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Decision-Making on Product Testing and Swapping Based on Multi-Index Evaluation System

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Abstract: As an emerging product, electronic products have a large market demand, but related enterprises are also faced with the problem of high prices of raw materials and easy loss in the production process. This paper establishes a multi-index evaluation system model for quantitative analysis, which aims to help enterprises improve production steps, formulate reasonable product production process detection and exchange strategies, and improve enterprise revenue. The core idea of this paper is to establish a multi-index evaluation system by selecting appropriate evaluation indicators, calculate the scores of different production testing and exchange schemes in the system, and select the scheme with the highest score as the final production inspection and exchange scheme of the enterprise. This paper not only takes corporate profit as an indicator, but also introduces corporate reputation factor and resource utilization, and fully considers the long-term impact of different production product testing and exchange schemes on corporate reputation and environment. In addition to selecting a number of comprehensive evaluation indicators, this paper also borrows the 0-1 programming idea, entropy weight method and principal component analysis method to calculate the comprehensive score of each scheme, and realizes the calculation of the comprehensive score of different schemes under different defective rates. The analysis of different enterprise sizes and product quantities shows that the multi-index evaluation system has a wide applicability, and also reveals the influence of enterprise size on the decision to test and replace production products.

Keywords: Electronic product production decision-making, Multi-index evaluation system, Entropy weight method, Principal component analysis.

1. Introduction

With the progress of social and economic development and scientific and technological level, the manufacturing market has shown steady growth and continued to be active. Nowadays, electronic products have gradually become indispensable consumer goods in people's daily life because of their convenient. The market scale is expanding and the market prospects are broad. In the production of electronic products, one of the basic challenges is that there is a risk of loss and defective rate in many stages of production. At the same time, the price of raw materials is high, and the cost of production technology is high. To this end, a few solutions have been proposed, such as research on the quality influencing factors and countermeasures in the production process of electronic products, investment decisions in electronic production that consider quality learning, and behavioral decisions that consider the interests of waste electronic products that take into account the responsibility for recycling targets. Despite these advances, most solutions are qualitative or do not consider a wide range of influencing factors, leaving the analysis insufficient in terms of quantification and comprehensiveness. In the quality influencing factors and coping strategies in the production process of electronic products, Tian Xiao proposed that the quality in the production process is affected by many factors, including human factors, mechanical equipment factors, material factors, methodological factors and external factors [1], and Liang Yu pointed out that the quality of electronic products should be improved by strengthening human resource management and other methods [2]. However, this only provides a qualitative analysis of the influencing factors, and does not quantify them, resulting in a lack of clarity in the boundaries of influence between the factors. Essentially, it is difficult for companies to make specific adjustments to the production process based on these qualitative factors alone. In the process optimization of quality improvement considering the input of manufacturers, Many i has conducted research on the investment decisions of electronic product manufacturers, specifically, through reasonable investment to improve quality, reduce quality problems to obtain profits, and reduce waste caused in the production process [3]. However, the model only takes into account the factor of quality learning, and still aims to maximize corporate profits, and lacks the impact of defective rate on corporate reputation and the environment. Proposal: Establish a multi-index evaluation system to quantitatively evaluate the detection and decision-making scheme in the production process of electronic products, and consider multiple influencing factors and conduct quantitative analysis. This paper systematically studies how to select appropriate indicators to comprehensively reflect the multi-faceted influences, establish a multi-index evaluation system [4-6], and then use mathematical methods to calculate the enterprise score. For the relatively simple production process without semi-finished products, three indicators were selected: corporate profit, corporate reputation factor and resource utilization, the independence and rationality of the three indicators were demonstrated by the correlation coefficient matrix, the original data were standardized and the entropy weight method [7, 8] was used to objectively determine the weights of the three indicators, and then the comprehensive score of the scheme was calculated. For the more complex production process with semi-finished products, seven indicators were selected to construct the evaluation system in the production decision-making process, and then the principal component analysis method [9, 10] was used to reduce the data dimensionality, and finally four evaluation indicators were determined, and the production plan was constructed with the help of the idea of 0-1 planning [11]. Then, in view of the fact that the defective rate is based on the sampling detection method, so there is a certain error, the full probability formula is introduced to correct the defective rate, and the scheme score under the evaluation system is recalculated, and it is found that the impact of the error of the defective rate on the production decision cannot be ignored. Finally, this paper analyzes the scale of different enterprises and the number of products, and obtains the scores of solutions under different enterprise scales, revealing the influence of different enterprise sizes on production testing and switching decisions.

