target users who had design experience and needed to endure long-term sedentariness as survey subjects to conduct a survey. According to the principle of pairwise comparison, the comparison of the same element

has the same importance, such as $C1/C1 = 1$. The important product of two elements that are opposite to each other is 1, such as $B1/B2 \times B2/B1 = 1$, which can be simplified when designing the questionnaire. The specific questionnaire form is shown in Table 4.

Table 4. Questionnaire for comparison of criteria layer elements.

Paired elements / scale	1	3	5	7	9
	Equally important	Slightly important	Obviously important	Strongly important	Extremely important
B_2/B_1					
B_3/B_1					
B_2/B_3					

Note: B_1 is environmental factors; B_2 is man-machine factors; B_3 is working factors

The expert scoring records are detailed in Table 5. The average value of the collected data is calculated, and the decimal point is rounded to obtain the weight of each

comparison element in the criterion layer, as shown in Table 6:

Table 5. Criteria-layer expert scoring statistics

Comparison group	1	2	3	4	5	6	7	8	9	10	Average value
B2Man-machine /B1environmental	3	3	1	5	3	3	5	3	1	5	3.2
B3 working /B1environmental	1	1	1	3	3	1	3	1	1	3	1.8

Table 6. Criteria layer element contrast weight matrix.

A	B1environment	B2Man-machine	B3working
B1 environment	1	1/3	1/2
B2 Man-machine	3	1	2
B3 working	2	1/2	1

3.3.2 Data calculation

The Equation (1) is split into calculations in order to make the calculation process clearer. The specific process is as follows:

$$\omega_i = \frac{1}{n} \sum_{j=1}^n \frac{a_{ij}}{\sum_{k=1}^n a_{kj}} \quad (1)$$

Step 1: Calculate the sum of each column of data

Table 7 Sum of the elements of each column

A	B ₁	B ₂	B ₃
B ₁	1	1/3	1/2
B ₂	3	1	2
B ₃	2	1/2	1
$\sum_{k=1}^n a_{kj}$	6	11/6	7/2

Step 2: Normalize each element in the data by column.

$$\bar{a}_{ij} = a_{ij} \left(\sum_{k=1}^n a_{kj} \right)^{-1} \quad (i,j=1, 2, \dots, n) \quad (2)$$

Table 8. Normalization of each element by column

A	B ₁	B ₂	B ₃
B ₁	1/6	2/11	1/7
B ₂	3/6	6/11	4/7
B ₃	2/6	3/11	2/7

Step 3: Add the normalized values of the above elements in the same row by column

$$\omega'' = \sum_{j=1}^n \bar{a}_{ij} \quad (3)$$

Table 9. Addition of normalized values of each row

A	B ₁	B ₂	B ₃	ω_i
B ₁	0.1667	0.1818	0.1429	0.4914
B ₂	0.5	0.5455	0.5714	1.6169
B ₃	0.3333	0.2727	0.2857	0.8917
$\sum a_{ij}$	1	1	1	3

Step 4: Divide the result of the addition of each row by *n* to get the weight of each element

Table 10. Weight values for each element

A	B ₁	B ₂	ω_i	ω_i
B ₁	0.1667	0.1818	0.4914	0.1638
B ₂	0.5	0.5455	1.6169	0.5390
B ₃	0.3333	0.2727	0.8917	0.2972

3.3.4 Judgment matrix consistency

Step 1: According to formula (4), if you want to find the maximum eigenvalue λ_{max} , you need first to calculate $(A\omega)$, that is:

$$\lambda_{max} = \sum_{j=1}^n \frac{(A\omega)_j}{n\omega_j} \tag{4}$$

$$A\omega = \begin{bmatrix} 1 & 1/3 & 1/2 \\ 3 & 1 & 2 \\ 2 & 1/2 & 1 \end{bmatrix} \begin{bmatrix} 0.1638 \\ 0.5390 \\ 0.2972 \end{bmatrix}$$

According to the principle of matrix multiplication calculation, we can get:

$$(A\omega)_1 = 1 \times 0.1638 + 1/3 \times 0.5390 + 1/2 \times 0.2972 = 0.4921$$

$$(A\omega)_2 = 3 \times 0.1638 + 1 \times 0.5390 + 2 \times 0.2972 = 1.6248$$

$$(A\omega)_3 = 2 \times 0.1638 + 1/2 \times 0.5390 + 1 \times 0.2972 = 0.8943$$

Step 2: Calculate the maximum characteristic root λ_{max} by formula (4), which:

$$\lambda_{max} = 0.4921 / (3 \times 0.1638) + 1.6248 / (3 \times 0.5390) + 0.8943 / (3 \times 0.2972) = 3.0092$$

