ISSN: 2414-1895
DOI: 10.6919/ICJE.202201_8(1).0049

Material Classification Model of Automobile Assembly Workshop based on Fuzzy Cluster Analysis

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Abstract

There are many materials needed for automobile assembly.and unreasonable material classification can cause waste of resources and time. Therefore, how to reasonably and scientifically classify materials is worth studying. In this paper, taking automobile manufacturing enterprises as the research object, three quantitative indexes and four qualitative indexes were selected, and the material classification index system was established. The fuzzy clustering analysis (FCA) method was used to classify the 20 representative materials in automobile assembly workshop into four categories: A to D. It improved the scientificity of material storage, the correctness of material supply and the efficiency of material distribution.

Keywords

Assembly Workshop, Material Classification, Fuzzy Cluster Analysis.

1. Introduction

Nowadays, automobiles have become a necessity for ordinary families in various countries. Due to the diverse needs of consumers, the variety of automotive product design, but also requires product upgrading, the automotive industry is increasingly fierce competition. As a new source of profit, logistics has become the focus of attention of major automobile enterprises in the process of gradual development [1, 2].

In the entire logistics activities, warehouse management is particularly important. Warehousing not only plays the important role of storing materials, but also connects other links in logistics activities. On the one hand, unreasonable material classification in warehouse management will increase the workload of warehouse management personnel; on the other hand, due to unreasonable material placement, invalid labor and waste of resources will be caused [3, 4]. Therefore, as an important part of warehouse management, reasonable material classification can make it easier for warehouse personnel to manage in the case of a wide variety of materials, and can quickly grasp the correct information. This paper can be regarded as a case analysis and supplement to the warehouse management of existing manufacturing enterprises, which has very important practical significance.

At present, the methods of material classification mainly include Activity Based Classification (ABC) method, Analytic Hierarchy Process (AHP), Kraljic matrix analysis method and so on [5, 6, 7]. The ABC method is the most commonly used, but this method only considers the influence of economic factors (i.e., the annual purchase amount is taken as the classification index), and ignores other important factors that are also included in the actual situation, which should also be considered when classifying materials. Later, scholars improved ABC method and put forward some new methods, such as establishing index system to classify materials.

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In this paper, the principle of material classification is proposed according to the specific situation of materials in an automobile company's assembly workshop. Combined with the material characteristics of the assembly workshop, the indicators are proposed and the classification index system is established, and the final classification results are obtained by using the fuzzy cluster analysis (FCA) method [8].

2. Construction of Material Classification Index System

2.1 Determination of Initial Index of Material Classification

Because there are many kinds of materials needed in the assembly workshop, there will be hundreds of materials involved in assembling one type of automobile. If all materials are analyzed by fuzzy clustering, the workload is too large and it is of little significance to participate in the classification because of the special properties of some materials. In order to simplify the calculation, some representative materials are selected for classification. Through field investigation in the assembly workshop, there are 147 kinds of assembly materials, and 20 kinds of representative materials are found out: engine, muffler, pressure relief wire drawing, generator, power switch, relay wire harness, round nut, fixed bolt, diesel fuel tank, air filter inlet pipe, wire harness tie, product nameplate, floor mat, vacuum hose, handle sleeve, dashboard, seat, motor wire, configuration information card and parking reflective paste.

Considering the material characteristics, material supply and demand and other factors, seven indexes were selected, including general degree of materials, proportion of material inventory amount, the degree of difficulty of supply, material transportation guarantee, material substitution, material demand stability and price stability. The first three are quantitative indexes and the last four are qualitative indexes.

(1) General degree of materials(A1). Classification of materials is carried out considering the general degree of each material and Eq. (1) is used for calculation, and the result is the average value in the last three months.

$$Generalrate = \frac{\text{the number of automobile models used by a certain material on that day}}{\text{the total number of automobile models produced on that day}} \tag{1}$$

(2) Proportion of material inventory amount (A2). According to the inventory data of the assembly workshop in recent three years, the proportion of a material in the inventory amount of all materials is calculated.

(3) The degree of difficulty of supply (A3). This index includes the complexity of material production process, the preparation period of raw materials, the limitation of output, the complexity of logistics and so on. This indexes uses the lead time of materials as the data source and takes days as a unit.

(4) Material transportation guarantee (A4). Material transportation guarantee refers to the guarantee level of packaging and transportation of suppliers.

(5) Material substitution (A5). Material substitution refers to whether there is a substitute for a certain type of material, where the difficulty of material substitution is used to determine the elasticity of material category.

(6) Material demand stability (A6). According to the material demand fluctuation, it is divided into stable demand materials, fluctuant demand materials and general demand materials. The demand of stable demand materials can be effectively predicted, while the extraction frequency of fluctuating demand materials is uncertain and cannot be effectively predicted, while the general demand materials are in between.

