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Application of comprehensive evaluation method based on combination weight in valve workshop layout

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The evaluation index system and evaluation method for the reliability of current workshop facility layout have not yet formed the standard. Taking the facility layout plan of valve production workshop as the research object, 9 evaluation indexes were put forward from four aspects of working environment, layout cost, production flexibility and management convenience, and a comprehensive evaluation system of valve production workshop layout was established. The AHP- entropy weight method was used to calculate the index weight. Based on the survey data and experts' opinions, the evaluation model is used for analysis and evaluation. The evaluation results of the facility layout plan of valve production workshop are consistent with the reality. The results show that the weight method of this model not only considers the objective opinions of workshop personnel, but also uses the knowledge and experience of experts, which makes the workshop facility layout evaluation more objective and accurate, and provides reference for the standards of workshop facility layout evaluation.

Keywords: Combination weight; Valve; Production workshop layout; AHP- entropy weight method; Comprehensive evaluation

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Introduction

Since the 1980s, along with the unit manufacturing, agile manufacturing, integrated manufacturing and so on a series of ways of production, cause production system of logistics status change, need to update the workshop facility layout scheme to adapt to the new valve production system. [1] Production facilities in the system layout to reduce production cost and improve the operational performance of production play a more and more important role. According to a recent study on workshop facility layout, an efficient arrangement can save 10% to 30% of the logistics transportation cost and improve production efficiency. [1] Because of the workshop layout problem is a NP complete problem, not the optimal solution, so the layout of vague and uncertain. How to help enterprises to policy makers for the workshop production system choose efficient facilities layout scheme became a hot issue of research. But not yet at home and abroad for professional assessment workshop facility layout. But not yet at home and abroad for professional assessment workshop facility layout. Study of workshop facilities layout evaluation is too subjective, mostly reference value is limited. Xu Yue tried to apply the AHP algorithm to the selection of the shop layout plan in his graduation thesis Ningkai machining branch workshop layout plan evaluation research [2], but due to the strong subjectivity of the AHP algorithm and the large number of indicators, the difference between the judgment matrix and the consensus matrix may be large, so the effect is not very good. On this basis, Zhang Lei used AHP-fuzzy mathematical algorithm to evaluate the assembly workshop [3]. However, when the layout problem is evaluated by the AHP algorithm and fuzzy mathematics comprehensive evaluation method, the subjective influence will determine the weight vector of the index, so the evaluation results obtained need to be discussed. As the valve production workshop facility layout evaluation index involves many factors such as environment, work cost, logistics efficiency, safety, etc., both qualitative analysis and quantitative analysis need to be considered, and a single evaluation method cannot take into account the impact of subjective and objective factors.

Therefore, based on the research of relevant literature on the factors affecting the layout of workshop facilities, an evaluation system for the layout of workshop facilities is constructed. The Analytic Hierarchy Process (AHP)-entropy method is used to determine the reasonable weight of the workshop facility layout index. This article takes the layout of a valve production workshop as an example, based on consideration of various factors, selects the best facility layout plan, and provides reference for the workshop layout of similar valve manufacturers.

1. Evaluation model of valve production workshop

1.1 Construction of index evaluation system for production workshop

The establishment of the evaluation system of the valve production workshop facility layout plan requires comprehensive consideration of the work environment, layout cost, production line flexibility, workshop management and other factors. The selected indicators should be able to objectively measure the pros and cons of the facility layout plan, and evaluate the efficiency of the plan from a comprehensive perspective. Therefore, when determining the evaluation index system and evaluation methods, the principles of the shortest material handling distance, the principle of flexibility, the principle of efficient use of space, and the principle of production safety should be followed. [4]

When evaluating the facility layout plan of the valve production workshop, comprehensive consideration should be given to the plant workshop design specifications and the development level

of the enterprise. With the goal of improving the production efficiency of the valve production workshop, an indicator system was established from four aspects: working environment, layout cost, production line flexibility and workshop management. According to the affiliation between various factors, eleven indicators are selected to comprehensively evaluate the layout of the valve production workshop, and then build a hierarchical structure [5].