Step 3: Calculate the consistency index CI according to formula (5), which:

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{5}$$

$$CI = (3.0092 - 3) / (3 - 1) = 0.0046$$

Step 4: Calculate the consistency ratio CR according to formula (4). Among them, RI can be seen by looking up Table 11 [6]. When the order is 3, RI = 0.52. then: CR = 0.0046 / 0.52 = 0.0088

Table 11. RI table of average random consistency indicators.

Matrix order	1	2	3	4	5	6	7	8
RI	0	0	0.52	0.89	1.12	1.26	1.36	1.41

Step 5: According to the CR judgment principle, when CR is less than 0.1, the consistency of the matrix can be accepted. Since 0.0088 is less than 0.1, the above matrix is consistent, and the weight of each element is valid.

By sorting the elements of the criterion layer at a single level, experts believe that human-machine factors are the most important among the three influencing factors for

employee health, accounting for 54%; followed by work factors, accounting for 29.7%. Finally, environmental factors account for 16.3%.

4 Measure-layer weight calculation

The criterion layer contains three elements. Because it is not easy for people to understand, we choose the expert evaluation method to assign elements to it. The elements in the measure layer are detailed seven specific functions, which are easy for the target group to understand. Therefore, we choose the general audience to assign the importance of the elements.

As shown in Figure 4, we did not choose the method of directly assigning values to pairs of elements for the

importance of the elements. When two elements are compared, it is not easy for many people to distinguish the order of comparison between the elements, which not only increases the difficulty of the work but also is not conducive to ensuring the accuracy of the data. Therefore, this evaluation uses the method of the overall evaluation of all the elements of the measure layer. This form is dramatically concise, and it is easy for people to grasp the whole (see Appendix 1 for the complete evaluation table).

Importance evaluation scale for functions of healthy office furniture (Part)

How important is the function lighting adjustment to you?

1 2 3 4 5 6 7 8 9

How important is the function air purification to you?

1 2 3 4 5 6 7 8 9

How important is the function height adjustment to you?

1 2 3 4 5 6 7 8 9

How important is the function sitting posture correction to you?

1 2 3 4 5 6 7 8 9

Figure 4. Importance evaluation scale for functions of healthy office furniture (Part)

A total of 30 typical target users were selected for the survey. We arrange the number of people for each important scale of functions, as shown in Table 12.

Table 12. Number of people voting for the importance of each element

Indicators	1	2	3	4	5	6	7	8	9
Lighting adjustment C ₁	0	3	2	3	6	3	4	5	4
Air purification C ₂	6	5	8	3	3	2	1	2	0
Height adjustment C ₃	0	2	3	3	4	3	4	5	6
Sitting posture correction C ₄	5	4	5	3	6	3	2	1	1
Distinguish between leisure and busy state C ₅	4	5	5	4	3	3	2	3	1
Sedentary reminder C ₆	0	0	0	0	2	4	5	12	7
Planning work C ₇	0	0	1	2	1	3	8	8	7

Sum up the above data and calculate the average, as shown in Table 13:

4.1 Constructing the judgment matrix

Table 13. Sum and average value of each group

	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	C ₇
X _{C₁}	176	102	185	119	125	228	217
\bar{X}_{C_1}	5.8667	3.4	6.1667	3.9667	4.1667	7.6	7.2333

According to the comparison scale table proposed by Saaty, when the importance of two elements is the same, the importance scale is 1. Therefore, the value of two elements with different importance ranges from 2 to 9. From the above table, the ratio of the two elements with the strongest contrast is $C_6 / C_2 = 228/30 \div 102/30 = 228/102$; the ratio of the two elements with the weakest contrast is $C_5 / C_4 = 125/30 \div 119/30 = 125/119$. Finally, we take the X axis as the comparison scale and the Y axis as the ratio of two elements, and set the equation as $y = kx + b$. We can bring in the value to get:

$$\begin{cases} 228/102 = 9k + b \\ 125/119 = 2k + b \end{cases}$$

The solution is $k = 0.1693$; $b = 0.7118$.

