Optimal Research on Production Decision Based on Profit Maximization and Violent Search Algorithm

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Abstract. In electronic product manufacturing, balancing quality control and cost control has become increasingly challenging due to complex assembly processes and multiple influencing factors. This study proposes a production decision-making optimization model based on profit maximization, considering various factors including parts inspection, finished product inspection, disassembly strategy, and exchange loss. Four 0-1 decision variables are introduced to describe the detection and dismantling strategy, with the objective function constructed by combining assembly parameters, detection costs, dismantling costs, and replacement losses. Through violent search algorithm optimization of 16 different inspection and dismantling strategies, the results show that optimal decisions vary significantly under different parameter scenarios. For instance, strategy "1101" achieves the highest profit of 15.966 in low defective rate scenarios, while strategy "0000" performs better with 18.587 profit in high defective rate scenarios. The study demonstrates that testing and dismantling strategies should be dynamically adjusted based on defective rates and costs, with optimal decisions increasing profit by 8%-12%.

Keywords: Profit maximization, Optimization of production decisions, Detection strategies, Disassembly costs, Violent search algorithms.

1. Introduction

In recent years, with the increasingly fierce market competition and consumer awareness of rights and interests, electronic product manufacturers are faced with enormous quality control pressure. How to ensure product quality at the same time, but also minimize production costs, and improve corporate profits, has become a key issue in production decision-making [1]. In the automated production process, involving multiple processes, multiple parts, and accessories, different quality levels of parts and accessories on the quality of finished products and production costs have different impacts [2]. Unqualified electronic products may lead to unstable performance of the finished product, increasing the cost of testing and rework. At the same time, the cost and accuracy of the testing process, the rework and dismantling strategy of unqualified products, etc., all have an important impact on the cost and profit of the enterprise [3]. Therefore, manufacturers urgently need a scientific decision-making model that can comprehensively consider the quality of parts, finished product testing, rework and dismantling, and other factors, to find the best balance between quality and cost, and to maximize profits [4]. However, traditional production decision-making often relies on experience and intuition, lack of systematic theoretical guidance, decision-making science, and accuracy is difficult to ensure [5].

To simplify the research process, this study assumes that the two parts and the defective rate of the finished product are known, and it is assumed that the production of the finished product requires the purchase of part 1 and part 2 for assembly. Assembly of finished products, as long as a spare part is not qualified, the finished product is not qualified; even if both parts are qualified, the finished product may not be qualified. For the unqualified finished product, the enterprise can choose to scrap or dismantle, dismantling does not damage the spare parts, but needs to pay dismantling costs [6]. Considering the reality of the enterprise production process, first need to decide whether to test the spare parts, substandard products will be directly discarded. After that, the enterprise has to decide whether to test the assembled finished products. Only qualified products can be sold in the market. For the detection of substandard products, enterprises need to decide whether to disassemble, disassembled spare parts will be re-tested and screened through the first two steps. When consumers buy substandard products, the enterprise will unconditionally exchange, them but will also bear a certain amount of exchange losses, such as logistics costs, and damage to the reputation of the enterprise. The returned substandard products will also go through the process of disassembly and reuse again in the third stage. According to the assumptions, this study will formulate the "spare parts detection strategy" and "cost detection strategy", introduce decision variables, assembly parameters and disassembly correction rate, and other parameters to construct the production decision-making profit maximization model and use the violent search algorithm to solve the model.

2. Optimization Model for Assembly Line Inspection Strategy

2.1. Develop a detection strategy

This study proposes a spare parts detection strategy and a finished product detection strategy. In this case, the spare parts detection strategy is: there are 2 types of spare parts, each of which can be selected to be detected or not detected. Therefore, there are a total of 2×2=4 combinations of strategies for spare parts. The finished product detection strategy is: each finished product can choose to be detected or not detected, and the failed finished product can choose to be disassembled or not disassembled. Thus, there are a total of 2×2=4 strategy combinations for finished goods.