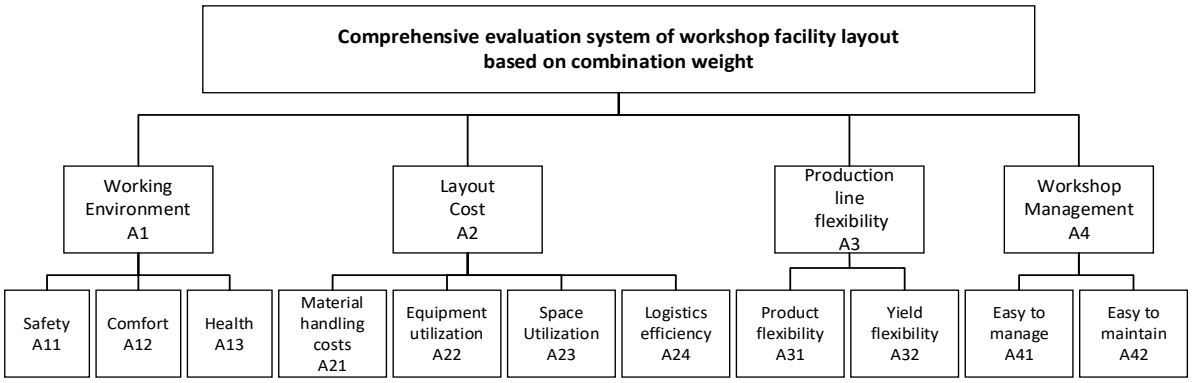

Fig.1. Comprehensive evaluation system of workshop facility layout based on combination weight.

1.1.1 Work environment evaluation index

In the study of working environment indicators, mainly from three aspects: safety, comfort and health. Safety settings such as safe passages and safe exits should be considered during layout design. It is the prerequisite for normal operation and maintenance of the workshop; the enthusiasm of employees is represented by the comfort index; environmental protection is reflected by the health index.

Work environment evaluation index

When researching the working environment indexes, it is mainly carried out from three aspects: safety, comfort and health. Safety settings such as safe passages and safe exits should be considered during layout design. It is the prerequisite for normal operation and maintenance of the workshop; the enthusiasm of employees is represented by the comfort index; environmental protection is reflected by the health index.

Layout cost evaluation index

Layout cost evaluation indicators are mainly used to evaluate the economic effects of layout. Material handling costs (A21) represent the costs incurred in the production and handling of valve components; equipment utilization (A22) is a measure of workshop equipment usage; space utilization (A23) is a measure of workshop space utilization, and it has an important impression of being able to expand capacity; logistics efficiency (A24) is the ratio of the total input of logistics handling equipment to the total output. These are used to measure the overall operational efficiency of production.

Evaluation index of production line flexibility

The evaluation index of production line flexibility is mainly composed of product flexibility (A31) and output flexibility (A32). Product flexibility mainly refers to the selected workshop layout facility layout plan can better adapt to changes in the production line and production workshop facilities when the company produces products. This does not have a specific value as a basis, and it mostly depends on the opinions of experts; the flexibility of output changes means that the layout of the production workshop facilities can respond quickly to meet the production requirements when the output changes. [6]

Evaluation index of workshop management

Workshop management evaluation indicators

include ease of management (A41) and ease of maintenance (A42). Maintenance convenience refers to ensuring the normal operation of production activities in the production workshop; management convenience measures the management status and maintainability of the workshop, and it is an important factor in the efficient operation of the workshop.

1.1.2 Production line flexibility evaluation index

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1.1.3 Workshop management evaluation index

Workshop management evaluation indicators include ease of management (A41) and ease of maintenance (A42). Maintenance convenience refers to ensuring the normal operation of production activities in the production workshop; management convenience measures the management status and maintainability of the workshop, and it is an important factor in the efficient operation of the workshop.

1.2 Evaluation index weight determination

The layout of workshop facilities is a complex system of man-machine-environment. The indicators cover a wide range. Analyzing the correlation between the indicators and clarifying the relative importance is of great significance to promoting the optimization of the workshop layout. In the evaluation of complex systems, combined with expert opinions and workshop personnel opinions, comprehensive consideration of weight indicators.

American operations researcher Thomas proposed an analytic hierarchy process (AHP), which unifies qualitative analysis and quantitative analysis. It makes full use of the expert's knowledge and experience, but does not take into account the subjective ambiguity of the expert's judgment. Due to the limited professional background and level of experts, it is not easy to judge the degree of important differences when the number of indicators is large.

