

# Optimization of Electronic Product Inspection and Defective Product Handling

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**Abstract:** This paper establishes a decision optimization model to help enterprises make better decisions on the quality and cost management of electronic products in the production and sales process, and improve product efficiency. At the same time, combined with the production practice, the theoretical mathematical model is applied to the actual production process, and the practicability of the model is tested. The mixed integer linear programming model is established, and the effective production decision-making scheme with multiple decision points in each link is given, which can effectively reduce the defective rate in the production process of enterprises. Due to the sequence of processes, it is necessary to analyze from spare parts to semi-finished products to finished products. The decision tree model is used to decompose each decision point, so that the final result can get the optimal decision scheme.

**Keywords:** Hypothesis testing model, Cost benefit analysis, Mixed integer linear programming, Decision tree model.

## 1. Introduction

The decision-making problem faced by enterprises is how to select appropriate detection and processing strategies at each stage (spare parts procurement, assembly, finished product sales, etc.), reasonably minimize the total production cost, and control the product quality at the same time.

Automated optical inspection(AOI) and machine learning-based defect detection have revolutionized electronic product inspection. For instance, a study by Li et al. [1] demonstrates the efficacy of convolutional neural networks (CNNs) in identifying soldering defects on printed circuit boards (PCBs). Similarly, Wang and Zhang[2] propose a hybrid framework combining deep learning with infrared thermography for non-destructive testing, enabling real-time detection of subsurface defects in semiconductor components. Albin and Friedman[3] advocate for a shift from reactive inspection to proactive process improvement, emphasizing the use of Pareto charts and yield loss metrics to prioritize defect types. Chen et al. [4] introduces a cloud-based system that correlates environmental parameters (e.g. temperature, humidity) with defect rates, enabling predictive adjustments to assembly lines. Efficient defective product handling requires a balance between rework, scrap, and recovery processes. A case study by Kim and Park[5] on smartphone manufacturing highlights the economic benefits of implementing a tiered defect classification system. By categorizing defects as critical, major, or minor, manufacturers can allocate resources judiciously automatically diverting critical defects to rework stations while recycling minor defects for component recovery. This strategy reduced scrap costs by 22% and improved overall equipment effectiveness (OEE) by 18%[6].

The mathematical model is established by using one-sided test method, and the relevant test statistics are calculated. The minimum number of samples is calculated under different confidence levels, so as to obtain the minimum number of tests. In order to give the optimal decision-making scheme, we need to ensure that the cost of the enterprise is the lowest, so we set four factors for decision-making: "whether to detect the parts, whether to discard the detected unqualified parts",

"whether to detect the finished products, whether to disassemble the detected unqualified parts", "whether to reuse the parts or finished products after disassembly" and "processing decision after returning the unqualified products". We first estimate the defective rate of parts through sampling inspection, then simulate the inspection results through Bernoulli distribution, and then calculate the defective rate of semi-finished products and finished products.

## 2. Preliminary

### 2.1. Assumptions

1. The defective rate of parts 1 and 2 is independent.
2. Unqualified finished products can be disassembled or discarded without affecting subsequent production.
3. The market demand is large enough that all qualified products can be sold.
4. Defective products will cause users to return and exchange goods, and the enterprise needs to bear the corresponding exchange loss.

### 2.2. Notations

The symbols used in the paper are listed in Table 1.

Symbols	Notations	Unit
$P$	Actual defective rate	
$P_0$	Nominal value	
$n$	Total number of samples	piece
$x$	Quantity of defective products	piece
$N_1$	Purchase quantity of spare parts 1	piece
$N_2$	Purchase quantity of spare parts 2	piece
$c_1$	Unit price of spare parts 1	Yuan/piece
$c_2$	Unit price of spare parts 2	Yuan/piece
$C_{pur}$	Total purchase cost of	element

$x_1, x_2$	spare parts 1 and 2 Whether to detect the decision variables of parts 1 and 2	
$d_1$	Testing cost of spare parts 1	Yuan/piece
$d_2$	Testing cost of spare parts 2	Yuan/piece
$C_{test}$	Total testing cost of parts 1 and 2	element
$N_f$	Quantity of finished products	piece
$P_f$	Defective rate of finished products	
$d_f$	Testing cost per finished product	Yuan/piece
$C_{testcost}$	Total cost of finished product inspection	element
$r$	Disassembly cost of each nonconforming finished product	Yuan/piece
$l$	Exchange loss after each nonconforming finished product enters the market	Yuan/piece
$C_{sepcost}$	Total disassembly cost of nonconforming finished products	element
$C_{ruincost}$	Total scrap loss of	element

nonconforming finished  
products

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### 3. Models for testing the Defective and finished products

