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Comparing Test Methods in ABCtronics: An Example of Global Urban Air Quality Result Testing

Hetong Zhou[1,a,*]

[1]*Information Technology, Auburn University at Montgomery, Montgomery 36124, United States*
a. hzhou1@aum.edu
**corresponding author*

Abstract: This article explores the importance of the methods in quality control in the semiconductor industry. Three test methods in ABC tronics, a semiconductor company from "Case-ABCtronics: Manufacturing, Quality Control, and Client Interfaces", will be used to test the data comes from an air quality database available on Kaggle. These data initially taken from Numbeo as an aggregation of user voting. The results of the three different methods are analyzed to draw their respective conclusion, that is whether the investigation report will be accepted or not. In the comparison of three methods, the new testing method is more likely to reject the entire result, and individual chip testing method is a most recommended test method with several advantages. The article emphasizes the usefulness of the findings for other manufacturers in the industry who are looking to improve their quality control measures and maintain high standards of product quality.

Keywords: Quality control, hypergeometric distribution, Poisson distribution, geometric distribution

1. Introduction

The semiconductor industry is highly competitive, with countries such as China, India, and the US investing heavily in the industry to gain a competitive advantage. Policymakers provide government incentives to support the industry, such as tax incentives, funding for research and development, and workforce development, to help their countries regain their competitiveness in the semiconductor industry [1]. During production, maintaining quality control is paramount to ensure products adhere to the prescribed standards. Quality control is a systematic approach that guarantees a product or service attains the desired level of excellence. This enhances consumer satisfaction and establishes a preference for quality over pricing in fiercely competitive industries. Additionally, maintaining quality control is imperative for organizations to sustain their competitiveness and performance [2].

ABCtronics is a semiconductor manufacturing company that specializes in producing integrated circuit (IC) chips. Established in 1997, ABCtronics started as a small-scale operation but has now evolved into a medium-sized enterprise. They offer a range of wafer product lines, including mingled-signal united circuits, analog circuits, and high-stress round boards. XYZsoft is the company's primary client and accounts for a significant portion of its business [3]. In the course of IC development, a specific number of chips are produced. These chips can be classified into two categories: good (G) and bad (B) elements, based on design specifications. The manufacturing yield can be affected by various factors such as chemical concentration errors, etching and mask faults,

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environmental conditions during wafer foundry, and tester accuracy. Quality assurance in manufacturing IC chips involves ensuring that the manufacturing and testing processes are optimized to minimize the loss of manufacturing yield and maximize the number of good parts produced [4]. Manufacturing IC chips involves high costs for quality guarantee. As the intricacy of IC chip design rises, the likelihood of faulty production also increases. That's why quality checks are integrated at multiple stages of the manufacturing process. XYZsoft attaches great importance to quality control, since it is of utmost importance to ensure that the products meet the required standards.

This essay focuses on comparing different test methods in quality control and analyzing their impact on the results in ABCtronics. It is important to understand the differences in the results produced by different test methods based on the research question and the characteristics of the data. The Basic Methods Handbook for Clinical Orthopaedic Research explains that different statistical tests can affect the results of the same data in various ways [5]. The methodology used in this study includes statistical analysis, case studies and data visualization. Data visualization is the graphical representation of data and information. It involves the use of visual elements such as charts, graphs, and maps to communicate complex data in a clear and concise manner. It is also an important feature of the interactive web application for statistical process control (SPC) analysis [6]. The objectives of this study are to explore the impact of quality control measures on the manufacturing process, to compare different test methods in quality control, and to analyze the effect of different test methods on the results.

