Mathematical Modeling and Algorithm Application
ISSN: 3006-0842 | Vol. 5, No. 1, 2025

Research on Optimal Decision Model in the Production Process of Elec-Tronic Products

Chang Liu[1, +], Rongjie Cai[1, +, *], Zhengxi Xiao[1], Guanliang Chen[1], Xin Guo[2], Yingzhi Ma[2], Xiuyuan Yang[1]

[1]Guangdong Ocean University, St. Petersburg Institute of Shipbuilding and Marine Technology, Zhanjiang 524088, Guangdong, China

[2]Guangdong Ocean University, College of electronics and information engineer-ing, Zhanjiang 524088, Guangdong, China

[*] **Corresponding author**: Rongjie Cai

[+]**Co-first author**

Abstract: With the rapid development of manufacturing industry, product quality control has gradu-ally become one of the core topics in enterprise production management. How to arrange the quality inspection frequency reasonably and optimize the waste disposal method in the produc-tion process to minimize the production cost and ensure the product quality to meet the standard has become the focus of enterprise managers and researchers. In order to solve this problem, based on dynamic optimization theory and quality control idea, this paper establishes a dynamic decision-making model that comprehensively considers detection frequency, defective rate and disassembly income, and deeply studies the solution and application of the model.

Keywords: Dynamic Optimization, Quality Control, Detection Frequency, Disassembly Decision, Defective Rate

1. Introduction

1.1. Problem background

In the process of modern industrial production, product quality control is a crucial link in enterprise management. Especially in the manufacture of electronic products, the quality of spare parts directly determines the quality of finished products. In the process of production and assembly, enterprises often need to deal with the problem of defective parts and finished products. How to detect defective products efficiently and make corresponding decisions has become a big problem.

To produce a best-selling electronic product, an enterprise needs to purchase two main spare parts and assemble them into finished products. In this process, the problem of defective parts and finished products is very important. Enterprises should not only decide whether to inspect spare parts, but also make decisions on the inspection and treatment of assembled products. For example, should unqualified finished products be dismantled and recycled, or should they be scrapped directly? Every decision will have an impact on the cost, product quality and market reputation of the enterprise.

In addition, with the increasing complexity of production process, it is also a challenge for enterprises to formulate scientific and reasonable detection and decision-making strategies according to different defective rates in the production process of multi-process and multi-parts This paper aims to help enterprises design reasonable inspection and decision-making schemes, optimize production processes, reduce costs and improve production efficiency through mathematical modeling.

1.2. Question put forward

When the production process involves multiple processes and more kinds of spare parts, the quality control of enterprises becomes more complicated. In this case, enterprises not only need to consider whether to test spare parts and finished products, but also make reasonable decisions in each process to ensure the quality and efficiency of the whole production chain. In the context of multiple processes and multiple spare parts, how can enterprises reasonably arrange the inspection and disassembly decisions at each stage and optimize the whole production process?

2. Problem analysis

Enterprises need to make reasonable inspection and treatment decisions step by step according to the quality of each process and spare parts. Need to consider:

1. How does the defective rate of spare parts in different processes affect the defective rate of semi-finished products and finished products?

2. Under the condition of multi-process, how to design a multi-stage inspection scheme to ensure the quality of finished products and reduce unnecessary inspection and processing costs.

3. Analyze the opportunity and benefit of disassembly, and evaluate whether the unqualified products should be disassembled at a certain stage and the spare parts should be recycled in the case of multiple processes and spare parts.

3. Model hypothesis and symbolic explanation

3.1. Basic assumptions of the model

1) The defective rate of spare parts can be determined by sampling inspection;
2) The defective rate of finished products is closely related to the defective rate of spare parts;
3) Disassembly operation will not further damage the spare parts.

3.2. Symbol description

Table 1. Symbol description

symbol	meaning	unit
p_1	Defective rate of spare parts 1	Unitless
p_2	Defective rate of spare parts 2	Unitless
C_1	Purchase unit price of spare parts 1	Yuan/piece
C_2	Purchase unit price of spare parts 2	Yuan/piece
C_{test1}	Inspection cost of spare part 1	Yuan/piece
C_{test2}	Inspection cost of spare parts 2	Yuan/piece
p_f	Defective rate of finished products	Unitless
C_f	Assembly cost of finished products	Yuan/piece
C_{testf}	Inspection cost of finished products	Yuan/piece
C_m	Market selling price of finished products	Yuan/piece
C_r	Exchange loss of unqualified finished products	Yuan/piece

4. Model establishment and solution

4.1. Model establishment and solution

4.1.1. model building

1. Process detection decision model

For each process (process 1 and process 2) in the production process, we need to establish a testing decision model to judge whether the products of each process should be tested. The main purpose of testing is to reduce the rate of defective products, so as to reduce the losses caused by unqualified products entering the market.

