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Research on Multi-process Production Decision Optimization Based on Genetic Algorithm

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Abstract: This paper studies the decision optimization problem in the multi-process production process of an enterprise in the production of best-selling electronic products. Aiming at the assembly process of two kinds of key parts, this paper uses genetic algorithm, exhaustion method and other theories and methods to optimize it with the product multi-process production process. By establishing the decision model, the problems of calculating the number of sampling inspection under the condition of nominal value, making the optimal decision in the production process of the enterprise, the global optimal detection and processing decision under the condition of multi-process production, as well as recalculating the defective rate and solving it again through sampling inspection are solved respectively. The results show that the proposed model and method can significantly reduce the production cost and increase the profits of enterprises.

Keywords: Genetic algorithm, exhaustion method, Multi-objective optimization.

1. Introduction

With the rapid development of the electronic product industry, complex supply chain and production process have become one of the key factors for enterprises to compete. In the production process, the quality of raw materials, spare parts, semi-finished products and finished products will have an impact on the product entering the market. A company is committed to the production of a best-selling electronic products, need to carefully select two vital parts for assembly. However, if one of these parts fails, the finished product fails; Even if both parts pass, the finished product after assembly may still fail. Therefore, how to ensure product quality and reasonable cost control has become an important issue faced by enterprises.

This paper aims to provide a feasible solution for the enterprise by deeply studying the decision optimization problem in the multi-process production process [1]. By using genetic algorithm [2], exhaustion method [3], and other theories and methods [4], this paper will design the optimal sampling detection scheme, and jointly optimize it with the multi-process production process of the product, so as to establish the decision model in the joint production process of the two [5]. Through this model, enterprises can realize the minimization of production cost under the premise of ensuring product quality, so as to enhance the competitiveness and profitability of enterprises.

2. Multi-decision Link Analysis and Cost-benefit Model

For the enterprise in the production process of a number of production process decision, including parts testing, assembly of finished products testing, unqualified finished products disassembly and replacement problems. In order to ensure that the enterprise can obtain the maximum profit, it is necessary to analyze the process at each stage, choose the decision plan with the least cost, but also consider the balance of inspection costs, whether to disassemble, and the calculation of rework and direct discard costs.

First of all, the enterprise needs to consider the detection of spare parts 1 and spare parts 2, if the spare parts 1 and spare parts 2 are tested, it will greatly reduce the probability of unqualified finished products, but the detection cost will rise sharply, so it is necessary to consider the impact of the defective rate of spare parts on the defective rate of finished products in each case. If parts 1 and 2 are not tested, the defective rate of finished products will increase. Although this method saves the testing cost, it will lead to an increase in the cost of testing and disassembly of finished products in the process.

Secondly, the enterprise also has to consider the situation of finished product testing. In the assembly link, even if the two parts are qualified, the finished product may not be qualified after assembly, which requires us to determine whether to test the finished product. The testing process of the finished product is the key to ensure the quality of the finished product entering the market. If the finished products are tested, it will ensure that the qualified rate of the finished products is reached, otherwise it can not determine the qualified rate of the finished products, which must consider the balance relationship between the testing cost of the finished products and the qualified rate of the finished products and the subsequent disassembly and replacement cost of the finished products, to ensure the maximum profit of the enterprise.100%

Finally, for the flow of unqualified finished products, enterprises can choose to discard or disassemble directly. For unqualified finished products purchased by users, enterprises should also consider whether to discard or disassemble after replacement. The disassembled parts can still be used to avoid waste, but also consider that the finished products are not fully qualified after assembly of disassembled parts. There will be a part of unqualified products, at the same time, disassembly also needs to generate costs, enterprises need to design the best plan to avoid a substantial increase in costs, in order to obtain the maximum profit.

2.1. Establishment of Cost-benefit Model

This chapter needs to solve the problems in each stage of the production process under various circumstances, and make decisions, and give specific decision plans and corresponding indicators.

(a) The parameter setting of defective production rate and cost.