Finally, the total number of strategies is obtained: 2×2×4 = 16 different combinations of strategies, where each combination represents the decision to detect parts 1 and 2, and the decision to detect and disassemble the finished product, as shown in Fig. 1.

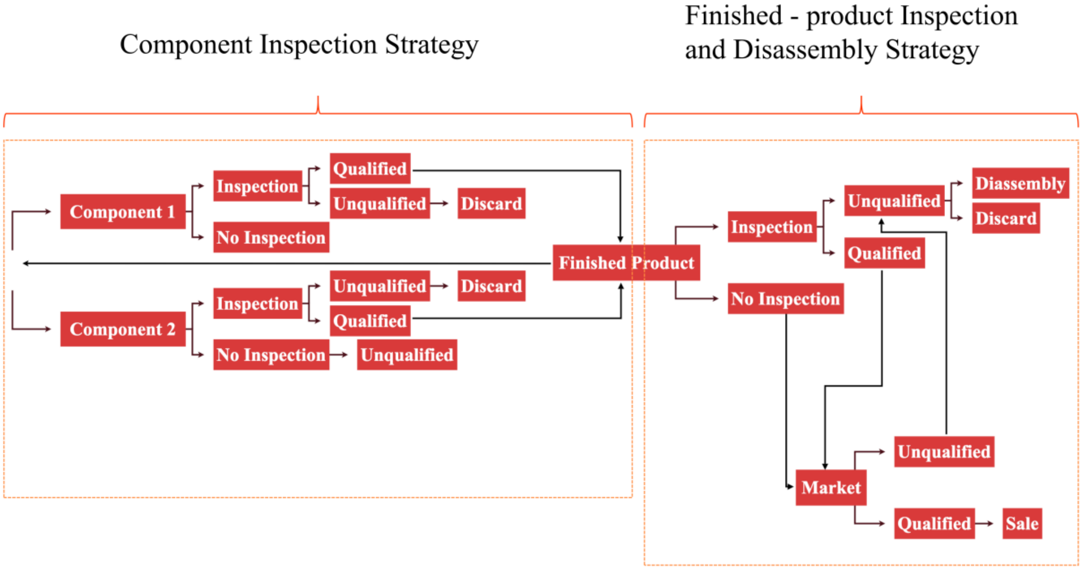

Figure 1. Flowchart of the total strategy

2.2. Decision variables and assembly parameters

In this study, unit "1" is used as the overall number of products or spare parts for discussion. According to the decision-making needs of the enterprise, four 0-1 decision variables are first introduced: f_1, f_2, f_3, f_j to indicate the decision-making of the enterprise at each stage, where $f_i (i = 1,2,3)$ indicates whether or not to test the spare parts 1, spare parts 2, and the finished product in that case, respectively, and their fulfillment:

$$f_i = \begin{cases} 1, & \textit{carry out the detection} \\ 0, & \textit{do not carry out the detection} \end{cases}, \quad \text{where } \ i = 1,2,3 \tag{1}$$

f_j denotes the fulfillment of whether or not disassembly is performed on the substandard product for that case:

$$f_j = \begin{cases} 1, & \text{disassemble the non-conforming finished products} \\ 0, & \text{do not disassemble} \end{cases} \tag{2}$$

In this study, the passing rate is calculated by replacing the defective rate with the passing rate, and based on the given defective rate, the passing rate of spare part 1, spare part 2, and the finished product can be calculated separately α_i :

$$\alpha_i = 1 - p_{inferior,i}, i = 1, 2, 3 \tag{3}$$

Where, $p_{inferior,i}, i = 1, 2, 3$ represents the defective rate of spare parts 1, 2, and finished products respectively.