#### 3.1. One-tailed test and optimizing

The total cost of spare parts can be expressed as

$$C_{pur} = N_1 c_1 + N_2 c_1 \quad (1)$$

This cost is the cost that the enterprise needs to obtain spare parts, and is not affected by the subsequent inspection and disassembly production process[7]. Enterprises can choose whether to test parts 1 and 2. The purpose of testing is to identify and eliminate defective products, but testing needs to increase the cost of testing. The quantity of finished products depends on the quantity of qualified spare parts. Since the finished product is composed of parts 1 and 2, the quantity of finished products depends on the qualified quantity of the two parts. Moreover, if the enterprise chooses to test one or two kinds of spare parts, all defective parts in the spare parts will be eliminated. On the contrary, if it does not test, the qualified quantity of the spare parts will be affected by the secondary product rate. Therefore, the quantity of finished products is determined by the minimum value of qualified parts 1 and 2, i.e

$$N_f = \min (x_1 N_1 + (1 - x_1) N_1 (1 - P_1), x_2 N_2 + (1 - x_2) N_2 (1 - P_2)) \quad (2)$$

The defective rate PF of finished products is determined by the non detected defective parts. If the enterprise chooses to test parts 1 and 2, the defective products will be eliminated,

and the defective rate of finished products will be greatly reduced

$$P_f = (1 - x_1) P_1 + (1 - x_2) P_2 - (1 - x_1)(1 - x_2) P_1 P_2 \quad (3)$$

The total cost is the sum of all cost items, including the purchase cost of spare parts, testing cost, and the processing

cost of unqualified finished products

$$C_{zong} = (N_1 C_1 + N_2 C_2) + (x_1 N_1 d_1 + x_2 N_2 d_2) + (x_f N_f d_f) + (x_d P_f N_f r) + (1 - x_d) P_f N_f \quad (4)$$

#### 3.2. The establishment of models

First of all, we need to make it clear that the objective function is for the enterprise to obtain the maximum profit value[8]. But if we want to use the intlinprog function, we need to turn the problem into a minimum optimization problem, that is, profit maximization into negative profit minimization, that is

$$\min - [N_f(1 - P_f)S - C_{gross}] \quad (5)$$

Next, in order to solve the profit minimization problem, we need to construct the coefficients in the objective function into a linear shape and convert it to intlinprog.

Finally, we will consider the purchase of 10000 spare parts 1 and 10000 spare parts respectively. According to the results of model operation, the optimal detection and processing strategy is in Table 2.

**Table 2.** Indicator results

Case	Cost (yuan)
Do not detect spare parts 1	400
Do not detect spare parts 2	1800
Do not test finished products	600
Unqualified finished products detected by disassembly	500
Disassembling unqualified finished products returned by users	500
total cost	3800
income	50400
profit	46600

According to the results of the model operation, enterprises should choose to test spare parts 1. That is, it also shows that although testing will incur additional testing costs (the cost of testing spare parts 1 is), in the first case, due to the high defective rate of spare parts (=0.1), failure to test will lead to defective products entering the finished product stage, which will affect the quality of finished products after entering the finished product stage, thus bringing greater cost risks and

crises. Therefore, we need to check spare parts 1 to remove the unqualified defective parts in spare parts 1, so as to ensure that the spare parts entering the finished product production stage are qualified, which will improve the quality assurance of finished products and bring greater benefits to enterprises profit.

According to the results of the model operation, enterprises should choose not to detect spare parts 2. That is, although detecting spare parts 2 can eliminate some defective rates, due to the low defective rate of spare parts 2 (=0.1) and the high cost of detection, the influence on the finished products after entering the finished product stage is not significantly different from that without detection. Therefore, the economic benefit is greater when we do not need to inspect spare parts 2.

### 3.3. Analysis

The enterprise should choose to test the finished products, that is, it also shows that although the testing will generate additional testing costs, the enterprise will reduce the risk of defective products entering the market in order to reduce the impact of defective products entering the market on the company's reputation and profits[9]. Therefore, although the detection needs to increase a certain cost risk, the quality assurance of finished products has been greatly improved. Enterprises can reduce the market risk through the detection of defective products. The total cost of the enterprise under the optimal detection and processing strategy is 483998. This is the lowest combined cost when the enterprise chooses whether to inspect or disassemble each spare part and finished

$$R = N_f S_f - (C_{LPJJC} + C_{BCPJJC} + C_{CPJC} + C_{CHAIJ} + C_{ZPCB}) \quad (8)$$

Finally, we have constructed the objective function and constraint function. We can use the optimization algorithm to solve this problem, and use the intlinprog function in MATLAB to solve this integer linear programming problem. Then, for uncertain decision processing, we use robust optimization and other algorithms to improve the practicability and reliability of the model.

In this paper, we will use a more complex decision tree model and cost-effectiveness analysis model. Therefore, we calculate the settlement of enterprise profits by segments through linear programming and optimization algorithm to determine the cost of each decision point and the impact on subsequent products or semi products.

The results of MATLAB optimization operation show that the optimal decision-making strategy of the enterprise is shown in Table 3.

product. Under this cost, enterprises can maximize profits. Although detection and disassembly will bring additional production costs, they can eliminate defective products and recycle resources through chemical industry, and enterprises can avoid greater loss risk caused by defective products entering the market. Therefore, it is beneficial to maximize profits on the whole.