Table 1. Parameters of each variable in the production stage

	Parts 1	Parts 2	Finished Products	Unqualified finished products
Unit price of purchase	C_{p_1}	c_{p_2}		
Rate of defective goods	p_1	p_2	p_f	
Testing costs	c_{d_1}	c_{d_2}	$C_{\text{Fin\_inspection}}$	
Assembly costs			C_{assembly}	
Replacement costs			c_r	
Dismantling charges			c_t	

Since there are different situations between the purchase of spare parts and the production of finished products, and the defective rate of spare parts, purchase price and testing cost are not exactly the same in each case, and each stage will produce two decision schemes with different results, in order to facilitate the establishment of the model, we set the parameters of each variable in the production stage uniformly, as shown in Table 1.

(b) Set the decision variables.

For the two kinds of choice decision problem in each production process, variable parameter setting and computer binary language are used to specify whether to detect, whether to disassemble, whether to exchange, so as to facilitate the establishment of subsequent models and give the optimal decision scheme.

X_1: Whether to detect spare parts 1 (yes 1, no 0); X_2 : Whether to detect parts 2 (yes 1, no 0); X_f: Whether to test finished products (yes 1, no 0); X_t : whether to disassemble unqualified finished products (yes 1, no 0).

(c) Cost-benefit model formula

According to the planning of the production decision flow chart above and the setting of decision variables, each decision point will cause different costs, these costs have direct costs and indirect costs, such as the purchase cost of spare parts, the assembly cost of finished products is the direct cost, the detection cost, the dismantling cost, etc., is the indirect cost. Therefore, we establish a cost-benefit model, by weighing the costs and benefits of each link, to achieve the total cost of minimization.

- Parts testing cost calculation formula

$$c_0 = x_1 * C_{d_1} * n_1 + x_2 * c_{d_2} * n_2 \tag{1}$$

Where c_0 is the inspection cost of spare parts, x_1 is whether the inspection cost c_{d_1} of spare parts is part 1, n_1 is the number of spare parts 1, x_2 is whether the inspection cost of spare parts and c_{d_2} spare parts 2, n_2 is the number of spare parts 2.

Obviously, the cost of spare parts testing is related to the cost of testing and the number of spare parts, the loss of spare parts testing is obvious, if the spare parts are not tested, the unqualified rate of spare parts can not be excluded, these defective products will lead to subsequent losses, then we should strictly control the detection of spare parts.

- The total cost of assembly calculation formula.

$$c_1 = c_a * n_f \tag{2}$$

Where, c_1 is the cost of assembling finished products, c_a is the cost of assembling finished products, and n_f is the number of finished products assembled. Since the assembly of the finished product is a probability problem, even if the two parts are fully qualified, it is impossible to avoid the qualification of the finished product. At the same time, the single assembly cost and the number of assembly should be taken into account.

- The formula for calculating the cost of finished product inspection

$$c_{\text{Fin\_inspection}} = x_f * c_d * n_f \tag{3}$$

Where, $C_{\text{Fin\_inspection}}$ is the cost of finished product inspection, x_f is whether the finished product is tested, n_f is the number of finished products assembled.

The testing of finished products is also an important point. Through the calculation formula, we can clearly see that the cost of finished products testing is related to the testing of finished products and spare parts, and the testing of finished products will also affect the entry of finished products into the market.

- Change the cost calculation formula.

$$c_{\text{change}} = \left(1 - x_t\right) * c_r * p_f * n_f \tag{4}$$

Where, c_{change} is the replacement cost of unqualified finished products, x_t is whether to disassemble unqualified finished products, p_f is the defective rate of finished products.

With the help of the finished product replacement formula, we understand that the cost of replacement is directly related to whether to choose replacement, the defective rate of finished products and the replacement loss, which has the greatest impact on the defective rate of finished products, but also take into account the detection of spare parts and finished products to ensure the lowest replacement cost of finished products.

- Disassembly cost calculation formula

$$c_{\text{split}} = x_t * c_t * p_f * n_f \tag{5}$$

Where, c_{split} is the cost of dismantling finished products, c_t is the cost of dismantling unqualified finished products.