2. There is No Multi-Index Evaluation System for Semi-Finished Product Processes

First of all, consider the situation of two spare parts, and the production decision to be made is as follows: whether to test the spare parts, if a certain spare parts are not tested, this kind of parts will directly enter the assembly link; Otherwise, the detected unqualified parts will be discarded; Whether each finished product is tested after assembly, if not tested, the assembled finished product directly enters the market, otherwise only the finished product that passes the test enters the market; Whether the detected unqualified finished products are disassembled, if not disassembled, the unqualified finished products will be discarded directly, otherwise the disassembled spare parts will be put into use again; For the nonconforming products purchased by the user, the enterprise will unconditionally replace them, and incur a certain amount of replacement losses, and reconsider whether to dismantle the returned nonconforming products. Suppose that the products in the production stage are tested or not tested at the same time, and the number of spare parts purchased by the enterprise is the same. Table 1 shows the defective rate $p_i(i = 1,2,3)$, purchase unit price $b_i(i = 1,2,3)$, testing cost $c_i(i = 1,2,3)$, replacement loss e and dismantling cost m of common electronic products and corresponding spare parts on the market. Next, this paper will elaborate on the establishment and calculation of the multi-index evaluation system under the condition of case 1.

Table 1. Common electronic products and their parts, finished product costs

Case	Spare parts 1			Spare parts 2			Finished product				Non-conforming products	
	p_1	b_1	c_1	p_2	b_2	c_2	p_3	b_3	c_3	d	e	m
1	10%	4	2	10%	18	3	10%	6	3	56	6	5
2	20%	4	2	20%	18	3	20%	6	3	56	6	5
3	10%	4	2	10%	18	3	10%	6	3	56	30	5
4	20%	4	1	20%	18	1	20%	6	2	56	30	5
5	10%	4	8	20%	18	1	10%	6	2	56	10	5
6	5%	4	2	5%	18	3	5%	6	3	56	10	40

In view of the above situation, a specific decision-making scheme is given, and the following indicators are selected to construct a multi-index evaluation system: a. Corporate profit ω: use ω to represent corporate profits, P represents sales, F represents fixed costs, C represents non-fixed costs, fixed costs refer to the initial cost of purchasing spare parts, non-fixed costs include parts dismantling costs, finished product assembly costs, finished product dismantling costs, replacement logistics losses etc. The parts after dismantling can be used in the next production process, so the parts can be recycled after dismantling.

Corporate Profit Definition:

$$\omega = P - F - C \tag{1}$$

Corporate Reputation Factor α : In order to comprehensively consider the factors such as corporate image and reputation, define a corporate reputation factor to quantify the current credit level, and set the initial value of the factor to be α_0 and $\alpha_0 = 1$. Users will return defective products after buying, but also reduce the trust in the company, it is possible that the next time no longer buy the company's products, the value of the reputation factor decreases, the more users buy defective products, the greater the damage to the company's reputation, the lower the credit value of the enterprise, the smaller the reputation factor. The number of defective products sold n is inversely proportional to the value of the company's reputation factor, and the reputation factor of the enterprise becomes 0.999 times that every additional user receives a defective electronic product.

Corporate Reputation Factor:

$$\alpha = 0.999^n \alpha_0 \tag{2}$$

Resource utilization: because the production process is not dismantled, there may be the discarding of defective parts, the discarding of defective products, and the defective parts and defective products that are not used will inevitably cause a waste of resources. Environmental protection is also an important factor for an enterprise to achieve long-term stable and sustainable production, and from the perspective of environmental protection, resource utilization indicators are introduced to quantify the environmental protection level of enterprises. u is equal to the proportion of spare parts effectively used in the specific scheme, and the initial value of u is u_0, $u_0 = 1$.

Calculate the value of the eight schemes in the three indicators: firstly, assume that the number of spare parts purchased by the enterprise M is a fixed value, $M = 10000$, the number of products produced is N, and the number of products that need to be replaced is D. Drawing on the idea of 0-1 planning, 0 represents the production process does not take the corresponding steps, 1 represents the corresponding steps in the production process, and it is necessary to decide whether to detect spare parts, whether to detect the finished product, whether to disassemble these three steps, each step has two values of 0 and 1, it can be known that there are a total of 8 possible production schemes, scheme one means that all spare parts and finished products are not tested and disassembled, scheme two means that spare parts are not detected, and finished products are not detected, but the returned unqualified products are disassembled, Scheme 3 means that the spare parts are not tested, the finished product is tested but not disassembled, scheme 4 means that the spare parts are not tested, the finished product is tested and disassembled, scheme 5 means that the spare parts are tested, and the finished product is neither detected nor disassembled, scheme 6 means that the spare parts are tested, the finished product is not tested but the unqualified finished product is dismantled after return, scheme 7 means that the spare parts are tested, the finished product is tested but not disassembled, and the scheme 8 means that the spare parts are tested, and the finished product is tested and disassembled.