Therefore, on the basis of preserving the experience of experts, the experience data of workshop personnel is excavated, and objective assignment method (entropy method) is introduced. The AHP-entropy method is used to determine the index weight, and the subjective and objective factors are comprehensively considered to make the evaluation result more scientific and objective.

1.2.1 Subjective weight determination based on AHP

AHP divides relevant elements into a hierarchical structure, subjectively quantifies different elements, and checks the consistency and rationality of the matrix layer by layer. The main idea is divided into 3 steps, as shown in the figure below: [7]

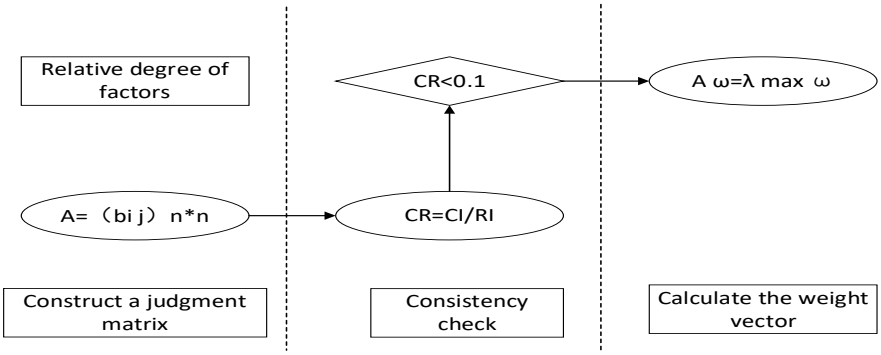

Fig.2. The idea of AHP algorithm to determine the weight.

Establish a judgment matrix

AHP requires the mutual importance of elements to be calculated layer by layer [8], and the important relationship of the 1-9 scale method is shown in Table 1 below:

Table 1 Important relationship

Scale	Implication
1	Index I is just as important as index J
3	Index I is slightly more important than index J
5	Index I is significantly more important than index J
7	Index I is strongly more important than index J
9	Index I is extremely important than index J
2、4、6、8	Index I and index J compare the median values between the above

A judgment matrix is constructed by comparing the exact importance of a certain level of the previous level among the elements of the same level and combining the 1-9 scale method in Table 1 below. As shown below:

$$A=\left(\mathrm{a}_{ij}\right)_{nn}=\begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \tag{1}$$

In the formula: a_{ij} - Index i versus index j.

Calculated weight coefficient

The geometric average method is used to solve the weight, and the obtained column vector is normalized to obtain the weight vector.

$$\omega_i=\frac{\left(\prod_{j=1}^{n}a_{ij}\right)^{\frac{1}{n}}}{\sum_{k=1}^{n}\left(\prod_{j=1}^{n}a_{kj}\right)^{\frac{1}{n}}},\quad (i=1,2,\cdots,n) \tag{2}$$

Consistency judgment

First, the maximum eigenvalue of the matrix is calculated

$$\lambda_{\max}=\frac{1}{n}\sum_{i=1}^{n}\frac{(A\omega)_i}{\omega_i} \tag{3}$$

Where ω_i represents the normalized index weight.

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

Through n (the number of indexes in every two judgment matrices), the index RI corresponding to the average random consistency is found, and the consistency index test CR of the criterion layer is finally obtained:

$$CR=\frac{CI}{RI} \tag{5}$$

If CR <0.1, it can be considered as accepting the consistency of the judgment matrix; Otherwise it

will need to be modified.

1.2.2 Determination of objective weight based on entropy method

Entropy method is used as a method to objectively determine the weight. It uses the relationship between the degree of indicator variation and the amount of information to change the entropy weight. It can effectively avoid the influence of subjective factors, making the evaluation results more objective. The figure below is the idea of determining weight by entropy method.