Obviously, the disassembly cost of unqualified finished products is not completely affected by factors such as disassembly and disassembly cost, but also by the testing of spare parts and finished products. After disassembly, the spare parts can also be recycled for assembly and sale again, but extra costs will be incurred in the process. It is necessary to consider the relationship between the disassembly cost after disassembly and the cost incurred before the sale of the finished product and the selling price of the finished product.

- Total cost calculation formula.

$$C_{\text{all}} = C_0 + C_1 + C_{\text{Fin\_inspection}} + C_{\text{split}} + C_{\text{change?}} \quad (6)$$

From the above formula, we can clearly see that the total cost is closely related to the cost of inspection of spare parts, inspection of finished products, replacement of finished products and dismantling of finished products. With the help of the above formula, the total cost of the production process is calculated by calculating the inspection cost of spare parts, the assembly and inspection cost of the finished product, and the disassembly and replacement cost of the unqualified finished product.

- The probability of entering the assembly process.

$$p_{\text{mod}} = (1-x_1)*p_1 + (1-x_2)*p_2 - (1-x_1)*(1-x_2)*p_1*p_2 \quad (7)$$

- The rate of defective finished products.

$$p_f = 1-(1-p_{\text{mod}})^2 \quad (8)$$

The above two formulas can calculate the probability of parts entering the assembly stage and the defective rate of finished products, which is obviously related to the defective rate of parts 1 and parts 2, and whether to detect parts 1 and parts 2 will also affect the probability of parts entering assembly and the defective rate of finished products.

2.2. Establishment and Solution of Genetic Algorithm Model

Genetic Algorithm (GA) is a computational model simulating the biological evolution process of natural selection and genetic mechanism of Darwinian biological evolution [6], and it is a method to search for the optimal solution by simulating the natural evolution process. For the probability of an individual being selected for reproduction is proportional to its fitness, if we assume that Pi is the probability of the i th individual being selected, then:

$$p_i = \frac{f(x_i)}{\sum_{j=1}^{N} f(x_j)} \quad (9)$$

Where $f(x_i)$ is the fitness of the first individual and N the number of individuals in the population. By repeating this step, the genetic algorithm can gradually improve the quality of the solution after multi-generation iteration and approach the optimal solution.

By setting the parameters of the production defective rate and cost, assuming the decision variables and establishing the cost-benefit formula, the factors affecting the production cost can be fully understood. In order to obtain the optimal solution with the lowest enterprise cost in the production process, a genetic algorithm model was established [7]. Firstly, the bar chart of defective rate and inspection cost of spare parts and finished products is shown in Figure 1 and Figure 2.