Take x_0 as an example: the formula for calculating the three indicators (the remaining seven calculation methods are similar to Option 1)

$$\omega = d \cdot M - (b_1 + b_2)M - b_3 M - (1 - (1 - p_1)(1 - p_2)(1 - p_3)) \cdot e \cdot M \quad (3)$$

$$\alpha = 0.999^{(1-(1-p_1)(1-p_2)(1-p_3))M} \cdot \alpha_0 \quad (4)$$

$$u = (1 - p_1)(1 - p_2)(1 - p_3) \quad (5)$$

Test of the rationality of the indicators: After the three indicators of the eight schemes are calculated respectively, the scatter plot and heat map of the matrix are made through the calculation of the correlation matrix coefficient of the index, so as to test the independence of the indicators and verify the rationality of the indicators.

As shown in Figure 1 and Figure 2, the independence of the three indicators is good, indicating that the three indicators measure different aspects of the enterprise's production, and the selection of these three indicators can comprehensively and systematically evaluate the production process of the enterprise and make optimal decisions.

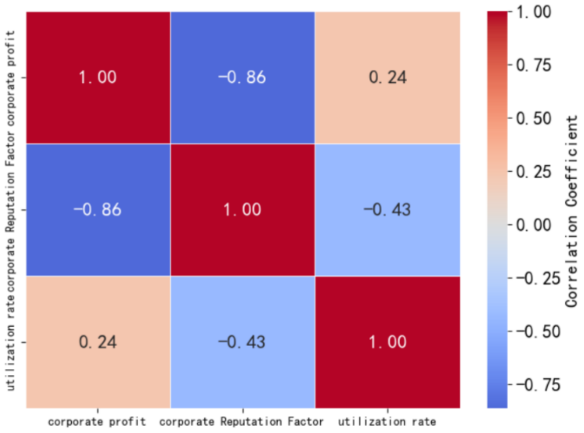

Figure 1. Heatmap of the indicator

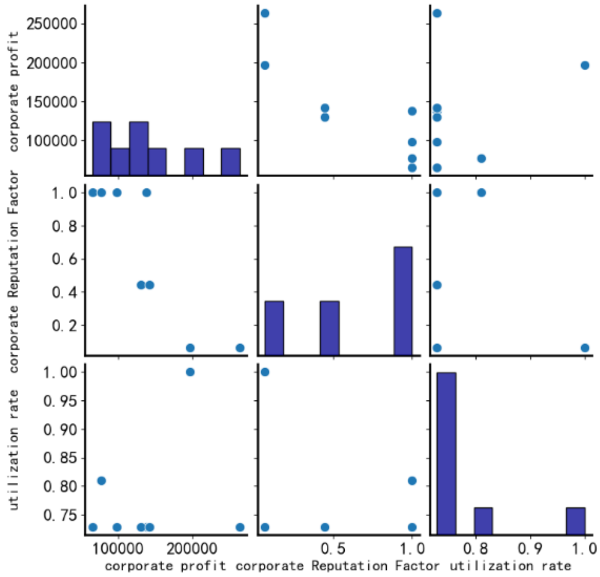

Figure 2. Three-indicator scatter matrix

Establishment of the weights of each index: After verifying the rationality of the indicators, the weights of each index need to be calculated accordingly. In order to reduce the influence of different data units on the calculation results, the data is standardized firstly, and then the entropy weight method is used to objectively assign the weights of the three indicators, and the weight vectors are $\gamma = (0.327, 0.204, 0.469)$, γ_1 is the weight of enterprise profits, γ_2 is the weight of enterprise reputation factor, and γ_3 is the weight of enterprise resource utilization.