1 parameter definition

Defective rate of process 1 (for example, 0.28, which means that 28% of the products in process 1 are defective).p_1

Defective rate of operation 2.p_2

Inspection cost of operation 1 (yuan/piece).C_{test1}

Inspection cost of operation 2 (yuan/piece).C_{test2}

Market price of finished products (RMB/piece).C_m

Return loss (RMB/piece), that is, economic loss caused by product return.C_r

2 Expected loss calculation

Failure to inspect the process may lead to defective products entering the downstream process or market, resulting in losses. We can calculate the expected loss when the process is not tested.

1. Expected loss not detected in process 1:

$$\text{Expected loss}_1 = p_1 \times (C_m - C_r) \tag{1}$$

2. Expected loss not detected in process 2:

$$\text{Expected loss}_2 = p_2 \times (C_m - C_r) \tag{2}$$

3 detection decision formula

By comparing the detection cost with the expected loss, we can make a decision whether to carry out the detection:

If the detection cost is less than or equal to the expected loss, it should be detected; Otherwise, no detection is carried out.

1. Detection decision conditions of process 1:

$$C_{test1} \leq \text{Expected loss}_1 \tag{3}$$

2. Detection decision conditions of process 2:

$$C_{test2} \leq \text{Expected loss}_2 \tag{4}$$

If the above conditions are met, the enterprise should carry out the inspection of corresponding processes to reduce the generation of unqualified products.

2. Decision model for disassembly of unqualified products

When an enterprise finds unqualified products, it needs to decide whether to disassemble them. Disassembly can recover some spare parts, thus reducing the losses caused by unqualified products, but disassembly itself also needs to pay a certain cost. Therefore, the key to disassembly decision-making is to calculate whether the benefits of disassembly are greater than the costs.

1 parameter definition

the defective rate of finished products, that is, the proportion of unqualified products.p_f

$C_{recycle}$: Value of parts recovered after dismantling (RMB/piece).

Disassembly cost (yuan/piece).C_d

2 Disassembly income calculation

The benefits of dismantling mainly come from the value of recovered spare parts, but at the same time, the dismantling cost needs to be considered. The formula of dismantling income is:

$$\text{dismantling income} = p_f \times C_{recycle} C_d \tag{5}$$

3 Disassembly decision formula

According to the dismantling income, we can judge whether dismantling should be carried out:

If the dismantling income is greater than or equal to 0, it should be dismantled to recover part of the value;

If the dismantling income is negative, it should not be dismantled and the unqualified products should be discarded directly.

$$\text{dismantling income} \geq 0 \tag{6}$$

3. Chart support analysis

In order to assist decision-making, enterprises can use charts to visually analyze the defective rate and dismantling income of working procedures:

Heat map of process defect rate: shows the defect rate of different processes, and helps enterprises to judge which process needs to be tested first.

Disassembly decision boundary map: shows whether disassembly is beneficial under different defective rate conditions, so as to determine the optimal disassembly decision.

Process defect rate comparison chart: compare the defect rates of multiple processes to help enterprises decide the allocation of testing resources.

4.1.2. Model solution and analysis

In this part, we will solve the model, and combine the analysis chart and decision report to optimize the detection and treatment of each process and nonconforming products.

1. Process detection decision-making solution and analysis

According to the provided defective rate and inspection cost, enterprises need to judge whether to inspect the process.

1 parameter setting

According to the data in the decision report:

Defective rate of process 1, inspection cost of process 1 = 3 yuan.$p_1 = 0.28 C_{test1}$

Defective rate of process 2, inspection cost of process 2 = 4 yuan.$p_2 = 0.23 C_{test2}$

The market price of finished products is RMB, and the loss is RMB.$C_m = 56 C_r = 40$

2 Expected loss calculation

1. Expected loss of non-detection in process 1:

$$\text{Expected loss}_1 = p_1 \times (C_m C_r) = 0.28 \times (5640) = 4.48 \text{ Yuan} \quad (7)$$

2. Expected loss of non-detection in process 2:

$$\text{Expected loss}_2 = p_2 \times (C_m C_r) = 0.23 \times (5640) = 3.68 \text{ Yuan} \quad (8)$$

3 detection decision analysis

The detection cost of operation 1 is less than the expected loss, so the enterprise should detect operation 1. $C_{test1} = 3\ \ 4.48$

The detection cost of operation 2 is greater than the expected loss, so the enterprise should not detect operation 2.$C_{test2} = 4\ \ 3.68$

Conclusion: According to the analysis, the enterprise should carry out the inspection of process 1, while the inspection cost of process 2 is higher than the expected loss, so it can choose not to carry out the inspection.