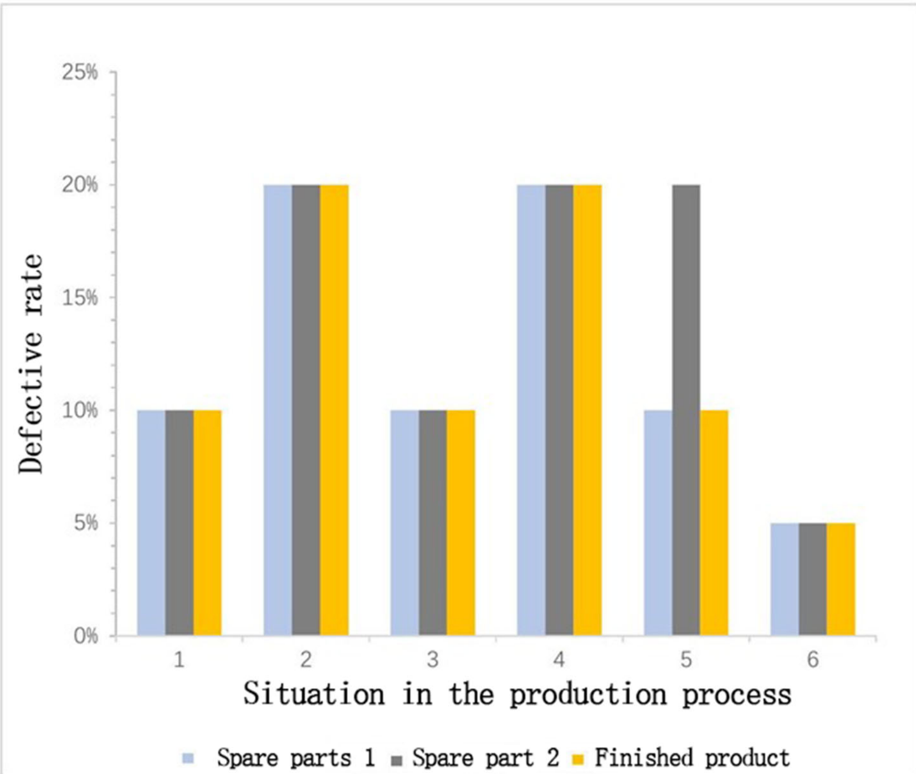

Figure 1. Bar chart of defective rate of spare parts and finished products

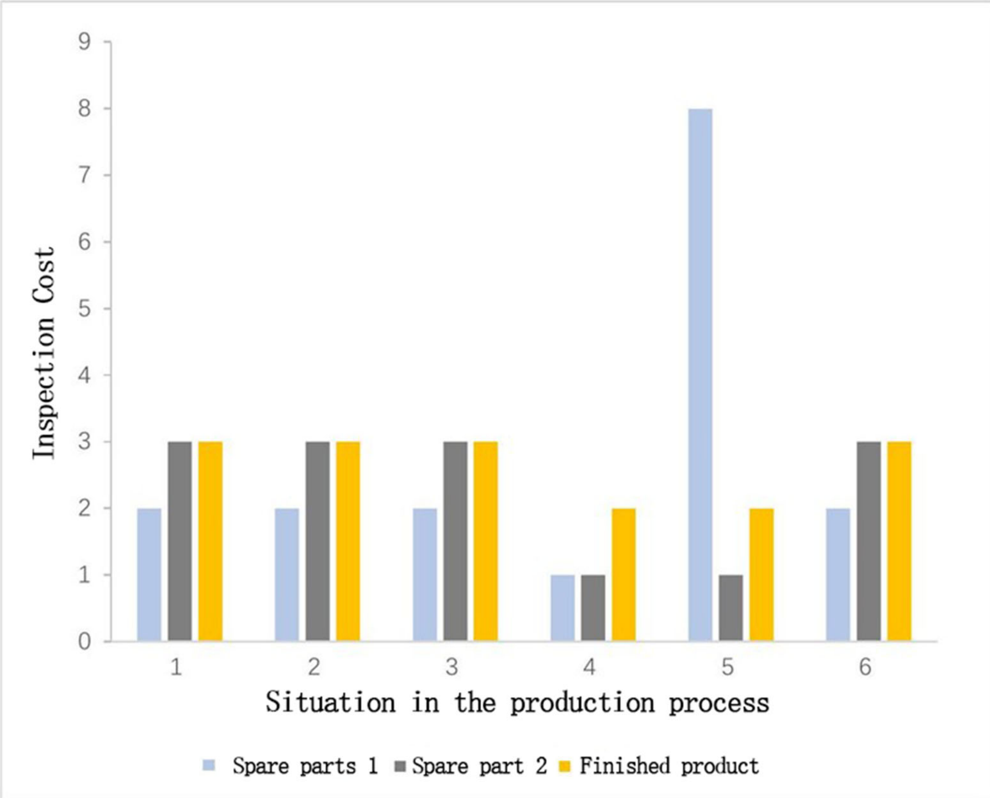

Figure 2. Bar chart of inspection cost of spare parts and finished products

Next, the corresponding strategy is given for each production situation and the corresponding total cost is calculated. With the help of this method, the final state of each strategy in different production situations can be compared in detail to help obtain a more optimized feasible production plan.