## 4. Mixed integer linear programmings

Because it is produced by multiple processes, the processes behind the defective rate will be affected by the former. Therefore, we need to analyze step by step, starting from the spare parts stage, then analyzing the semi-finished products, and finally analyzing the products. According to the decision tree model, the final decision of each decision point is disintegrated, so that the final result can get the optimal decision scheme[10]. Because there is a fixed defective rate for each kind of spare parts, if not detected, the defective products will also enter the next process for assembly. If detected, the defective rate will not enter the next process. We can ask the qualified quantity of starting finished products to be

$$N_f = N_f(1 - p_f) \quad (6)$$

The total detection cost can be expressed as

$$C_{JIANC} = C_{LPJJC} + C_{BCPJJC} + C_{CPJC} \quad (7)$$

By substituting revenue and total cost, we can get the objective function we need to find

**Table 3.** Indicator results for cost

Working procedure	Cost
Do not detect spare parts 1	200
Do not detect spare parts 2	800
Do not detect spare parts 3	1200
Do not detect spare parts 4	200
Do not detect spare parts 5	800
Do not detect spare parts 6	1200
Do not detect spare parts 7	800
Do not detect spare parts 8	1200
Do not detect semi-finished products	2400
Unqualified finished products	4000
Unqualified products detected during disassembly	1000
Disassembly of nonconforming products returned by users	1000
total cost	14800
Total revenue	180000
profit	165200

For the results of running in the model, the model does not detect all spare parts, semi-finished products and finished products. In this case, the enterprise can still obtain the maximum profit of 165200 yuan. For enterprises, the loss caused by not testing is less than the cost caused by testing, so for enterprises, the profit is the largest when not testing.

We need to assume that the enterprise has accepted this batch of production spare parts. Therefore, we need to decide whether the enterprise needs to continue to test or disassemble each spare part and process in the next production process. Next, I will apply the results of sampling inspection to

production and optimize the model again.

The main purpose of enterprises' inspection of finished products is to prevent defective products from entering the market. Therefore, the following rules can also be used to judge whether the finished products need to be inspected: if the enterprise passes the unilateral inspection sampling inspection scheme in question 1

If the quality of the finished product is good and the defective rate is low, then it is not necessary to test, otherwise it is necessary to test. According to the calculation of solving the model in MATLAB, the results are shown in Table 4.

**Table 4.** Indicator results for cost again

Working procedure	Cost
Do not detect spare parts 1	88.8
Do not detect spare parts 2	355.2
Do not detect spare parts 3	532.8
Do not detect spare parts 4	88.8
Do not detect spare parts 5	355.2
Do not detect spare parts 6	532.8
Do not detect spare parts 7	355.2
Do not detect spare parts 8	532.8
Do not detect semi-finished products	3204
Unqualified finished products	4505.4
Unqualified products detected during disassembly	2491
Disassembly of nonconforming products returned by users	2491
total cost	15533
Total revenue	150180
profit	134647

From case 1 to case 3, both parts 1 and 2 will not be tested. This shows that under the unilateral test based on problem 1, the defective rate of parts 1 and 2 is low, which has little impact on the profits of the enterprise. For unqualified finished products, the enterprise needs to test, because the price of finished products is cheap, and its cost value is far less than the damage caused by non testing, so the enterprise chooses to test the finished products. Finally, whether the unqualified disassembled products need to be disassembled, the enterprise chooses to disassemble, because the cost of disassembly is lower than the cost value directly reimbursed after it is not disassembled, so the enterprise chooses to disassemble. For case 4 and case 5: different from the previous three cases, here we choose to detect Part 2 instead of Part 1, because for Part 2, the secondary product rate is high, and the cost hazard of detection is less than that of non detection. Therefore, the enterprise chooses to test spare parts 2, and the rest are the same. For the sixth case, the enterprise chooses not to test the parts 1 and 2, and does not decompose the unqualified products, but the enterprise chooses to test the finished products, because the cost of disassembly is compared with the value that the disassembled parts can bring to the enterprise, and not disassembling the unqualified finished products is the best choice.

## 5. Conclusions

We take advantage of the fact that the unilateral test requires a clear direction of alternative hypotheses, a credible conclusion can be obtained by testing a small number of samples. A systematic and comprehensive decision support, quantitative cost-effectiveness, intuitive and visual decision-making framework are given to improve the correctness of the decision-making. The uncertainty of sampling inspection and defective rate is introduced, and the model can adapt to the changes and uncertainties in real production. However, when the direction of concern has no significant results, it is easy to ignore the other direction of benefits, which leads to the limitations of result interpretation and increases the risk of making the second type of error. In this paper we use the probability model, which can be used in the financial industry to calculate the default probability and assess the lending risk based on the borrower's historical data and credit scoring model.

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