2. Decision-making solution and analysis of disassembly of unqualified products

After discovering unqualified products, enterprises need to decide whether to disassemble them. According to the model parameters provided, the enterprise can recycle some spare parts through disassembly, but it needs to pay a certain disassembly cost.

1 parameter setting

Defective rate of finished products.$p_f = 0.19$

Disassembling cost yuan, recycling value yuan. $C_d = 5 C_{recycle} = 10$

2 Disassembly income calculation

$$\text{dismantling income} = p_f \times C_{recycle} C_d = 0.19 \times 105 = 3 \text{ Yuan} \quad (9)$$

Because the dismantling income is positive (3 yuan), dismantling can recover part of the cost, so in theory, enterprises can choose to dismantle unqualified products.

3 decision analysis

However, the analysis in the decision report shows that enterprises choose not to disassemble unqualified products. The reason may be that even if the income is positive, enterprises are more inclined to reduce the extra cost of the process rather than relying on the dismantling income, so it is recommended not to dismantle the unqualified products in the report.

Conclusion: According to calculation, disassembly is feasible in theory, but in actual decision-making, enterprises choose not to disassemble unqualified products.

3. Chart analysis

1. Heat map of defective parts rate:

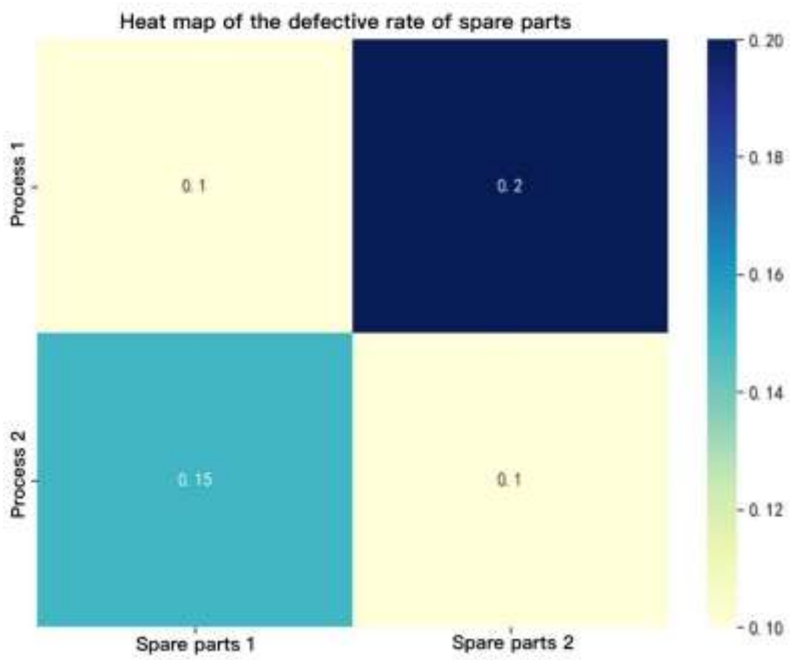

Figure 1. Heat map of defective rate of spare parts

As can be seen from the figure, the defective rate distribution of different processes and spare parts, the defective rate of process 1 and process 2 is between 0.1 and 0.2 respectively. This diagram can help enterprises to understand the impact of the defective rate of each process.

