Construction and Application of Quality Assurance Capability Evaluation Model for Co-production of Cigarette Materials Based on AHP-Entropy Method

Liu Ruidong[1], Wang Hanqing[2], Bao Jun[3], Lou Lingyun[4], Zheng Huali*

Cooperative Production Office of Zhejiang China Tobacco Industry Co., Ltd.No.77 Zhongshan South Road, Shangcheng District, Hangzhou City, China

[1]liuruidong@zjtobacco.com,[2]wanghq@zjtobacco.com,
[3]baoj@zjtobacco.com,[4]loulingyun@zjtobacco.com,
*corresponding author, zhenghuali@zjtobacco.com

Abstract. Because the tobacco industry is under the monopoly system, the annual production plan of industrial companies is a fixed index value, which limits the possibility of expanding production capacity of more rapidly developing companies, because it can always encounter the situation that there is a market but no plan, which may also lead to some enterprises having a plan but no market. Cooperative production among tobacco enterprises is to cope with this situation. The quality of cigarette materials used in cigarette production has an important impact on the quality of cigarette products. At present, with the change of the industry situation, the supply mode of cooperatively produced cigarette materials has gradually become dominated by the partners, and the specifications and proportions of self-purchased cigarette materials of cooperative manufacturers are also increasing year by year. In order to ensure the stability of the quality of cooperatively produced cigarette products, it is necessary to establish a systematic and effective evaluation model for the quality assurance capability of cigarette materials. To scientifically guide the quality control of tobacco materials for cooperative production. The method of using a set of multi-index comprehensive evaluation model to guide quality control has been widely used in tobacco processing, packaging and other processes. The common methods to determine the weight in the evaluation system are principal component analysis, analytic hierarchy process (AHP), entropy weight method and so on. The principal component analysis method is suitable for the system with strong correlation among the indexes, while AHP and entropy weight rule do not require the correlation among the indexes. AHP is a kind of method which is formed by expert scoring to obtain the weight, mainly relying on the subjective experience of experts. Entropy weight method is an objective method to determine the weight by analyzing the measured data structure of the evaluation index, but the disadvantage is that it only analyzes the data itself and ignores the importance of the index itself. Therefore, the system uses the method of entropy weight and AHP to calculate the weight and construct the evaluation model of comprehensive quality assurance capability of cooperative production of tobacco materials.

B. K. Kandel et al. (eds.), *Proceedings of the 2023 8th International Conference on Engineering Management (ICEM 2023)*, Atlantis Highlights in Engineering 23,
https://doi.org/10.2991/978-94-6463-308-5_35

Keywords: cooperative production; tobacco materials; quality assurance; AHP, entropy weight method

1 Introduction

At present, the quality control of cooperatively produced tobacco materials mainly focuses on verifying the quality inspection report of cooperatively produced self-purchased tobacco materials and preventing defective materials from flowing into the production process. The quality supervision of tobacco materials for cooperative production is mainly carried out by checking the quality report of tobacco materials purchased by the importing party, and verifying the results of appearance, performance and safety testing of the tobacco materials purchased by the importing party according to the quality standards and testing requirements of the tobacco materials exported by the company. Through the analysis and study of the key quality nodes of tobacco materials, the evaluation model of the guarantee ability of the key quality nodes in the process of inspection, traceability and use of tobacco materials is established, which can scientifically guide the cooperative manufacturers to carry out the work of material quality control, enhance the team's ability to find problems, and help to enhance the quality of materials used by the importers. So as to ensure the realization of homogeneous production of the company's products.

2 Current situation investigation

The cooperative manufacturers of Z Company are all over the country, and there are as many as 25 tobacco materials to be purchased for cigarette production. The tobacco material manufacturers involved in the procurement of the cooperative manufacturers are numerous and widely distributed, and the quality of tobacco materials produced by different material manufacturers is different. The different testing level of tobacco materials, production process control and internal control ability of cooperative manufacturers make the ability to find problems in the process of testing and using tobacco materials different.

Through the analysis of the results of Z Company's regular supervision and inspection of the tobacco materials of the cooperative manufacturers and the use of the materials of the cooperative manufacturers in recent years, it is found that the current quality of tobacco materials has the following characteristics:

The quality of tobacco materials is generally good. From 2015 to 2020, the qualified rate of Z Company's sampling quality of tobacco materials from cooperative manufacturers was 98%, and showed an upward trend year by year.

In the process of cigarette production, there are many cases of production stagnation caused by the quality problems of cigarette materials.