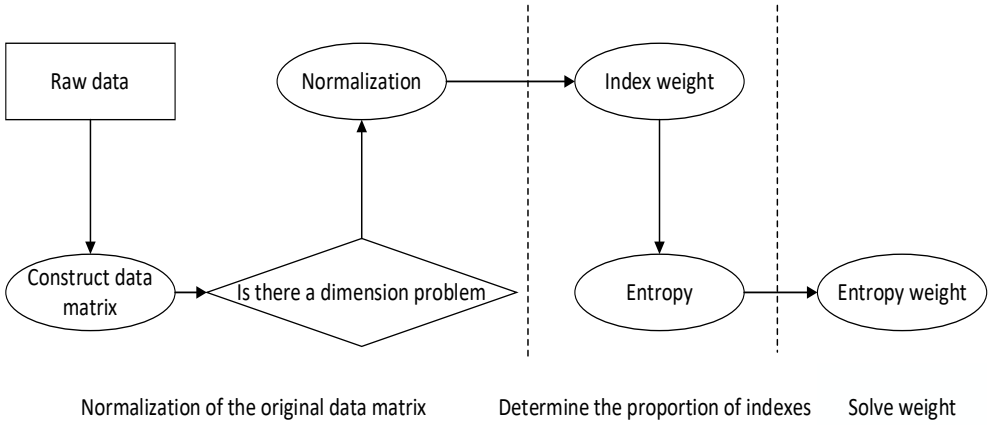

Fig.3. The idea of Entropy Method to Determine Weight.

(1) The initial data matrix is standardized

The original data matrix $X_{ij} = \{x_{ij}\}_{mn}$ was constructed based on M indexes and N evaluation objects. Judge whether there is a negative number in the matrix, if it exists, perform non-negative operation, the specific formula is as follows:

$$\tilde{z}_{ij} = \frac{x_{ij} - \min\left\{x_{1j}, x_{2j}, \cdots, x_{nj}\right\}}{\max\left\{x_{1j}, x_{2j}, \cdots, x_{nj}\right\} - \min\left\{x_{1j}, x_{2j}, \cdots, x_{nj}\right\}} \quad (6)$$

Where x_{ij} is the original value, j is the evaluation value, and n is the evaluation target value.

(2) Calculate the proportion of the i-th sample under the n-th index and regard it as the probability used in the calculation of relative entropy. Formula is as follows:

$$p_{ij} = \frac{\tilde{z}_{ij}}{\sum_{i=1}^{n} \tilde{z}_{ij}} \quad (7)$$

Where $\tilde{z}_{ij}$ is a non-negative matrix, and $\sum_{i=1}^{n} p_{ij} = 1$.

(3) Calculate the information entropy of each indicator, calculate the information utility value, and normalize the entropy weight of each indicator.

$$e_j = -\frac{1}{\ln n} \sum_{i=1}^{n} p_{ij} \ln\left(p_{ij}\right) (j = 1, 2, \cdots, m) \quad (8)$$

Get the entropy weight of each indicator.

$$W_j = \frac{1 - e_j}{\sum_{j=1}^{n} \left(1 - e_j\right)} (j = 1, 2, \cdots, m) \quad (9)$$

1.2.3 Combination weight based on AHP-entropy weight method

AHP algorithm can make full use of expert knowledge and experience. However, the entropy method helps to reduce the subjectivity of index weights, and combines subjective and objective weighting to obtain a more objective and accurate comprehensive weight. The synthetic formula is as follows:

$$C_j = \frac{\omega_i W_j}{\sum_{j=1}^{n} \omega_i W_j} \tag{10}$$

2. Evaluation of a valve workshop layout plan

2.1 Data collection

A valve production workshop layout diagram is as follows: [9]

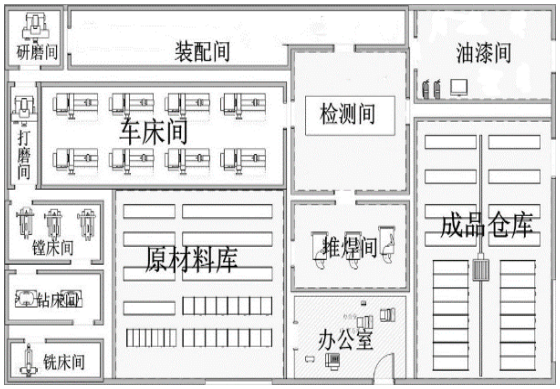

Fig.4. Layout 1.