Regarding quality control test methods, the study compares three different methods: The first method is Lot Acceptance Testing Method (LATM), LATM is the current method employed by ABCtronics, where an automated machine randomly chooses 25 IC chips from a lot of 500 without replacing them. If the sample contains less than two defects, the lot is accepted; otherwise, it is denied. This provided the program manager with data-based, customizable, and nonparametric risk estimates for accepting material, aiming to balance the risk between the government and contractor while increasing production throughput [7]. For this test method, the probability needs to be calculated by Hypergeometric distribution. Hypergeometric distribution is always used for error analysis in approximate computing and stochastic computing. These fields deal with the trade-off between accuracy and efficiency in computing, and the hypergeometric distribution may be used to model the probability of errors occurring in these systems [8]. The second method is Individual Chip Testing Method (ICTM), proposed by the Quality Review Team (QRT), involves taking a sample of 25 IC chips one by one from a lot of 500, but this time with a replacement. If a defective chip is found, rework is immediately done on that chip. For this test method, the Poisson distribution is needed in calculating probability. The Poisson distribution is a discrete probability distribution that is used as a model for count data, such as the number of traffic accidents or the number of phone calls received within a given time span [9]. The third method is XYZsoft's new testing method. XYZsoft has applied a module-smart testing approach for their product. In circuit module M (CM), there is a sequence connection involving three chips from ABCtronics. Previous to this new testing process, XYZsoft reported that in a standard lot enclosing 20 CMs, they discovered three defective items. They noted that in most cases, the issue was with ABCtronics' chips. Now, they have put a stricter policy in place, where they calculate the number of nondefectives before encountering a particular number of defects, and they start the count of 3. For this test method, the probability needs to be calculated from the Negative Binomial distribution. The Negative Binomial distribution is a probability distribution that describes the number of failures before a certain number of successes occur in a sequence of independent Bernoulli trials, where the probability of success is the same for each trial [10].

The findings of this study can be useful for other manufacturers in the industry who are looking to improve their quality control measures and maintain high standards of product quality.

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2. Methods

2.1. Data Source

To ensure data integrity and experimental accuracy in the process of comparing test methods, all data tested in this essay comes from an air quality database available on Kaggle. This dataset is one of the public parts of City API project data. The Air Quality Index (AQI) is a numerical scale used to assess the condition of air quality and inform you about whether the air you're breathing is clean or polluted today or in the near future.

2.2. Selection and Description of Indicators

These data cover air quality for 3964 cities around the world in 2020, initially taken from Numbeo as an aggregation of user voting. Air quality varies from 0 (bad quality) to 100 (top good quality). Table 1 presents statistics on the variability of survey data.

Table 1: Basic information

	Air quality	Water pollution
Mean	62.25	44.63
Variance	30.94	25.66
Standard deviation	957.58	658.64
Max	100	100
Min	0	0

2.3. Three Test Methods

Cities with an air quality of 0 are set as unqualified cities, which are needed to be recorded. After counting a total of 3964 cities, 277 cities are unqualified cities, unqualified rate from these data is 0.07. Assuming the accurate unqualified rate that's based on data from the air quality station is 0.1. The three test methods will be applied in a simulated sampling statistics group. If the data from the sample group does not pass the test, then the results of this urban air quality survey will not be accepted. The following corresponding formulas of the three test methods calculate the passing rate of the statistical group.

2.3.1. Hypergeometric Distribution

The hypergeometric distribution is an important discrete probability distribution whose probability mass function can be defined in this way: assuming that the finite aggregate contains N samples, of which m are of passing quality, the remaining N-m are failing samples, and if n samples are drawn from this finite aggregate, the probability that k of them are of passing quality is:

$$P = (X = k) = \frac{C_m^k \times C_{N-M}^{n-k}}{C_N^n} \quad (1)$$

2.3.2. Poisson Distribution

The Poisson distribution is suitable for describing the number of times a random event occurs per unit of time. The probability P(x) of the actual occurrence of x times under the condition of observing things occurring m times on average can be expressed by the following formula:

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$$P = (X = k) = \frac{m^k \times e^{-m}}{k!} \quad (2)$$

2.3.3. Geometric Distribution

Geometric distribution is a discrete probability distribution. In a Bernoulli test, the probability of case A occurring in each try is noted as p. The trial is conducted until the occurrence of event A is stopped, at which point the number of trials conducted is k, and its distribution is given as:

$$P = (X = k) = p(1-p)^{k-1} \quad (3)$$

3. Result and Discussion

For LATM, 300 cities were randomly selected from 3964 cities, and if less than 30 of them failed, the result was accepted, otherwise rejected. Figure 1 shows the probability distribution of failing cities in a sample of 30 cities, and according to the results, the acceptance rate of the results of the interviews for the air quality survey for this LATM test was 98.43%.