3 Definition of Quality Assurance Capability Evaluation Model for Cigarette Materials

Commonly used product quality evaluation is generally composed of qualified rate, high quality rate, market complaint compensation rate and other indicators, considering that the index design should follow the principles of scientificity, practicability and operability, combined with the actual situation of quality supervision of cooperative production of tobacco materials, to construct the evaluation index of quality assurance ability of cooperative production of tobacco materials. Team members identify customers by correlation diagram, analyze customer needs by Kano model, and after several rounds of discussion and modification on the basis of identifying key needs, they believe that in the actual quality control of cooperative production materials, material quality assurance is mainly based on material inspection and process discovery as the core content, relying on material inspection. With the help of the results of material supervision and inspection and the results of instrument comparison as the means of inspection, a three-tier evaluation index system was finally established. As shown in Figure 1, the criteria layer includes 3 primary indicators and 8 secondary indicators.

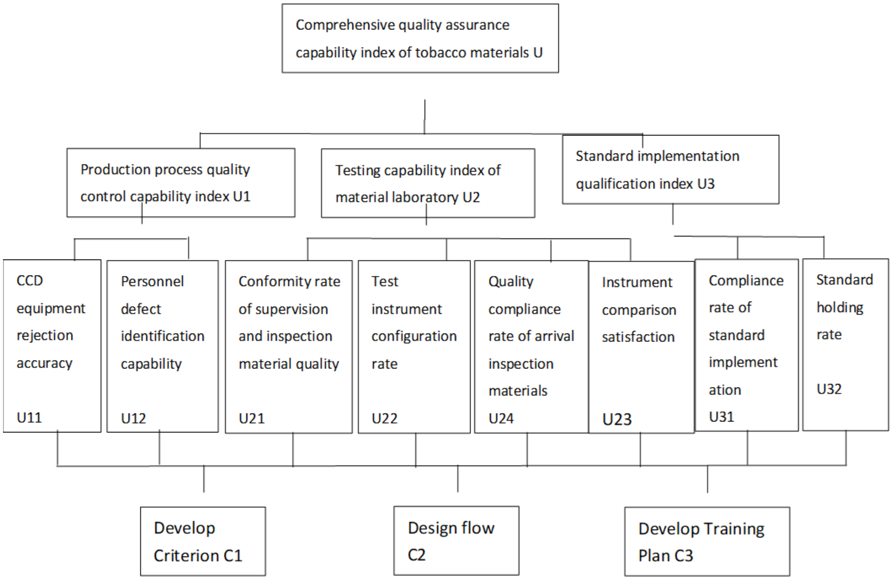

Fig. 1. An evaluation hierarchy model for comprehensive quality assurance capability of cigarette material

3.1 Combined evaluation of AHP and entropy weight method

AHP calculates the weight of each element by constructing a judgment matrix and scoring by experts, and the scoring mechanism is based on the work experience of experts. In this project, the practical significance of AHP weight is the subjective judgment of experts on the importance of evaluation indicators. Entropy is a measure of the degree of system needlessness [1]. In the field of statistics, entropy weight method determines the weight of data source indicators by calculating the degree of data dispersion [3]. When the data is more dispersed, the smaller the entropy value is, the more information the data contains and the greater the weight is [4]. In this project, the degree of data dispersion represents the dispersion and fluctuation of material quality assurance capability in the regional dimension [6]. The greater the entropy value is, the greater the improvement space of related indicators is [7]. Considering that the AHP method scores the importance subjectively, while the entropy method only analyzes the objective information of the data structure, the weighting method combining the two weighting methods is called the combination weighting method in this paper.

3.1.1 Determination of evaluation index weight based on AHP.

The judgment matrix is constructed, and 10 industry experts are invited to compare the matrix elements in pairs to obtain the importance judgment value. And average that expert judgment values to obtain a mean value judgment matrix. The results of the analysis were calculated using SPSSAU as follows

Table 1. Index weight of quality assurance capability of tobacco materials based on AHP

Item	Eigenvector	Weight value	The largest eigenvalue	CI value
CCD equipment rejection accuracy	0.404	5.054%	8.173	0.025
Personnel defect identification capability	0.876	10.951%		
Supervise and inspect the conformity rate of material quality	1.567	19.591%		
Test instrument configuration rate	0.588	7.352%		
Instrument comparison satisfaction	0.905	11.315%		
Conformity rate of material quality in arrival inspection	1.353	16.917%		
Compliance rate of standard implementation	1.438	17.972%		
Standard holding rate	0.868	10.848%		

Table 2. Summary of Consistency Test Results

The largest characteristic root	CI value	RI value	CR value	Consistency test results
8.173	0.025	1.410	0.018	Through

The consistency test result shown in the Table 2 is $CR = 0.018 < 0.1$, the judgment matrix of this study meets the consistency test, and the calculated weights are consistent.