After the number of spare parts 1 and 2 is specified for all the selected strategies, the MATLAB program is used for iterative calculation, and the optimal solution of enterprise decision-making in the production process is finally obtained, as shown in Table 2.

Table 2. Optimal solution results for each case

Situation	Minimum cost	Decisions
1	617.56	$[0 \quad 0 \quad 0 \quad 1]$
2	716.16	$[0 \quad 0 \quad 0 \quad 1]$
3	617.56	$[0 \quad 0 \quad 0 \quad 1]$
4	680.00	$[1 \quad 1 \quad 0 \quad 0]$
5	656.00	$[0 \quad 1 \quad 0 \quad 1]$
6	628.40	$[0 \quad 0 \quad 0 \quad 0]$

After solving the optimal solutions for different production situations respectively, as shown in Table 2, we can see the parts detection, finished product detection and disassembly of unqualified finished products in each optimal solution situation.

3. The Optimization Method of Multi-process Production Decision Problem

Based on the above solution, the number of processes and the number of spare parts in the production process are increased, which is a simple special case (1 process, 2 spare parts). For the production of multiple parts in multiple processes, it is more necessary to pay attention to many influencing factors such as defective rate, detection cost and dismantling cost.

From the perspective of the production process, it is required to deal with multiple processes, multiple parts, each part will have a certain defective rate, too high defective rate will affect the number of finished products and the defective rate of finished products, but also affect the market quality of finished products, due to the increase in the production process, The defective rate of spare parts will not only affect the quality of finished products, but also affect the quality of semi-finished products, but also consider whether to disassemble semi-finished products and the defective rate of semi-finished products.

In addition, the complexity of the decision is also related to whether to repeat the detection and assembly, multi-process manufacturing and processing problems will involve multiple related processes, such as whether the detection of spare parts first affects the quality of the first type of semi-finished products, and whether the detection of the first type of semi-finished products will disturb the quality of the latter. Make the most reasonable decision in multiple links to minimize the disturbance factors.

3.1. The Establishment of Simulation Model

In view of the multi-process and multi-parts problem, which involves the optimal detection and decision problem of many parts, in order to ensure a more perfect decision in the complex situation of multi-stage and multi-process, the model and algorithm need to be deeply processed and optimized. The model should not only take into account the complexity of multiple parts detection, but also consider the detection and disassembly of semi-finished products in multiple processes. In view of the above problems, we decide to use the form of exhaustive method to calculate the multi-stage production decision problem.

Since it involves multiple processes and parts, and the defective rate, purchase price and detection cost of parts in each process are not exactly the same, and each stage will produce the detection and disassembly of semi-finished products, in order to facilitate the establishment of the model, we set the parameters of each variable in the production stage. The defective rate of spare parts i is p_i, the purchase price is c_{p_i}, and the testing cost is c_{d_i}; The defective rate of each process j is p_{f_j}, the assembly cost is c_{a_j} and the inspection cost of the finished product is c_{d_j}; The dismantling cost of unqualified finished products (semi-finished products) is c_t, and the replacement cost is c_r.

(a) Set the decision variable.

For various selection decision-making problems in each production process, variable parameter setting and computer binary language are used to specify whether to detect, disassemble and exchange the problems, so as to facilitate the establishment of subsequent models and give the optimal decision scheme.

x_i: Whether to detect spare parts i (yes 1, no 0).

y_j: Whether to test the finished product of process j (yes 1, no 0).

z_j : Whether to disassemble the unqualified finished products detected in process j (yes 1, no 0).

(b) Cost-benefit model formula.

Mainly for the multi-process multi-objective production situation, through the production process decision to judge the cost change problem, and give the optimal solution, according to the above production process parameters and decision variables set, each decision point will cause different costs, these costs have direct costs and indirect costs, such as the purchase cost of spare parts, The assembly cost of the finished product is the direct cost, the detection cost, the disassembly cost, etc., is the indirect cost. Therefore, we establish a cost-benefit model to minimize the total cost by weighing the cost and benefit of each link.