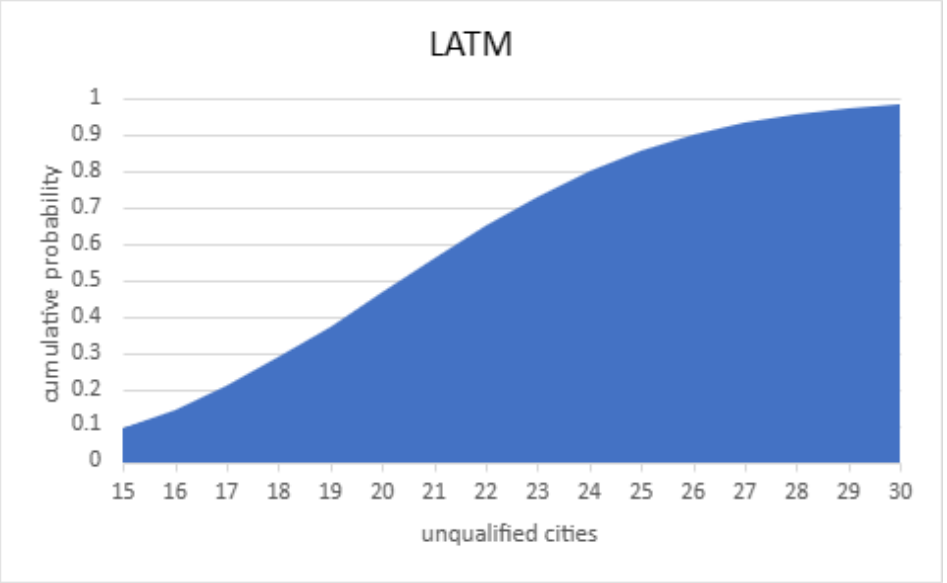

Figure 1: LATM probability distribution

In ICTM, a sample of 300 items selects one after the other from a lot of 3964, with replacement allowed. This means that a previously selected item can be returned to the lot for the next draw. If an unqualified city is found, it will be recorded immediately and put back to the group, recorded cities are not been seen as unqualified city again. The same threshold of 30 failed cities is used to determine whether to accept the results or not. Figure 2 shows the probability distribution of failing cities in a sample of 30 cities, it's similar to LATM test, and the acceptance rate of the results of the interviews for the air quality survey for this ICTM test is 97.63%.

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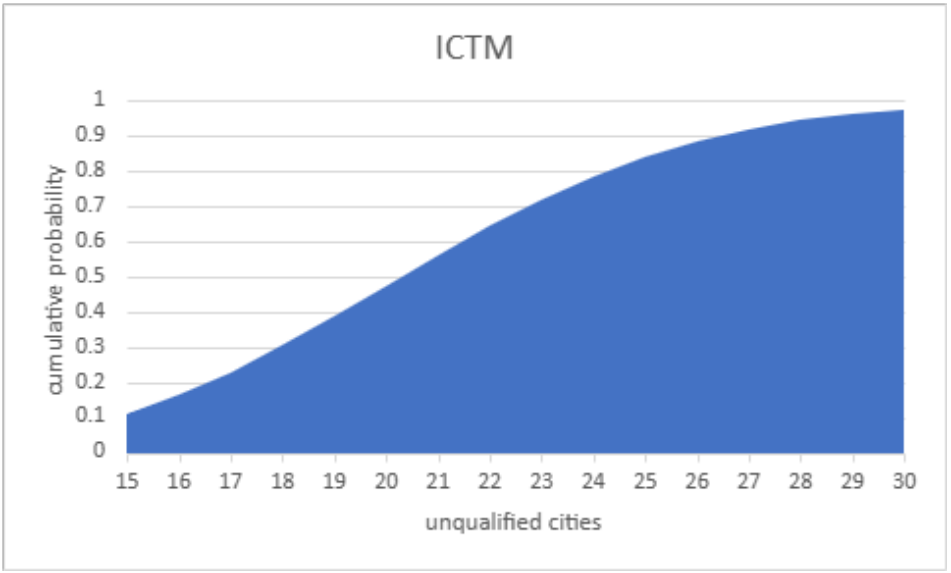

Figure 2: LATM probability distribution

For the new testing method, it will be examined one by one from a sample of 300 cities, counting the total number of cities when it encounters an unqualified city. If the number of cities is more than 10, the data will be accepted. Figure 3 shows the probability distribution of total cities, the acceptance rate for the results of this test was only 48.92%, much lower than the two tests above.