3.1.2 Determination of evaluation index weight based on entropy weight method.

The calculation steps of the entropy weight method are as follows:

The measured data with different dimensions are normalized [2]. For m evaluation indexes ($I = 1,2,3 \ldots M$), n measured data ($J = 1, 2, 3 \ldots n$). The normalization formula is:

$$y_{ij} = \frac{x_{ij} - minx_{ij}}{maxx_{ij} - minx_{ij}} \quad (1)$$

Calculation of entropy [5]. According to the definition of entropy in statistics, the formula for calculating the entropy of the ith index is:

$$P_i = -\frac{\sum_{i=1}^{m} k_{ij} \ln k_{ij}}{\ln m}, \; k_{ij} = \frac{y_{ij}}{\sum_{i=1}^{n} y_{ij}} \quad (2)$$

It can be seen from Equation 1 and Equation 2 that when y_{ij}(j=1,2,3… N) When all are equal, the entropy value P_i The maximum value is obtained, at which the degree of dispersion is the smallest.

3) Entropy weight method [8]. Entropy index:

$$\beta_i = \frac{1 - P_i}{m - \sum_{i=1}^{m} P_i} \quad (3)$$

Using Equation 3 according to the calculated entropy value of each index Empower.β_iThe larger the index is, the greater the influence of index I on the comprehensive evaluation is [9].

After standardizing the mean value of each evaluation index data from 2015 to 2020, the entropy weight TOPSIS calculation results are as follows using SPSSAU

Table 3. Summary of Weight Calculation Results by Entropy Method

Item	Information entropy value e	Information utility value d	Weight coefficient w
CCD equipment rejection accuracy	1.0000	0.0000	0.00%
Personnel defect identification capability	0.9996	0.0004	2.48%
Supervise and inspect the conformity rate of material quality	0.9995	0.0005	3.56%
Test instrument configuration rate	0.9961	0.0039	26.78%
Instrument comparison satisfaction	0.9919	0.0081	55.23%
Conformity rate of material quality in arrival inspection	1.0000	0.0000	0.00%
Compliance rate of standard implementation	0.9983	0.0017	11.96%
Standard holding rate	1.0000	0.0000	0.00%

3.1.3 Combination weighting method.

α_iIs the index weight calculated by AHP,β_iIs the index weight calculated by entropy weight method.w_iIs the combined weight:[10]

$$w_i = \frac{\sqrt{\alpha_i \beta_i}}{\sum_{i=1}^{n} \sqrt{\alpha_i \beta_i}}, \; \sum_{i=1}^{n} w_i = 1, w_i \geq 0, i = 1,2,\ldots,m \quad (4)$$

The combination weight w calculated by Equation 4 from the data of Table 1 and Table 3 is shown in Table 4:

Table 4. Combined weights of evaluation indexes

Evaluation index	AHP weight α	Weight β of entropy weight method	The combined weight w
CCD equipment rejection accuracy	5.054%	0.00%	0.00%
Personnel defect identification capability	10.951%	2.48%	7.75%
Supervise and inspect the conformity rate of material quality	19.591%	3.56%	12.42%
Test instrument configuration rate	7.352%	26.78%	20.86%
Instrument comparison satisfaction	11.315%	55.23%	37.17%
Conformity rate of material quality in arrival inspection	16.917%	0.00%	0.00%
Compliance rate of standard implementation	17.972%	11.96%	21.80%
Standard holding rate	10.848%	0.00%	0.00%

It can be seen from Table 4 that the total weight of personnel defect identification ability, quality compliance rate of supervision and inspection materials, allocation rate of testing instruments, satisfaction of instrument comparison and compliance rate of standard implementation in the combined weight after comprehensive evaluation by AHP method and entropy weight method reaches 100% [11]. These five indicators are taken as the key evaluation indicators of the project, and their definitions are shown in the Table 5:

Table 5. Definition of evaluation indexes for quality assurance capability of cigarette materials