2. Disassembly decision boundary diagram:

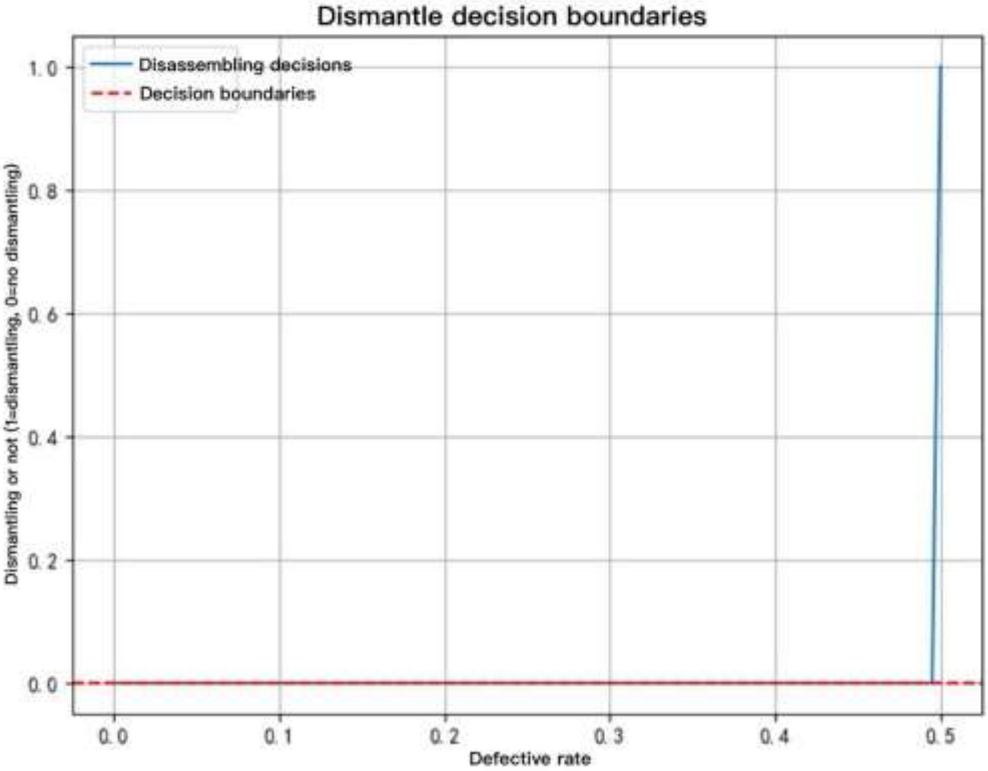

Figure 2. Disassembly decision boundary diagram

This diagram shows the boundaries of the disassembly decision. The economy of disassembly will change under different defective rate. When the defective rate is high, dismantling can recover part of the proceeds; When the defective rate is low, disassembly is unprofitable.

3. Comparison chart of process defective rate:

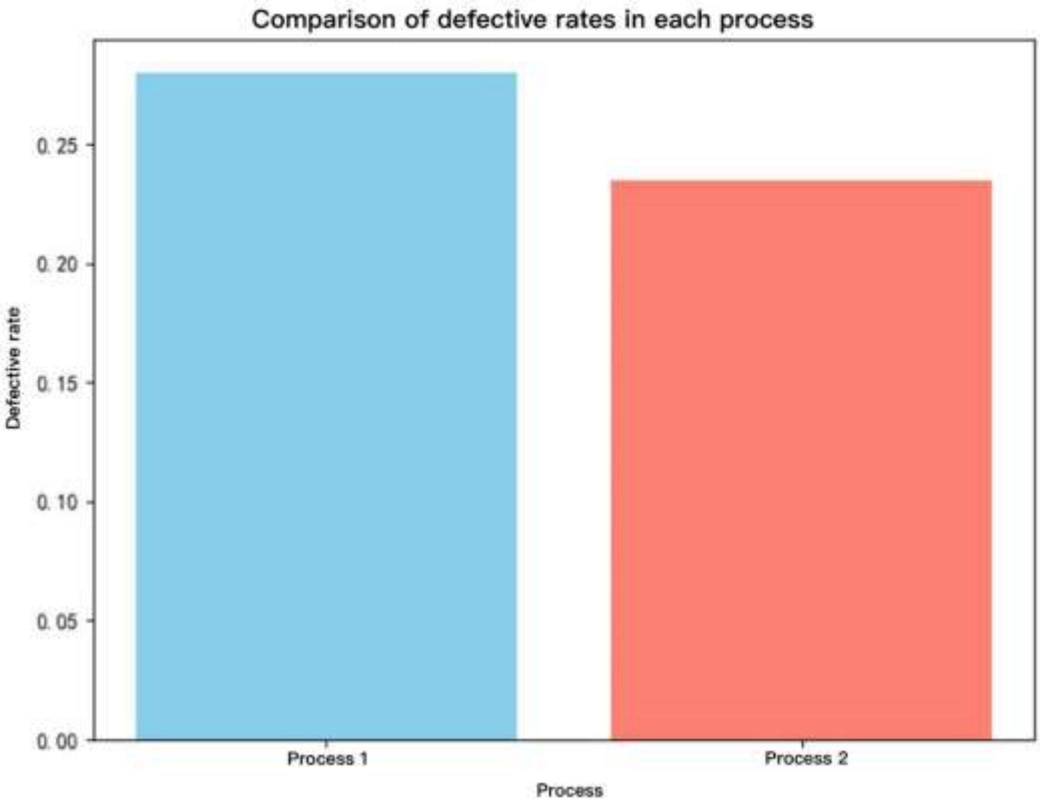

Figure 3. Comparison chart of defective rate of working procedure

The chart shows the comparison of defective rate between process 1 and process 2. The defective rate of process 1 is high, so it is a reasonable choice to give priority to the detection of process 1, while the defective rate of process 2 is relatively low, so it is unnecessary to detect it.