(3) Scheme score and ranking: After obtaining the specific values of the three indicators and weights, the specific score S of the enterprise in this multi-index evaluation system is calculated, and the calculation formula of S is as follows:

$$S = \gamma_1 \cdot \omega + \gamma_2 \cdot \alpha + \gamma_3 \cdot u \quad (6)$$

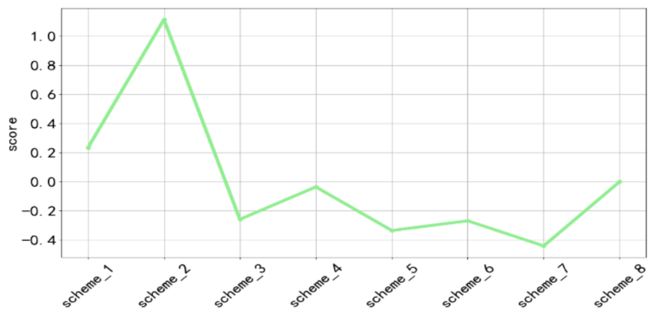

Figure 3. Scenario 1 scores

Under the condition of case 1, the score of each scheme is shown in Figure 3, and it can be seen that the second scheme has the highest score, so the second scheme (not testing spare parts, not testing finished products, but dismantling) is taken as the final decision of the enterprise: Then, the scores of eight schemes in the six cases in Table 1 are calculated respectively, and the results are the highest scores of scheme 2 (parts are not tested, finished products are tested, but not disassembled), and the optimal scores in various cases are shown in Figure 4.

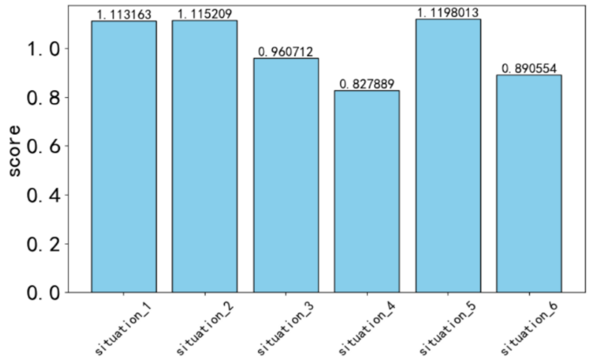

Figure 4. Optimal solution scores in different scenarios

3. There is A Multi-Index Evaluation System for The Semi-Finished Product Process

Table 2. Common electronic products and their parts, semi-finished products and finished product costs

Spare parts	p_1	b_1	c_1	Semi-finished products	p_2	b_2	c_2	m_1
1	10%	2	1	1	10%	8	4	6
2	10%	8	1	2	10%	8	4	6
3	10%	12	2	3	10%	8	4	6
4	10%	2	1	/	p_3	b_3	c_3	m_2
5	10%	8	1	Finished product	10%	8	6	10
6	10%	12	2	/				
7	10%	8	1	/	d		e	
8	10%	12	2	Finished product	200		40	

The process with semi-finished products is more complex than the process without semi-finished products, and the information on the assembly process of the finished product and the corresponding spare parts, semi-finished products, and the defective rate of the finished product are shown in Table 2. The corresponding parts assembly is: spare parts 1, 2, 3 processing to obtain semi-finished product 1, spare parts 4, 5, 6 processing to obtain semi-finished product 2, spare parts 7, 8 processing to obtain semi-finished product 3, further processing from semi-finished product 1, 2, 3 to obtain finished product. Table 2 shows the defective rate $p_i(i = 1,2,3)$, purchase unit price $b_i(i = 1,2,3)$, testing cost $c_i(i = 1,2)$, replacement loss e and dismantling cost $m_i(i = 1,2,3)$ of common electronic products and corresponding spare parts on the market. Next, this paper will elaborate on the establishment and calculation of the multi-index evaluation system under the condition of case 1.

1) Select the corresponding indicator

a. After increasing the semi-finished product, the process is more complex, and the number of spare parts is more, so more indicators are needed to constitute the evaluation system, so as to better optimize decision-making, the profit of the enterprise and the reputation factor of the enterprise still follow the α of the enterprise profit ω and the enterprise reputation factor defined in the process of no semi-finished product, for the environmental protection benefits of the enterprise, the use of spare parts resource utilization rate u_1, the utilization rate of semi-finished product resources u_2 and the utilization rate of finished product resources u_3 three indicators to measure.

b. In addition, considering the impact of the quantity β finished products and the complexity of the process on the development of the enterprise, this paper introduces the process complexity λ to measure the complexity of the process in the production process of the enterprise, the initial value of the process complexity is 0, and the complexity of the process is increased by 1 for each inspection or disassembly.