(7) Price stability (A7). There are many factors that affect the price, such as time period, material cost, etc. Here, the degree of influence measures the price stability.

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The material classification index system is shown in Figure 1.

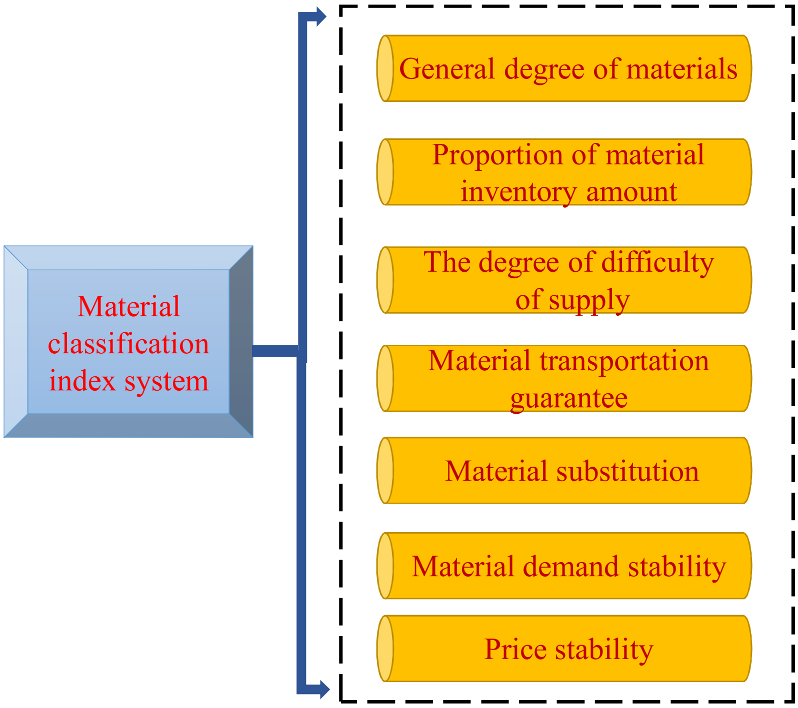

Figure 1. The material classification index system

2.2 Quantification of Evaluation Indexes

The quantitative data of evaluation indexes are shown in Table 1.

Table1. Quantification of material classification evaluation index

Evaluation indexes	Content	Initial data
A1	Actual generic ratio	Actual generic ratio
A2	Proportion of inventory amount	Proportion of inventory amount
A3	Lead time	days
A4	Good	A4=1
	General	A4 =3
	Bad	A4 =5
A5	Easy to replace	A5=1
	Generally replaceable	A5 =3
	Not easy to replace	A5=5
A6	Stable	A6=1
	Average	A6=3
	Fluctuating	A6=5
A7	Stable	A7=1
	Average	A7=3
	Fluctuating	A7=5

 Volume 8 Issue 1, 2022
DOI: 10.6919/ICJE.202201_8(1).0049

With the assistance of workers in the storage department, the data statistics of the indexes A1, A2 and A3 were carried out, and the indexes were obtained after taking the average value. The indexes A4, A5, A6 and A7 were scored by expert scoring method. The summarized statistical indexes of materials are shown in Table 2.

Table 2. Material statistics indexes

Meterial number	Indexes / Material name	A1	A2	A3	A4	A5	A6	A7
1	engine	100%	19.45%	15	1	3	1	1
2	muffler	85%	3.31%	32	3	1	3	1
3	pressure relief wire drawing	10%	1.24%	20	1	1	1	1
4	generator	100%	18.48%	20	1	3	1	1
5	power switch	77%	1.11%	35	3	1	1	1
6	relay wire harness	20%	4.73%	25	1	3	3	1
7	round nut	80%	1.01%	46	3	1	1	1
8	fixed bolt	85%	1.21%	46	3	1	1	1
9	diesel fuel tank	60%	3.43%	30	5	3	3	3
10	air filter inlet pipe	20%	0.98%	40	1	3	3	1
11	wire harness tie	90%	0.68%	40	3	1	1	1
12	product nameplate	95%	0.56%	52	1	3	3	3
13	floor mat	65%	8.96%	35	1	3	5	3
14	vacuum hose	10%	0.78%	35	3	1	1	1
15	handle sleeve	66%	4.2%	45	5	3	5	3
16	dashboard	100%	7.8%	27	3	5	1	3
17	seat	100%	5.44%	38	1	5	1	3
18	motor wire	28%	1.29%	35	3	3	3	1
19	configuration information card	50%	6.45%	56	1	3	3	3
20	parking reflective paste	75%	0.23%	60	1	3	3	3