Serial number	Indicators	Indicator variable	Indicator content	Calculation formula
1	Test instrument configuration rate	y1	Statistics of the proportion of necessary testing instruments for cigarette materials of the cooperative manufacturers over the years	$y1 = \frac{\text{Necessary testing instruments for actual configuration}}{\text{Necessary testing instruments}} * 100\%$
2	Compliance rate of standard implementation	y2	The average score of the standard compliance rate of the quality standards, inspection methods and testing items corresponding to the tobacco materials used by the cooperative manufacturers over the years was counted.	$y2 = \frac{(\text{Standard implementation rate} + \text{compliance rate of inspection methods} + \text{coverage rate of inspection items})}{3}$ $\text{Standard implementation rate} = \frac{\text{Actual implementation standards}}{\text{Standards shall be implemented}} * 100\%$ $\text{Inspection method compliance rate} = \frac{\text{Method up to standard inspection item}}{\text{Items to be inspected}} * 100\%$ $\text{Inspection item coverage} = \frac{\text{Actual inspection items}}{\text{Items to be inspected}} * 100\%$
3	Supervise and inspect the conformity rate of material quality	y3	Make statistics of supervision and inspection results of Z Company over the years	$\text{Material quality compliance rate} = \frac{\text{Number of tobacco materials passing supervision and inspection}}{\text{Sampling number of tobacco materials for supervision and inspection}} * 100\%$
4	Instrument	y4	En is the ratio value commonly used in laboratory	$E_n = \frac{x - x_0}{\sqrt{u^2 - u_0^2}}$

	comparison satisfaction		comparison experiments. X is the test result data of the partner's laboratory. x_0 It is the data of laboratory test results of Z company. U is the measurement uncertainty of the testing instrument of the partner. u_0 It is the measurement uncertainty of Z company's testing instrument. P_r Is color skewness.	$y4 = \begin{cases} \sum\left(\left\lvert\frac{\lvert\ln\lvert E_n\rvert\rvert}{2*\ln\lvert E_n\rvert}-\frac{1}{2}\right\rvert*\frac{2.5-\lvert E_n\rvert}{2.5}\right)+\frac{2-P_r}{2}*0.8, & \lvert E_n\rvert \neq 1 \\ \frac{2-P_r}{2}*0.8, & \lvert E_n\rvert = 1 \end{cases}$
5	Process problem finding capability	y5	Count the mean value of the prevention and control ability of the personnel of each cooperative manufacturer over the years.	$y4 = \frac{\text{Accurate number of manually detected items}}{\text{Total number of manual detection items}}$
6	Quality assurance capability	Y	Quality assurance capability weighted value	$Y = \frac{\sum_{i=1}^{5} w_i * y_i}{\sum_{i=1}^{5} w_i}$

From the Table 4 and Table 5, we know Y = 0.2086 * Y1 + 0.2180 * Y2 + 0.1242 * y3 + 0.3717 * y4 + 0.0775 * y5

Using FEMA failure mode to analyze the five evaluation indexes of y1-y5, 22 failure factors are obtained. By summarizing the failure factors, it can be seen that the lack of quality assurance capability of tobacco materials mainly focuses on the following aspects [12]:

Lack of tracking and understanding of the instrument configuration of the cooperative manufacturer

The process of issuing the quality and inspection standards of tobacco materials is not clear, which leads to the failure of cooperative manufacturers to obtain the latest standards in time.

Improper use environment of testing instruments and equipment, and non-standard testing methods of inspectors

The ability of quality control in the use of tobacco materials needs to be improved

The quality problem handling process is not clear, and the response speed of problem handling needs to be improved.

4 Project improvement plan

4.1 Overall scheme

Since the materials for cooperative processing of cigarettes are mainly purchased by the cooperative party, the quality assurance capability of the materials mainly depends on the personnel discovery and laboratory test results of the cooperative manufacturer's production process. The improvement of this project will design the overall scheme for these two processes, including process design. The overall plan is shown in Table 6

Table 6. Standard formulation and training plan formulation

Serial number	Programme	Aim
1	Process design	Use ECRS process carding method to comb the operation process, optimize the process and improve the efficiency
2	Standard-setting	The material standards involving many enterprises are unified, and the operation process is guided by fixed standards.
3	Training plan development	Strengthen employee skills and awareness through training

4.2 Detailed plan

Based on the quality assurance capability of cigarette materials used in cigarette factories, the detailed design plan is shown in Table 7