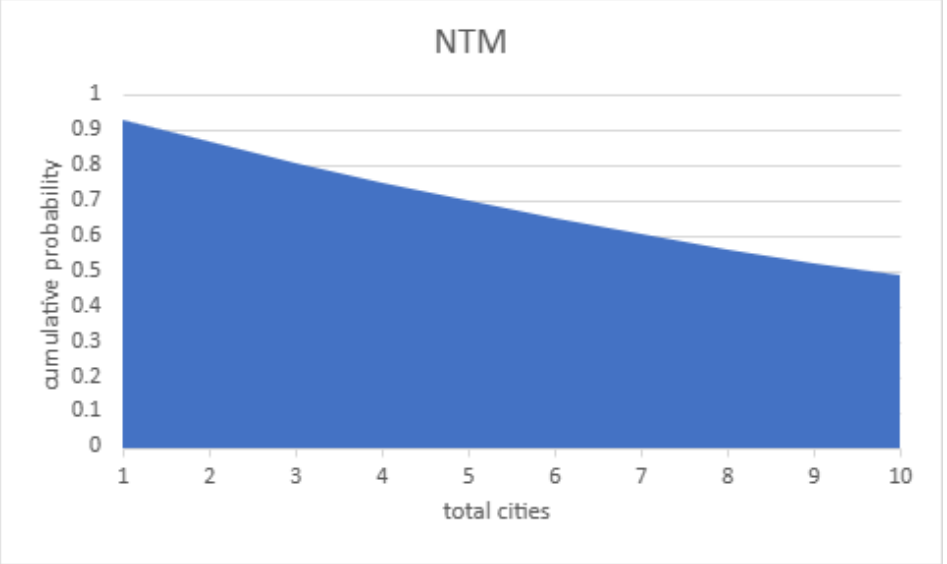

Figure 3: New testing method probability distribution

Analyzing the acceptance rate level, there is little difference between LATM and ICTM, while the new test method with XYZ soft is much lower, which may be due to the following reason: New testing method is a stricter policy than their previous testing process, which only reported the uqualified cities and did not necessarily reject the entire lot, unless a specific value is exceeded. In contrast, XYZsoft was more likely to reject entire lots of results even if only one qualified city was detected in a test-by-test. As it follows Geometric distribution, the probability of failure grows exponentially. This type of testing only allows for increased randomization and does not apply to verify the reliability of the data.

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Evaluating testing process level, the new testing policy required fewer samples to be tested, it did not rigorously represent of overall results which confirms. That may explain why the new test method received more complaints in ABCtronic case. ICTM is a better intuitive form of statistics than LATM, but does not provide the opportunity for immediate recorded, which may require extra time for notification.

Due to the inherent variability in data types, one for product quality production data and one for air quality survey data, there were also differences in the effectiveness of the three test methods. In ABCtronic case, LATM can guarantee sufficient quality control of chips. In contrast to LATM, ICTM addresses the flaw in the existing system by allowing for replacement of defective chips and immediate rework. This can help reduce the number of rejected lots and decrease production costs. It also ensures that only the defective chips are reworked, saving time and resources.

4. Conclusion

From the computation, the new test method has a high probability of rejecting the dataset. These data will be reassessed and corrected after rejected by this method, this leads to a decrease of efficiency in data analysis. Regarding to ABCtronic case, with the new quality control policy, almost every batch of CMs from XYZ Soft will be sent to ABCtronics for revision. The significant rise in the quantity of rework requests from XYZ soft reflects this exact circumstance. To avoid this situation, ICTM is a better choice.

ICTM is an optimized version of the LATM approach in the case. Based on the comparison, ICTM has advantages in the following aspects: ICTM provides higher precision in detecting and addressing defects on individual chips. This can significantly improve product quality and customer satisfaction; ICTM's real-time rework feature allows prompt rectification of defects, reducing the chances of defects propagating through the production process. ICTM's approach allows for better analysis of defect root causes, aiding in process improvement and long-term quality enhancement. Customer Satisfaction: Implementing ICTM aligns with customer expectations for defect-free products, enhancing ABCtronics' reputation and relationships with clients like XYZsoft. Although ICTM might incur slightly higher costs due to rework, the benefits of reduced defects, improved client relationships, and better process understanding outweigh these costs.

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