Step 4 summarize

Through the above solution and analysis, the following conclusions are drawn:

Process 1 inspection decision: enterprises should inspect process 1 to reduce the risk of defective products entering the market.

Operation 2 inspection decision: because the inspection cost is higher than the expected loss, the enterprise can choose not to inspect operation 2.

Dismantling decision of unqualified products: Although the dismantling income is positive, enterprises choose not to disassemble unqualified products and discard unqualified products directly based on the consideration of actual operating costs.

5. Model evaluation and popularization

5.1. Advantages of the model

5.1.1. Dynamic adjustment ability

The model can flexibly adjust the detection frequency and disassembly decision according to the dynamic change of defective rate. This makes the model have strong adaptability in practical application and can cope with possible changes in the production process. Through dynamic adjustment, enterprises can adopt different strategies in different periods to ensure product quality and optimize production costs.

5.1.2. Multi-factor comprehensive consideration

The model fully considers the influence of several key factors, such as defective rate, inspection cost, disassembly income and so on. The comprehensive consideration of these factors enables the model to reflect the actual production environment of enterprises more comprehensively and help enterprises make more accurate decisions. By balancing the detection cost and the loss caused by the defective rate, enterprises can effectively control various risks in production.

5.2. Deficiency of the model

5.2.1. Dependence of parameter estimation

The model relies on the accurate estimation of several key parameters (such as inspection cost, defective rate, disassembly income, etc.) in the process of solving. However, in actual production, the accurate acquisition of parameters may be affected by incomplete data or measurement errors. If these parameters are not estimated accurately, the decision made by the model may deviate from the actual optimal strategy.

5.2.2. Simplification of model assumptions

In order to facilitate analysis and calculation, the model simplifies some complicated situations in actual production. For example, the model assumes that the detection cost and defective rate change smoothly with time, but in actual production, the defective rate and detection cost may be affected by external factors such as production line efficiency and raw material quality, showing nonlinear fluctuations. In addition, the model also ignores unforeseen factors such as production equipment failure and personnel skill change, which may affect the applicability of the model.

5.3. Generalization of model

5.3.1. Suitable for various manufacturing industries.

This model is suitable for manufacturing enterprises with quality inspection and waste disassembly process, especially in the manufacturing industry with mass production and repetitive production.

5.3.2. Suitable for enterprises of different sizes.

This model is suitable for both large manufacturing enterprises and small and medium-sized enterprises. Large enterprises can optimize the model more carefully through the data analysis system, while small and medium-sized enterprises can use the simplified version of the model to improve production efficiency and reduce costs by adjusting the detection frequency and disassembly strategy. The promotion of this model does not depend on the scale of enterprises, so it has a wide range of applicability.

References

[1] Xu Haifeng, Cui Zhichao, Liu Zhiguang, et al. Optimal Path Planning and Tracking Control Algorithm for Self-driving Vehicles Based on Dynamic Programming [C]// China Highway Society, China Navigation Society, China Railway Society, China Aviation Society, China Automotive Engineering Society .2024 World Transportation Congress WTC2024 Proceedings (Transportation Planning and Air Transportation). School of Information Engineering, Chang 'an University; Chang 'an University School of Electronics and Control Engineering; ,2024:7.DOI:10.26914/c.cnkihy.2024.011109.

[2] Huang Jingyuan, Yu Shan, Wang Denghai, et al. Dynamic model of hydrogen station location based on multi-objective decision optimization [J]. Oil and gas and new energy, 2024,3602:1017.

[3] Xu Qi, Hou Xing, Wu Yating. Research on dynamic multi-objective optimization economic decision-making model based on reference point information prediction [J]. Journal of Anhui Business Vocational and Technical College, 2023,2201: 4347.doi: 10.13685/j.cnki.abc.000673.

[4] Jia junmin. research on interactive portfolio optimization decision-making based on preference change tracking [D]. Harbin institute of technology, 2022. doi: 10.7061/d.cnki.ghgdu.20060.1006060606666