Introducing the assembling number $q_i, i = 1, 2$ which represents the number of spare parts 1 and 2 available for assembly, only when tested, the spare parts available for assembly are qualified; otherwise all of them go to the market, i.e., their value is 1, which satisfies the following equation:

$$q_i = \begin{cases} \alpha_i, & f_i = 1 \\ 1, & f_i = 0 \end{cases}, \quad i = 1,2 \tag{4}$$

In this study, it is assumed that the ratio of the number of parts in the initial state before testing is 1:1 and that parts 1 and 2 are synthesized in the ratio of 1:1 so that the final number of assembled finished products can only be the minimum of the number of parts 1 and 2 available for assembly. Introduce the assembly number *Z*, meaning the minimum value of the number of parts 1 and 2 that can be assembled. It is satisfied:

$$Z = min\{q_1, q_2\} \tag{5}$$

Therefore, the number of assemblies can be for whether the detection of sub-case consideration: only when the spare parts are detected, at this time the two spare parts are exactly assembled, assembly of finished products before the spare parts qualification rate of 100%, the number of assemblies is *Z*, assembly after the number of qualified for the number of assembled and finished product qualification rate product; Otherwise, the number of qualified for the assembly is the product of the qualification rate. The disassembly schematic is shown in Fig. 2. The number of qualified parts *K* is:

$$K = \begin{cases} Z\alpha_3, & f_1 + f_2 = 2 \\ \alpha_1\alpha_2\alpha_3, & f_1 + f_2 < 2 \end{cases} \tag{6}$$

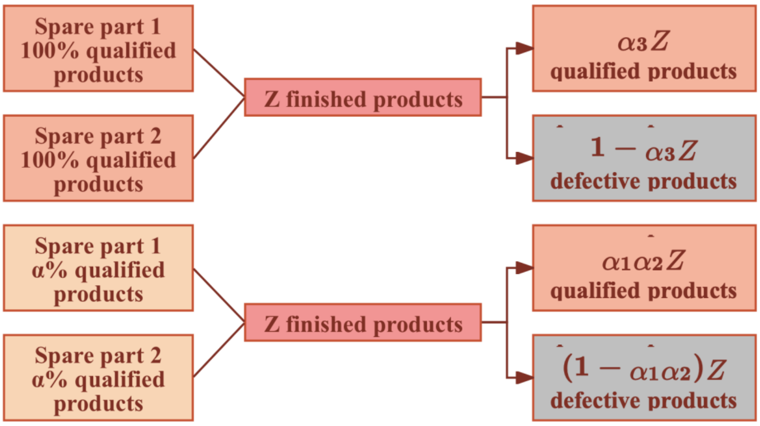

Figure 2. Disassembly Schematic

When the finished product is tested, at this time for the unqualified finished product will be disassembled or discarded, so the number of finished products is the same as the number of qualified, without testing, the number of finished products for the number of qualified, to get the number of finished products Q for:

$$Q = \begin{cases} K, f_j = 1 \\ Z, f_j = 0 \end{cases} \tag{7}$$

2.3. Constructing the total profit objective function

According to the total decision strategy, this study can analyze and obtain the enterprise's revenue and expenses mainly including the fixed costs of finished products C_f, assembly costs C_z', testing costs C_j, exchange losses C_d, dismantling costs C_{ss}, selling price W, and the following construction of the total profit L objective function:

$$\max L = W - C_{ss} - C_d - C_f - C_j \tag{8}$$

The total cost is analyzed to obtain the fixed cost as shown below C_f, assembly cost C_z', inspection cost C_j, swapping loss C_d, and disassembly cost C_{ss} shown schematically in Fig. 3:

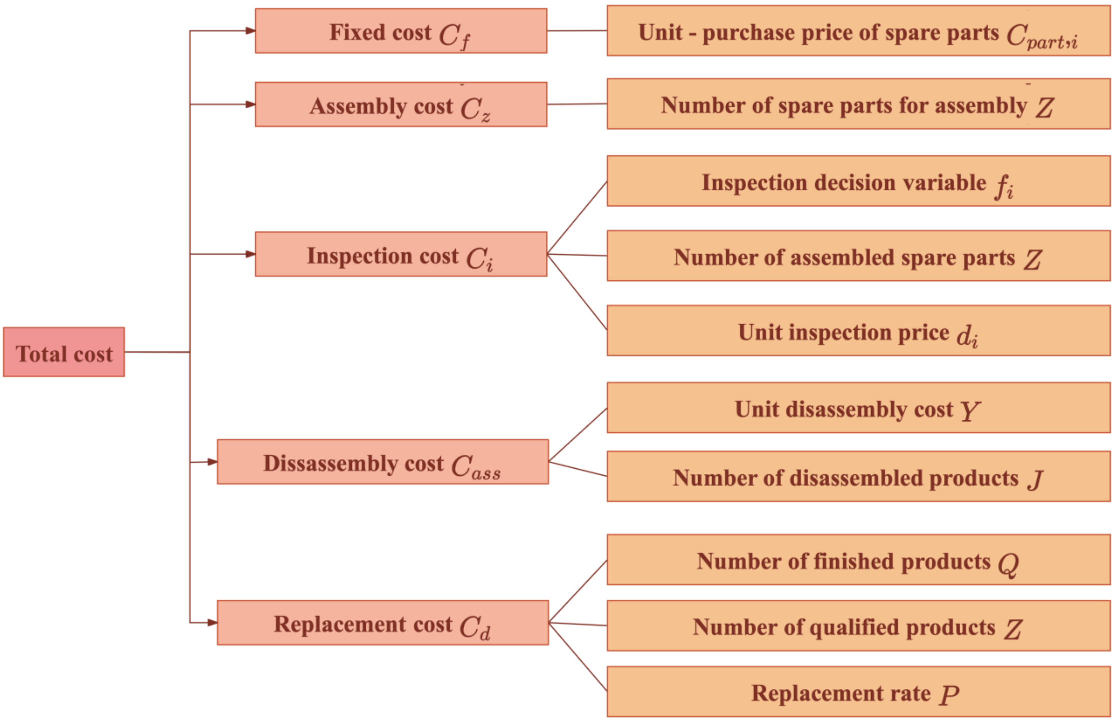

Figure 3. Total Cost Relationship Flowchart

The fixed cost of the finished product is the purchase unit price of the spare parts. Here the fixed cost required to produce a single piece of the finished product comes from the purchase unit price of spare part 1 and spare part 2, and the fixed cost per unit of the finished product C_f always:

$$C_f = \sum_{i=1}^{2} C_{part,i} \tag{9}$$

Where $C_{part,i}, i = 1,2$ denotes the purchase unit price of part i in this case.

In all six cases, the purchase unit price of each of Spare Part 1 and Spare Part 2 is the same, i.e., the fixed cost per unit of spare parts C_f is always the sum of the purchase unit price of Spare Part 1, 4, and the purchase unit price of Spare Part 18, i.e., 22.

Assembly cost is a variable cost, assembly cost is affected by the number of spare parts, depending on how many spare parts are available to be assembled into a finished product, since this study assumes that the spare parts are 1:1 before testing, and spare parts 1 and 2 are also synthesized in the same ratio of 1:1, the final number of assembled finished products can only be the smallest value of the spare parts 1 and 2 available for assembly, this study can analyze to get the total assembly of finished product The total assembly cost of the finished product can be analyzed in this study C_z'.

$$C_z' = C_z Z \tag{10}$$

Where C_z denotes the assembly cost of a single finished product in this case and Z denotes the number of finished products assembled.

For the testing cost, to solve the effect of whether the spare parts are tested or not on the number of finished products to be assembled, it can be reflected by using the decision variable defined earlier, and the number of finished products is affected by the number of spare parts that can be assembled, Z. Therefore, the testing cost function is established to obtain the testing cost C_j:

$$C_j = \sum_{i=1}^{2} d_i f_i + Z f_3 d_3 \tag{11}$$

Where $d_i, i = 1, 2, 3$ denotes the inspection costs for parts 1, 2, and finished products, respectively, and f_i denotes the 0-1 decision variables defined for (5).