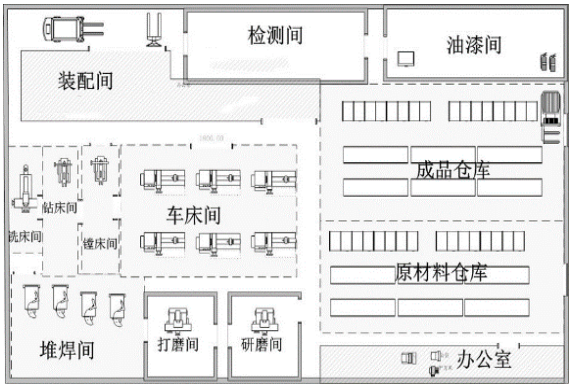

Fig.5. Layout 2.

Through questionnaires, 15 technicians in the workshop and 5 experts in the field of valves in universities were surveyed. This questionnaire uses a five-level scale, with 1 indicating poor, 2 indicating good, 3 indicating fair, 4 indicating good, and 5 indicating good. The expert's results for each indicator of facility layout are averaged. The results shown in the following table [5]:

Table 2 Experts' evaluation results on the layout plan.

Program / Index	Option One	Option Two
A11	4.2	3.7
A12	3.8	3.6
A21	3.7	3.4
A22	3.8	3.6
A23	3.3	3.5
A24	3.4	3.6
A31	4.2	4.3
A32	3.9	3.7
A41	3.1	3.2
A42	3.15	3.4

2.2 Comprehensive weight calculation

First, 10 experts make a judgment on the importance of each index, construct a judgment matrix and put it into formula 1, find the weight of each index, and make a consistency judgment. At the same time, it designs a worker workshop facility layout opinion form, and surveys 50 workers and managers to give their opinions on the quality of the workshop layout. This questionnaire uses a five-level scale, 1 means bad, 2 means good, 3 means fair, 4 means good, and 5 means good. Score each indicator.

According to formula (3), the maximum characteristic value of the calculated judgment matrix is λ_{max} =11, and the consistency index CR = 3.5060E-16<0.1 is obtained by formula (5). Through the consistency check, the subjective weight calculated by AHP is valid. Analyze based on statistical data, and calculate objective weights by entropy method. Put the subjective weight and the objective weight into formula (10) to get the combined weight. The detailed information is shown in the following table:

Table 3 Combination Weight Method Weight Table.

Index	Subjective weight	Objective weight	Combined weight
A11	0.3429	0.3643	0.3989
A12	0.0429	0.0664	0.0091
A13	0.1714	0.1623	0.0888
A21	0.0571	0.0664	0.1211
A22	0.0857	0.0786	0.2151
A23	0.0571	0.0742	0.1353
A24	0.0429	0.0126	0.0017
A31	0.0571	0.0630	0.0115
A32	0.0571	0.0701	0.0128
A41	0.0429	0.0229	0.0031
A42	0.0429	0.0191	0.0026

2.3 Comprehensive evaluation results

By combining the weight coefficients, the layout evaluation scores of Option One and Option Two are obtained:

$$S_i = \sum_{j=1}^{n} C_j P_{ij} \tag{11}$$

Where C_j is the combination weight calculated by the combination weight method, P_{ij} is the standardized value of the index and j is the evaluation index. It is concluded that the evaluation value of scheme one (0.5115)>the evaluation value of scheme two (0.4885). Referring to Xu Tianqi's paper, the conclusions are consistent, so the facility layout plan One is better.

3. Conclusion

On the basis of the workshop facility layout questionnaire and literature analysis, the establishment of a more comprehensive valve production

workshop facility layout evaluation index system from the work environment, layout costs, production line flexibility and workshop management four aspects, can science reflect workshop facility layout situation.

A workshop facility layout evaluation model based on the AHP-entropy weight method is proposed. Based on the data of the questionnaire, the interrelationship between the indicators is used as the basis for solving the indicator weights, which effectively utilizes expert knowledge and experience, and is based on objective data. Compared with the use of a single analytic hierarchy process and entropy method, the evaluation result is more objective and accurate, and it provides a new idea for the choice of workshop layout plan.

The results show that, considering the actual workshop conditions, the layout of the valve production workshop facilities fits the actual situation. The workshop facility layout evaluation method constructed by AHP-entropy weight method is effective and feasible.

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