2) Principal component analysis (PCA) was used to reduce the dimensionality of the data: After the data was standardized and the correlation coefficient matrix of the seven indicators was constructed, it was observed that the relationship between the seven indicators was intricate, and there was a strong correlation between some indicators, and the data of the seven dimensions was not conducive to subsequent calculation and analysis, so it was decided to use the principal component analysis (PCA) method to reduce the dimensionality of the data while retaining important information.

After processing, the 1st, 2nd, 3rd, and 4th principal components with a cumulative variance contribution rate of more than 85% were selected, which were as follows:

$$F_1 = 0.097\omega + 0.517\alpha - 0.363u_1 - 0.140u_2 + 0.121u_3 + 0.552\lambda - 0.503\beta \tag{7}$$

$$F_2 = 0.673\omega + 0.161\alpha - 0.188u_1 - 0.277u_2 - 0.573u_3 - 0.277\lambda + 0.066\beta \tag{8}$$

$$F_3 = -0.077\omega + 0.203\alpha + 0.507u_1 - 0.800u_2 + 0.223u_3 - 0.067\lambda + 0.031\beta \tag{9}$$

$$F_4 = 0.249\omega - 0.214\alpha - 0.537u_1 - 0.249u_2 + 0.557u_3 + 0.054\lambda - 0.478\beta \tag{10}$$

F_1 mainly reflects the long-term reputation of the enterprise and the complexity of processing, F_2 mainly reflects the operating income of the enterprise, F_3 measures the resource utilization ability of the enterprise, and F_4 shows the supply capacity of the enterprise.

3)Determination of index weights and calculation of the comprehensive score of enterprises.As with the process without semi-finished products, the entropy weight method is used to determine the weights of the four indexes γ_1=0.400, γ_2=0.286, γ_3=0.171, γ_4=0.143, and then the calculation formula of the comprehensive score S of the enterprise is obtained as follows:

$$S = \gamma_1 \cdot F_1 + \gamma_2 \cdot F_2 + \gamma_3 \cdot F_3 + \gamma_4 \cdot F_4 \tag{11}$$

Considering whether the eight spare parts are detected, whether the semi-finished products are detected, whether they are disassembled, whether the finished products are detected, whether they are disassembled, a total of 24 solutions are obtained, numbered 1-24, and then we calculate the score of the corresponding scheme in the evaluation system as shown in Figure 5 and Figure 6, from the ranking of the scheme, the scheme one has the highest score, so the production decision is: do not detect spare parts, semi-finished products, finished products, do not disassemble semi-finished products and finished products.

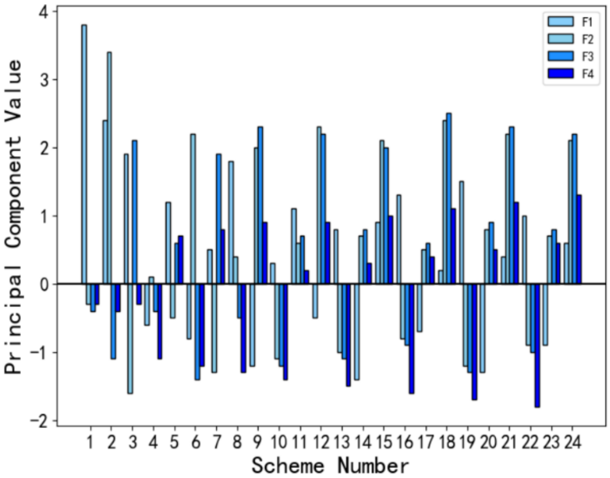

Figure 5. Principal component values

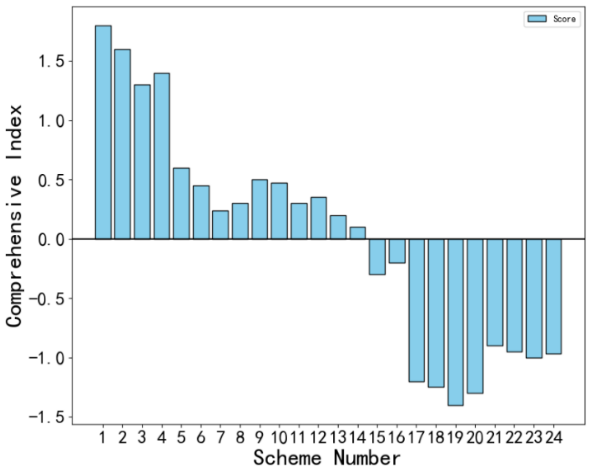

Figure 6. Scheme number

4. Correction of Defective Rate for Sampling Inspection

The above-mentioned defective rate is obtained by the method of sampling detection, and cannot guarantee 100% reliability, so the full probability formula is introduced to correct the defective rate, and the decision-making scheme with semi-finished product process is reconsidered when the reliability of the defective rate is 90% and 95%.