Table 7. Detailed scheme

Serial number	Evaluation index	Improve the route	Use the scheme
1	Test instrument configuration rate	Formulate the evaluation criteria for the material testing capability of the cooperative manufacturer, and regularly track the instrument configuration through the design of the instrument configuration inspection process of the cooperative manufacturer	Standard formulation and process design
2	Compliance rate of standard implementation	By sorting out the process of material standard distribution, we can reduce the intermediate links and increase multiple distribution channels to ensure that the standard is timely and accurately distributed to the cooperative manufacturers. Develop a material standard learning and training plan for employees of partner manufacturers.	Process design, training plan development
3	Supervise and inspect the conformity rate of material quality	Design and sort out the material process supervision ability of the team sent by Z company, optimize the problem material handling process and improve the response speed.	Process design
4	Instrument comparison satisfaction	To formulate standards for the use of tobacco material inspection equipment, and to ensure the consistency of inspection results by standardizing the use of environmental protection. Develop a training plan for inspectors on instrument operation methods, and standardize the consistency of operation.	Formulation of standards and training plans
5	Process problem finding capability	Establish process supervision operation standards, design regular identification process of defect identification capability, and design special training plan for difficult problems of identification.	Standard formulation, process design and training plan formulation

5 Conclusion

The evaluation system established by AHP-entropy method can timely find the problems in the quality assurance system of tobacco materials and effectively guide the relevant parties to carry out improvement work.

Through the score, we can know the specific missing items in the quality assurance capability of the materials used by each cooperative processing point, and use the relevant programs to improve. The support capability score of each processing point increased from 81.56 points before improvement to 87.58 points.

Cigarette material is an important part of cigarette, and the basic demand of tobacco enterprises is the cigarette material with stable quality, which adapts to the use conditions of modern cigarette equipment. Auxiliary materials with high quality and strong stability can not only improve the quality of cigarette products, but also improve production efficiency, reduce material consumption and reduce production time. With the continuous updating of cooperative cigarette lighting machinery and equipment and the continuous improvement of production speed, higher requirements are put forward for the quality of cigarette auxiliary materials. In order to meet the increasing product quality requirements, on the premise of guaranteeing the quality of auxiliary materials in cooperative production, the quality of tobacco materials is guaranteed to be stable and reliable through the joint monitoring of quality control technology and management methods, and the level of homogeneous manufacturing in cooperative production is improved.

References

1. Xiao Shuying. A Method for Evaluating the Quality of Cycling Based on Entropy Weight Analytic Hierarchy Process [J]. BeiJing: Transportation Engineering, 2023(4):10-17.
2. V. Vakharia, V. Gupta, P. Kankar, A multiscale permutation entropy based approach to select wavelet for fault diagnosis of ball bearings, Journal of Vibration and Control 21 (16) (2015) 3123–3131.
3. Wu ZhaoLi. Research on the Competitiveness of Inland River Ports Based on CRITIC Entropy Weight Method and TOPSIS Method [D] Chongqing Jiaotong University, 2022.
4. Wang ZongJun. Research on the Performance Evaluation System of Tobacco Commercial System Research Projects in Hubei Province Based on Analytic Hierarchy Process and Entropy Weight Method [J]. BeiJing: Science Technology and Industry, 2022(6):169-175.
5. A.S. Minhas, N. Sharma, P. Kankar, S. Singh, A comparative study for the selection of an entropy technique to classify bearing faults, in: 2019 IEEE
6. Hao ShaoPan. Construction of Index System for Factors Influencing the Transformation of Scientific and Technological Achievements Based on Delphi AHP Entropy Weight Method - Taking the Water Conservancy Industry as an Example[J]. BeiJing: Chinese University Science & Technology, 2022(12):88-95.
7. Lu XingYu. Research on multi-objective optimization of FDM molding process parameters based on entropy weight TOPSIS [J]. ShanXi: Journal of Mechanical Science and Technology, 2017(11):81-87.

8. Liu GuoCheng. Research and Empirical Analysis on Information System Audit Risk Assessment Based on AHP and Entropy Weight [J]. BeiJing: Auditing Research, 2016(1):55-61.
9. Li Fang. A Combination Evaluation Model Based on Entropy Weight Method[J]. ShanDong: Information Technology and Informatization, 2021(9):154-156.
10. Wu YingJun. Evaluation method for energy-saving and emission reduction effects of enterprises based on entropy weight method and expert scoring method [J]. ShangHai: Low Voltage Apparatus, 2015(16):70-75.
11. Zhu TianTong. A Comprehensive Decision Method for Power Grid Planning Schemes Based on Improved TOPSIS Method and Delphi Entropy Weight Comprehensive Weight Method [J]. ShangHai: Power System Protection and Control, 2018(12):97-105.
12. M. Rostaghi, H. Azami, Dispersion entropy: A measure for time-series analysis, IEEE Signal Processing Letters 23 (5) (2016) 610–614.