If the product is in the production process, 2 kinds of spare parts and finished products are in the testing process, as long as one of the links is not tested, this may lead to unqualified products entering the market, being purchased by the user to bring the loss of exchange, the introduction of the concept of the number of exchanges, the number of exchanges, D, that is, the number of substandard into the hands of the buyer is equal to the buyer to enter the hands of the entire number of finished products minus the number of qualified finished products, and therefore the number of exchanges to meet:

$$D = Q - K \tag{12}$$

Where Q denotes the number of finished products and K denotes the number of qualified products. From the transfer rate you can get the transfer loss C_d:

$$C_d = D \cdot \beta \tag{13}$$

Where β denotes the exchange loss of a single piece of finished product in this case and D denotes the exchange rate.

In the production process, there are only two cases, that may need to dismantle the finished product: when the enterprise assembly after the finished product is not tested on the finished product found to be substandard products may need to be dismantled; not tested on the finished product directly onto the market, the substandard products are purchased by the user, the enterprise is an unconditional replacement and dismantling of the substandard products, dismantling the product is shown in the following diagram:

For the above two cases, it can be known that no matter whether the enterprise inspects the finished product after assembling the finished product or not, it does not affect the total number of nonconforming products that need to be disassembled, and this study can get the number of disassembled products J, and the difference between the number of assembled products and the number of qualified products indicates the number of disassembled products:

$$J = Z - \alpha_1\alpha_2\alpha_3 \tag{14}$$

Thus for both cases, the product of the number of disassemblies and the disassembly cost of the finished product γ yields the disassembly cost C_{ss} :

$$C_{ss} = J\gamma \tag{15}$$

Enterprises mainly through the sale of finished products to gain revenue. Due to the non-conforming products on the market by the user to buy, the enterprise must be an unconditional replacement, brought about by the loss of replacement. The profit of the enterprise consists of two main parts: the profit of the qualified products assembled for the first time L_{z_1} and the qualified products assembled successfully after disassembly.

First, the firm's most significant revenue is the profit on the qualified product of the first assembly L_{z_1} , which is satisfied:

$$L_{z_1} = K\delta \tag{16}$$

Where K denotes the number of qualified products and δ denotes the market selling price of the finished product per unit price in this case.

Then, another part of the revenue is the profit from the re-disassembly of non-conforming finished products and assembling them into conforming products for sale, and it is found that the defective rate of the re-disassembled parts has changed. Therefore, the disassembly correction rate ρ is introduced.

As the untested unqualified spare parts in the assembly were found to be unqualified, disassembly is still unqualified, so the untested unqualified parts must exist in the disassembled spare parts when disassembled and reassembled when the substandard rate is no longer the initial substandard rate, that is, the existence of the conditional probability of the introduction of disassembling the correction coefficient ρ if it is the tested spare parts, then it will certainly be qualified spare parts, the qualification rate of 100 percent. Introduce the decision parameter $f_i, i = 1, 2$ and the former to take the big operation. Therefore, the disassembly correction coefficients ρ_1 and ρ_2 of the finished disassembled parts 1 and 2 are satisfied:

$$\rho_i = max\left\{1 - \frac{1-\alpha_i}{J},\ f_i\right\}, i = 1, 2 \tag{17}$$

Where, α_1 and α_2 denote the pass rate of part 1 and part 2 for the case, respectively, and $f_i, i = 1, 2$ denotes the 0-1 variable of whether parts 1 and 2 are disassembled or not as defined in (8).

After the first sale of qualified products, this time the number of disassembled unqualified for the number of assembled Z and the difference between the number of qualified products K, through the disassembly correction coefficients ρ_1 and ρ_2 , you can get the number of qualified parts and accessories after disassembly, and then multiplied by the finished product of the qualification rate α_3 and unit price of finished products of the market selling price of δ , you can get the profit of the dismantling L_s :

$$L_s = (Z - K)\rho_1\rho_2\alpha_3\delta \tag{18}$$

Therefore, the sum of the profit from the first sale of the conforming product and the profit from the second disassembly of the nonconforming product and reassembly of the conforming product is the gain from the sale of the conforming product W through equations (16) and (18):

$$W = K\delta + L_s \tag{19}$$

3. Model Solution and Results Analysis

3.1. Violent Search Algorithm

In the solution process, because there are a total of 16 strategy combinations for spare parts 1, 2, whether the finished product is tested or not, and whether the finished product is disassembled or not, considering that the number of combinations is relatively small, it can be directly solved for the maximum value of the production profit under the 16 strategy combinations of each of the 6 cases using the production profit maximization model, so this study uses the Violent Search Algorithm for the optimization of decision-making variables, which can solve the corresponding 16 strategy combinations in each case and compare them to obtain the optimal decision results and the maximum production profit obtained by the enterprise in each case [7].