3. Fuzzy Cluster Analysis Method

3.1 Standardization of Indexes

The significance of standardization lies in that indexes of different dimensions can be calculated together, and the specific calculation formula is as follows:

$$\bar{x}_{ij} = \frac{x_{ij} - \min_{1\leq i\leq m} x_{ij}}{\max_{1\leq i\leq m} x_{ij} - \min_{1\leq i\leq m} x_{ij}} > 0 \quad (2)$$

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$$\bar{x}_{ij}=\frac{\max_{1\le i\le m}x_{ij}-x_{ij}}{\max_{1\le i\le m}x_{ij}-\min_{1\le i\le m}x_{ij}}>0 \tag{3}$$

where $\bar{x}_{ij}$ refers to the relative membership degree of the ith index of the jth sample; $\max_{1\le i\le m}x_{ij}$ refers to the maximum value of the ith index; $\min_{1\le i\le m}x_{ij}$ refers to the minimum value of the ith index.

3.2 Construction of Fuzzy Similarity Matrix

The fuzzy similarity matrix is established by Eq.(4) and (5), and the fuzzy matrix is used to process the data. The similarity between E_i and E_j is r_{ij}, which reters to the fuzzy similarity matrix obtained by similarity of E_i and E_j according to m features. In this paper, euclidean distance is used to calculate r_{ij}, and c is a constant.

$$r_{ij}=1-cd \tag{4}$$

$$d=\sqrt{\sum_{k=1}^{n}(E_{ik}-E_{jk})^2} \tag{5}$$

3.3 Construction of Fuzzy Equivalent Matrix

In order to classify materials more objectively, it is necessary to transform the fuzzy similarity matrix R without transitivity into the fuzzy equivalent matrix R* with transitivity. In this paper, the transitive closure method is used to classify materials, which is mainly calculated by transitive closure $t(R)$, which can be obtained by R*.

$$t(R)=R^*\ ;R\times R=R^2,R^2\times R^2=R^4,\dots \tag{6}$$

After many operations, there will be a value of a, which makes $R^a\times R^a=R^{2a}$, and $R^a\times R^a=R^{2a}$ is established, the matrix R^a is the fuzzy equivalent matrix, which is abbreviated as $t(R)=R^a$.

3.4 Cluster Analysis

After the R^a matrix is obtained, an appropriate λ value should be selected. In practice, adjust the range of λ according to the needs of classification. By clustering, the materials with similar attributes are classified into one category. However, this classification result is not absolute, but is determined according to the actual classification needs.

4. Results and Conclusion

4.1 Results

The fuzzy similarity matrix obtained by formulas (5) and (6) is shown in Table 3.

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Table 3. The fuzzy similarity matrix

Number	1	2	3	4	5	6	7	8	9	10
1	1.00	0.82	0.86	0.98	0.81	0.86	0.80	0.79	0.85	0.86
2	0.82	1.00	0.82	0.83	0.99	0.83	0.93	0.95	0.85	0.82
3	0.86	0.82	1.00	0.86	0.83	0.95	0.82	0.81	0.84	0.99
4	0.98	0.83	0.86	1.00	0.82	0.86	0.81	0.80	0.86	0.87
5	0.81	0.99	0.83	0.82	1.00	0.84	0.94	0.96	0.85	0.82
6	0.86	0.83	0.95	0.86	0.84	1.00	0.81	0.82	0.82	0.95
7	0.80	0.93	0.82	0.81	0.94	0.81	1.00	0.95	0.86	0.81
8	0.79	0.95	0.81	0.80	0.96	0.82	0.95	1.00	0.84	0.81
9	0.85	0.85	0.84	0.86	0.85	0.82	0.86	0.84	1.00	0.84
10	0.86	0.82	0.99	0.87	0.82	0.95	0.81	0.81	0.84	1.00
11	0.81	0.97	0.81	0.82	0.98	0.82	0.95	0.98	0.84	0.81
12	0.81	0.98	0.83	0.82	0.99	0.84	0.94	0.96	0.84	0.83
13	0.82	0.95	0.84	0.83	0.95	0.83	0.95	0.93	0.87	0.84
14	0.81	0.99	0.82	0.82	1.00	0.83	0.94	0.96	0.85	0.82
15	0.80	0.96	0.82	0.81	0.97	0.83	0.95	0.98	0.84	0.82
16	0.86	0.85	0.84	0.86	0.84	0.82	0.86	0.83	0.99	0.84
17	0.82	0.82	0.81	0.82	0.82	0.79	0.85	0.82	0.94	0.81
18	0.85	0.83	0.95	0.86	0.83	0.99	0.81	0.82	0.82	0.95
19	0.80	0.94	0.83	0.81	0.94	0.82	0.98	0.95	0.86	0.83
20	0.80	0.96	0.82	0.81	0.98	0.83	0.95	0.98	0.84	0.82

(Continuation Table 3)