- Spare parts testing cost calculation formula.

$$c_0 = \sum_{i=1}^{n} x_i * c_{d_i} * n_i \tag{10}$$

Where, c_0 is the inspection cost of spare parts, x_i is whether to detect spare parts, c_{d_i} is the cost of finished product inspection of each process j, n_i is the quantity of purchased spare parts i, n indicating the quantity of all spare parts.

- Process assembly cost calculation formula.

$$C_{\text{assembly}} = \sum_{j=1}^{m} c_{a_j} * n_{f_j} \tag{11}$$

Where, C_{assembly} is the process assembly cost, c_{a_j} is the assembly cost of each process j, n_{f_j} is the finished product produced by process j, and m represents the number of all processes.

- The formula for calculating the cost of finished product inspection.

$$C_{\text{Fin\_inspection}} = \sum_{j=1}^{m} y_j * c_{d_j} * n_{f_i} \tag{12}$$

Where, $C_{\text{Fin\_inspection}}$ is the cost of finished product inspection, c_{d_j} is the cost of finished product inspection for each process j.

- Replace the cost calculation formula.

$$c_{\text{change}} = \sum_{\text{j}=1}^{m} \left(1 - z_j\right) * c_r * p_{f_j} * n_{f_j} \tag{13}$$

Where, c_{change} is the replacement cost of unqualified finished products (semi-finished products), z_j is whether to disassemble unqualified finished products detected in process j, c_r is the replacement cost of a single qualified finished product (semi-finished products), p_{f_j} is the rate of defective products per process.

- Disassembly cost calculation formula.

$$c_{\text{split}} = \sum_{\text{j}=1}^{m} z_j * c_{\text{t}} * p_{f_j} * n_{f_j} \tag{14}$$

Where, c_{split} is the dismantling cost of unqualified finished product (semi-finished product), and c_t is the dismantling cost of a single qualified finished product (semi-finished product).

- Formula for calculating the total cost.

$$C_{\text{all}} = C_0 + C_{\text{assembly}} + C_{\text{Fin\_inspection}} + C_{\text{split}} + C_{\text{change}} \tag{15}$$

From the above formula, we can clearly see that the total cost is closely related to the cost of inspection of spare parts, inspection of finished products, replacement of finished products and dismantling of finished products. The cost of each stage is determined by the above formula

Calculate the inspection cost of spare parts, the assembly and inspection cost of finished products and the disassembly and replacement cost of unqualified finished products, and calculate the total cost of the production process.

- The defective rate of parts and accessories entering the process.

$$p_{\text{mod}} = \left(1 - x_i\right) * p_i \tag{16}$$

The defective rate of process j.

$$p_{f_j} = 1 - \pi\left(1 - p_{\text{mod}}\right) \tag{17}$$

Where, π is the number of preceding processes.

3.2. Model Solving

It is necessary to solve the optimal decision scheme in the multi-stage production process. For the solution of the multi-stage process, the exhaustion method is used to list all the cases that can occur, and finally the optimal production decision under the condition of multi-process and multi-objective is obtained [8]. Through MATLAB program, the optimal decision scheme of multi-process and multi-parts is finally obtained as follows: Spare parts 1, spare parts 2, spare parts 3, spare parts 4, spare parts 5, spare parts 6, spare parts 7, spare parts 8, semi-finished products 1, semi-finished products 2 and semi-finished products 3 are not detected, all semi-finished products and finished products are disassembled, the final cost of consumption is 30462.50 yuan.

4. Conclusion

In this paper, genetic algorithm, exhaustion method and other theories and methods are used to deeply study the decision optimization in multi-process production. Aiming at the best-selling electronic products produced by an enterprise, the optimal sampling detection scheme is designed, and it is optimized with the multi-process production process. The results show that the proposed model and method can significantly reduce the production cost and increase the profits of the enterprise. At the same time, the applicability and effectiveness of the model are verified by simulation experiments in different situations. In the future, we can further study how to apply these theories and methods to other fields in order to promote the intelligent and efficient industrial production.

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