3.2. Solution results and analysis

The violent search algorithm can be solved for the firm's revenue resulting from the different decisions in the six scenarios. [8] Each decision combination is represented in binary, from left to right, as parts 1, and 2, whether the finished product is tested or not, and whether the finished product is disassembled or not, respectively, with "1" indicating yes and "0" indicating no [9]. The strategy combinations cover the various scenarios of parts 1, and 2, whether the finished product is tested or not, and whether the finished product is disassembled or not.

Analyzing the results of the solution, in case 1, the worst decision is 1010, the profit is 8.724, the optimal decision is 1101, the profit is 15.966; in case 2, the worst decision is 0110, the profit is -3.528, the optimal decision is 1111, the profit is 8.488; in case 3, the worst decision is 0000, the profit is 8.724, the optimal decision is 1101 with 1111 with a profit of 13.806; in case 4 the worst decision is 0000 with a profit of -13.968 and the optimal decision is 1111 with a profit of 10.848; in case 5 the worst decision is 1010 with a profit of 3.624 and the optimal decision is 0011 with a profit of 13.281; in case 6 the worst decision is 0000 with a profit of 18.587 and the optimal decision is 1111 with a profit of 5.332.

The optimal decisions for different spare parts and finished goods situations will be different and will largely determine the range of profitability of the business [10]. For example, case 2 shows that only the last 4 of the 16 decisions are profitable, while the others are loss-making, while in case 1, all 16 decisions are profitable and there are no loss-making decisions. This finding is reinforced by the fact that fixing a decision and observing it reveals that the profitability of the firm varies greatly from one situation to another under the same decision.

For the same spare parts of the finished product situation, different decisions lead to a great difference in corporate profits, analysis shows that the difference between the worst decision and the optimal decision fluctuates [8, 12], which shows that different decisions may lead to different disassembly costs, assembly costs, testing costs, etc. lead to the same spare parts and finished product situation of the profits of the different. The line graph of profit for each decision is shown in Fig. 4.

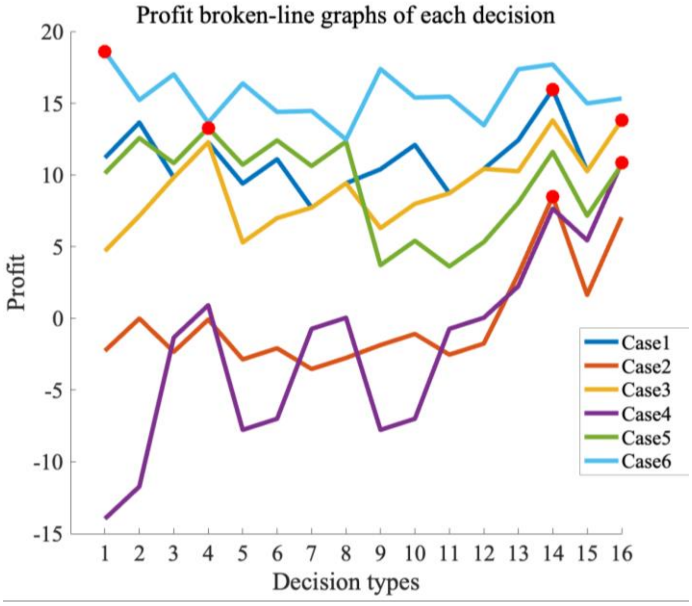

Figure 4. Profit by Decision Line Chart

In terms of the overall trend, the folded line in Figure 4 shows an up-and-down oscillating trend, indicating the complexity of the impact of different decision combinations on profitability. Certain decision categories show higher profits in some cases and poor performance in other cases, which may be related to specific parameters (e.g., defective rate, selling price, etc.) in that case [11].