Number	11	12	13	14	15	16	17	18	19	20
1	0.81	0.81	0.82	0.81	0.80	0.86	0.82	0.85	0.80	0.80
2	0.97	0.98	0.95	0.99	0.96	0.85	0.82	0.83	0.94	0.96
3	0.81	0.83	0.84	0.82	0.82	0.84	0.81	0.95	0.83	0.82
4	0.82	0.82	0.83	0.82	0.81	0.86	0.82	0.86	0.81	0.81
5	0.98	0.99	0.95	1.00	0.97	0.84	0.82	0.83	0.94	0.98
6	0.82	0.84	0.83	0.83	0.83	0.82	0.79	0.99	0.82	0.83
7	0.95	0.94	0.95	0.94	0.95	0.86	0.85	0.81	0.98	0.95
8	0.98	0.96	0.93	0.96	0.98	0.83	0.82	0.82	0.95	0.98
9	0.84	0.84	0.87	0.85	0.84	0.99	0.94	0.82	0.86	0.84
10	0.81	0.83	0.84	0.82	0.82	0.84	0.81	0.95	0.83	0.82
11	1.00	0.97	0.94	0.98	0.98	0.84	0.83	0.82	0.94	0.98
12	0.97	1.00	0.95	0.99	0.98	0.84	0.82	0.84	0.94	0.98
13	0.94	0.95	1.00	0.95	0.94	0.87	0.84	0.83	0.96	0.94
14	0.98	0.99	0.95	1.00	0.97	0.84	0.82	0.83	0.94	0.98
15	0.98	0.98	0.94	0.97	1.00	0.83	0.82	0.83	0.95	0.99
16	0.84	0.84	0.87	0.84	0.83	1.00	0.94	0.82	0.86	0.84
17	0.83	0.82	0.84	0.82	0.82	0.94	1.00	0.79	0.84	0.82
18	0.82	0.84	0.83	0.83	0.83	0.82	0.79	1.00	0.82	0.83
19	0.94	0.94	0.96	0.94	0.95	0.86	0.84	0.82	1.00	0.95
20	0.98	0.98	0.94	0.98	0.99	0.84	0.82	0.83	0.95	1.00

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Table 4. Classification results

Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	1	0	0	1	0	1	1	0	0	1	1	1	1	1	0	0	0	1	1
4	0	1	0	0	1	0	1	1	0	0	1	1	1	1	1	0	0	0	1	1
5	0	1	0	0	1	0	1	1	0	0	1	1	1	1	1	0	0	0	1	1
6	0	1	0	0	1	0	1	1	0	0	1	1	1	1	1	0	0	0	1	1
7	0	1	0	0	1	0	1	1	0	0	1	1	1	1	1	0	0	0	1	1
8	0	1	0	0	1	0	1	1	0	0	1	1	1	1	1	0	0	0	1	1
9	0	1	0	0	1	0	1	1	0	0	1	1	1	1	1	0	0	0	1	1
10	0	1	0	0	1	0	1	1	0	0	1	1	1	1	1	0	0	0	1	1
11	0	1	0	0	1	0	1	1	0	0	1	1	1	1	1	0	0	0	1	1
12	0	1	0	0	1	0	1	1	0	0	1	1	1	1	1	0	0	0	1	1
13	0	1	0	0	1	0	1	1	0	0	1	1	1	1	1	0	0	0	1	1
14	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0
15	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0
16	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0
17	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0
18	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0
19	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0
20	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0

In this paper, there are many kinds of materials to be studied and a lot of data to be processed. Therefore, the fuzzy equivalent matrix was deduced by using MATLAB software according to the fuzzy similarity matrix. When R= 0.88, the classification results were the best, as shown in Table 4.

According to the FCA theory, it can be seen from Table 4 that 20 kinds of materials were summarized into 4 groups, and combined with the material classification theory, materials were divided into 4 categories, denoted as type A, type B, type C and type D materials.

4.2 Conclusion

Type A materials are characterized by high material value, high importance, less suppliers and high risk, and the material numbers are 1 and 4; Type B materials are characterized by high material value, high importance, more suppliers and low risk and the material numbers are 9,16 and 17; Type C materials are characterized by low material value, low importance, less suppliers and high risk and the material numbers are 3,6,10 and 18; Type D materials are characterized by low material value, low importance, more suppliers and low risk and the material numbers are 2,5, 7,8,11,12,13,14,15,19 and 20.

In summary, the specific classification of 20 representative materials is shown in Table 5.

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Table 5. Specific material classification

Material type	Material number	Materials
A	1,4	engine,generator
B	9,16,17	diesel fuel tank, dashboard, seat
C	3,6,10,18	pressure relief wire drawing, relay wire harness, air filter inlet pipe,motor wire
D	2,5,7,8,11,12,13,14,15,19,20	Muffler; power switch, round nut, fixed bolt, wire harness tie, product nameplate, floor mat, vacuum hose, handle sleeve, configuration information card, parking reflective paste

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