Thus, the equation is: $y = 0.1693x + 0.7118$.

After finding the above equation, the ratio of the paired elements is brought into the equation. Further, the

importance of the pair of elements can be solved. It is worth noting that since this equation is a linear equation, the ratio of elements should all be greater than 1. The contrast of each pair of elements is:

- Environmental factors: Lighting adjustment
 C_1 /Air purification $C_2 = 6$
- Man-machine factor: Height adjustment
 C_3 /Sitting posture correction $C_4 = 5$
- Working factors: Sedentary reminder
 C_6 /status recognition $C_5 = 7$
- Planning work C_7 /status recognition $C_5 = 6$
 Sedentary reminder C_6 /planning work $C_7 = 2$

4.2 Single group weight calculation

Before performing total hierarchical sorting, we need to perform a single-level sorting on each set of data. The specific calculation process is the same as the criterion layer weight calculation process. The calculation results of each group of data are as follows:

Table 14. The Calculation of environmental factors

B ₁	C ₁	C ₂	ω_i^*	ω_i	λ_{max}	C.I.	R.I.
C ₁	1	6	1.7143	0.8572	2	0	0
C ₂	1/6	1	0.2857	0.1429			

Table 15. The Calculation of human-machine factors

B ₂	C ₃	C ₄	ω_i^*	ω_i	λ_{max}	C.I.	R.I.
C ₃	1	5	1.6667	0.8333	2	0	0
C ₄	1/5	1	0.3333	0.1667			

Table 16. The Calculation of working factors

B ₃	C ₅	C ₆	C ₇	ω_i^*	ω_i	λ_{max}	C.I.	R.I.
C ₅	1	1/7	1/6	0.2110	0.0703	3.0242	0.0121	0.0233
C ₆	7	1	2	1.7403	0.5801			
C ₇	6	1/2	1	0.8458	0.3496			

4.3 Calculation of total ranking weights

According to the above calculation results, we can construct a hierarchy total ranking judgment matrix, and calculate the functional weights of each measure layer

based on the formula (6). The judgment matrix is as follows:

$$\omega_i = \sum_{j=1}^m a_j b_{ij} \quad (i = 1, 2, \dots, n) \quad (6)$$

Table 17. Hierarchical total ranking judgment matrix

Hierarchy	B ₁	B ₂	B ₃
Criteria layer weighted value	0.1638	0.5390	0.2972
C ₁	0.8572	0	0
C ₂	0.1429	0	0
C ₃	0	0.8333	0
C ₄	0	0.1667	0
C ₅	0	0	0.0703
C ₆	0	0	0.5801

C_7	0	0	0.3496
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According to Formula (6), the following is obtained:

$$\omega_{C1} = \sum_{j=1}^3 b_j c_{1j} = 0.1638 \times 0.8572 + 0.5390 \times 0 + 0.2972 \times 0 = 0.1404$$

$$\omega_{C2} = \sum_{j=1}^3 b_j c_{2j} = 0.1638 \times 0.1429 + 0.5390 \times 0 + 0.2972 \times 0 = 0.0234$$

$$\omega_{C3} = \sum_{j=1}^3 b_j c_{3j} = 0.1638 \times 0 + 0.5390 \times 0.8333 + 0.2972 \times 0 = 0.4491$$

$$\omega_{C4} = \sum_{j=1}^3 b_j c_{4j} = 0.1638 \times 0 + 0.5390 \times 0.1667 + 0.2972 \times 0 = 0.0899$$

$$\omega_{C5} = \sum_{j=1}^3 b_j c_{5j} = 0.1638 \times 0 + 0.5390 \times 0 + 0.2972 \times 0.0703 = 0.0209$$

$$\omega_{C6} = \sum_{j=1}^3 b_j c_{6j} = 0.1638 \times 0 + 0.5390 \times 0 + 0.2972 \times 0.5801 = 0.1724$$

$$\omega_{C7} = \sum_{j=1}^3 b_j c_{7j} = 0.1638 \times 0 + 0.5390 \times 0 + 0.2972 \times 0.3496 = 0.1039$$