Analyzing Figure 4 in terms of optimal strategy identification, in most cases, decision types 5, 6, 11, 13, 14, and 16 perform better in terms of profits in specific situations, which indicates that these decisions are effective in increasing profits under specific combinations of parameters; certain decisions maintain higher profits in all situations, which indicates that these decisions have better applicability and robustness, for example, decision types 5 and 6 perform well in a variety of situations, for example, decision categories 5 and 6 perform well in a wide range of situations.

3.3. Analysis of optimal decisions

This study reflects the degree of responsibility between the optimal decision and corporate profits and profit parameters for six cases, which is obtained as shown in the table below (of which, for the optimal decision in case 3 there are 14 and 16, and this study chooses decision 14 for analysis):

Table 1. Optimal decision-making in the 6 cases

State of affairs	Total profit	Sell margins	Disassembly cost	Assembly cost	Inspection cost	Fixed cost	Exchange damages	Optimal decision
Scenario 1	15.966	49.896	0.99	5.4	5	22	0.54	14
Scenario 2	8.488	43.008	1.76	4.8	5	22	0.96	14
Scenario 3	13.806	49.896	0.99	5.4	7.7	22	0	16
Scenario 4	10.848	43.008	1.76	4.8	3.6	22	0	16
Scenario 5	13.28118	46.26218	2.981	6	2	22	0	4
Scenario 6	18.58675	48.013	0	6	0	22	1.42625	1

From Table 1, this study can conclude that: for case 1: the optimal decision is 14, i.e., "1101", corresponding to spare parts 1 and 2 being tested, the finished product is not tested, and the defective product is split; the enterprise obtains the maximum profit of 15.966. For case 2: the optimal decision is 14, i.e. "1101", corresponding to parts 1 and 2 are tested, the finished product is not tested, and the defective product is split; the enterprise obtains the maximum profit of 8.488. For case 3: the optimal decision is 16, i.e. "1111", corresponding to parts 1, and 2, and the finished product is tested and the finished product is split; the enterprise obtains the maximum profit of 13.806. For case 4: the optimal decision is 16, i.e., "1111", corresponding to parts 1, 2, and the finished product are tested, and the finished product is split; the enterprise obtains the maximum profit of 10.848. For case 5: the optimal decision is 4, i.e., "0011", corresponding to parts 1, 2, and the finished product are tested, and the finished product is split; the enterprise obtains the maximum profit of 13.806. For case 6: the optimal decision is 1, i.e., "0000", which corresponds to no testing of parts 1 and 2, no testing of finished products, and no splitting of defective products; the maximum profit is 18.58675.

4. Conclusion

Differences in profits may be related to factors such as the defective rate of spare parts, the market selling price of finished goods, exchange losses, and dismantling costs. When the fixed costs of the finished product are too high, even a low defective rate may result in a large loss of profit. Therefore, effective inspection and dismantling strategies are particularly important in high-selling price markets.

The fact that some of the strategies perform well in specific situations suggests that they may have been optimized for specific combinations of parameters. For example, decision categories 1 1, and 13 perform better in certain situations with high defective rates or high selling prices, which may be related to their effective cost control and risk management strategies in these situations.

This study has limitations in the diversity of disassembly methods and spare parts ratios (only 1:1 is considered), which restricts the practical applicability of the model. In the future, it is necessary to optimize the complex disassembly operation by combining intelligent algorithms, expand the experiments of multiple ratios of spare parts, integrate stochastic planning and other tools to synthesize the production factors and validate the practical applicability of the model through enterprise cooperation. This paper provides a research idea and framework applied to operations research-related fields, through the construction of the production decision profit maximization model, combined with a violent search algorithm solution, effectively proving the feasibility of the method in solving the enterprise production decision problem.

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