The modified defective rate of the full probability formula: the corrected defective rate is P, the reliability of the defective rate is η, the defective rate tested by sampling detection is p, and the defective rate greater than p is p', and the modified formula is as follows:

$$P = \eta \cdot p + (1 - \eta) \cdot p' \quad (12)$$

In the recalculation of the optimal scheme, p' is the defective value that falls outside the confidence interval, but it is impossible to know its specific value, only that it falls on the interval greater than p less than 1, and different p' values are selected, which are 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9 to recalculate the optimal decision-making scheme with semi-finished product process, and the results are shown in Table 3. It can be seen that although the confidence level is as high as 95%, the optimal scheme changes with the increase of the value of p' in the case of the existence of p', and the influence of p' can not be ignored.

Table 3. Numbers of optimal schemes at 90% and 95% confidence

p′	Optimal solution number (90% confidence)	Optimal solution number (95% confidence)
0.2	23	24
0.3	23	23
0.4	23	23
0.5	23	24
0.6	24	23
0.7	24	24
0.8	20	24
0.9	20	24

5. The Impact of Different Enterprise Sizes on Optimal Solution Decisions

The size of the enterprise will have an important impact on the decision-making, with the number of spare parts purchased (denoted as M) as a variable to measure the size of the enterprise, consider the number of spare parts purchased between 100-11000, and take the value in steps of 100 (a total of 100 M values). By calculating the scores of different schemes under the multi-index evaluation system of non-semi-finished process and semi-finished process, the optimal decision was made under different enterprise scales.

1) No semi-finished product process: change the value of M to calculate the score of each scheme in different situations, select the scheme with the highest score, we find that no matter what the value of M is, the optimal scheme from situation 1 to situation 8 has not changed, which is consistent with the optimal scheme results obtained from the analysis in the second part.

2) There is a semi-finished product process: still change the value of M to calculate the score of each scheme in different cases, select the scheme with the highest score, Figure 7 shows the proportion of the optimal scheme under 100 enterprise scales, and the optimal scheme of decision-making has changed under different M values. It can be concluded that when the production process is relatively simple, the influence of enterprise size on the optimal decision is small and negligible, and the influence of enterprise size on production decision can not be ignored when the production process is more complex.

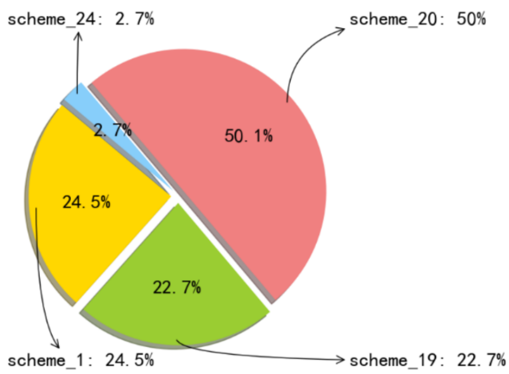

Figure 7. Proportion of optimal solutions for 100 different enterprise sizes

6. Conclusion

This paper constructs a multi-index evaluation system for enterprise decision-making, which aims to help enterprises make production decisions of electronic products. Under the condition of semi-finished product process and no semi-finished product, the entropy weight method is used to assign the standardized data, calculate the scores of different schemes, and select the scheme with the highest score as the final decision of the enterprise. The full probability formula adjusts for defective rates where the confidence level is not 100%, recalculates the score, and selects the optimal solution. In addition, this paper also discusses the applicability of the evaluation system to enterprises of different sizes. The model constructed in this paper only considers the emotion of the three kinds of spare parts purchased by the merchant to detect or not to detect at the same time, however, in the actual production of electronic products, the merchant can choose to detect the spare parts separately or in combination. When these situations are taken into account, the complexity of the model will increase significantly, the number of alternative solutions will increase significantly, and the amount of computation and the complexity of the formula will increase exponentially. Future research will try to consider the above more complex situations and explore reasonable calculation methods and optimization decisions under such more complex conditions.

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