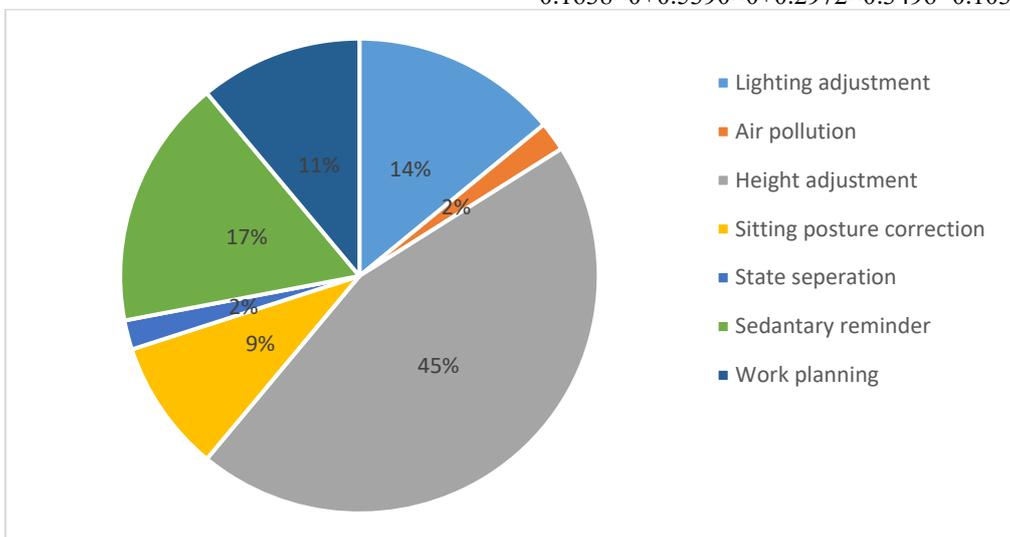


Figure 5. The weight ratio of each element in the hierarchy total order.

The final result shows that the expectations of office staff for the function of healthy office furniture from high to low are height adjustment (45%), sedentary reminder (17.2%), and LED lights that can automatically adjust the light on the desktop (14%), planning tasks to improve

work efficiency (10.4%), identifying and correcting bad sitting posture (9%), surrounding air purification function (2.3%), distinguishing between busy and leisure state (2.1%).

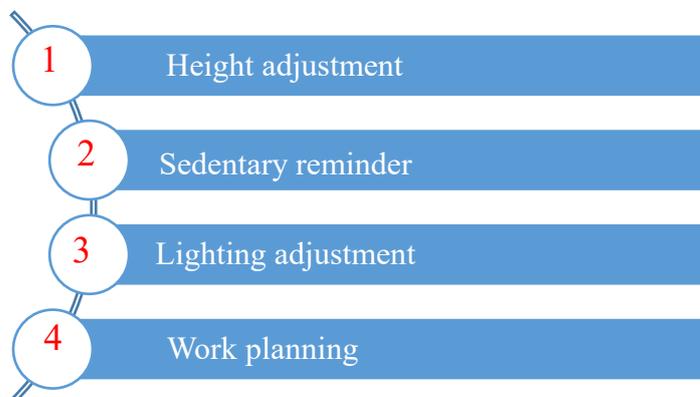


Figure 6. Functional ordering of healthy office furniture.

5 Conclusions

The determination of the importance of the function can help the designer to distinguish between the primary and the secondary, and it can also help designers to distribute the energy reasonably. It is easier for users to increase satisfaction. We use analytic hierarchy process to prioritize

the functions of the products, and finally determine the order of the functions of the healthy office furniture including the height adjustment function, the sedentary reminder function, the lighting adjustment function, and the planning task function.

Appendix: Importance evaluation scale for functions of healthy office furniture

Importance evaluation scale for functions of healthy office furniture

Hi, thank you for engagement in this survey on the importance of functions of healthy office furniture. Please rate the importance of the functions below.

How important is the function lighting adjustment to you?

1 2 3 4 5 6 7 8 9

How important is the function air purification to you?

1 2 3 4 5 6 7 8 9

How important is the function height adjustment to you?

1 2 3 4 5 6 7 8 9

How important is the function sitting posture correction to you?

1 2 3 4 5 6 7 8 9

How important is the function state separation to you?

1 2 3 4 5 6 7 8 9

How important is the function sedentary reminder to you?

1 2 3 4 5 6 7 8 9

How important is the function work planning to you?

1 2 3 4 5 6 7 8 9

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