

Case Study on a Semiconductor Manufacturing Company

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Abstract. As a semiconductor manufacturing company, ABCtronics takes its own process and wafer health-related issues very seriously, as these issues can lead to increased costs and even major accidents. Semiconductor companies face many common problems. For the downtime problem, according to the provided data, if it is assumed that it conforms to a uniform distribution, it can be calculated that the probability of downtime is less than or equal to 5 hours is 86.75%. For the chemical impurity problem, this paper calculates the beta distribution, which shows that the company's current state of the manufacturing process is satisfactory. QRT proposes a new method (ICTM) for quality control strategies, which outperforms and replaces the original method (LATM). Then, when dealing with the related problems of the client interface, this paper chooses two distributions, namely hypergeometric and beta distributions, both of which show that the new technology adopted by ICTM can effectively improve the quality of the chips produced by the company. From the data presented in this paper, it can be deduced that the data for the time (in years) before IC chip failure conforms to the characteristics of an exponential distribution. ABCtronics has a good chance of meeting PQR system expectations for product life of six years or more. For the construction of sales data model, this paper finds and demonstrates that the multivariate linear model proposed by SMT is not very reasonable.

Keywords: Probability distribution; Sampling distribution; Linear regression; Confidence interval.

1. Introduction

Statistics is widely used in business and economics and these fields include accounting, economics and finance. It is obvious that in these fields abundant data are required for the decision makers to decide wisely. In this article, methods of statistics will be used to solve some problems related to a semiconductor manufacturing called ABCtronics.

Making chips, or integrated circuits, utilized in common electrical and electronic equipment is known as semiconductor processing. On chips made of pure semiconductor materials, electronic circuits are gradually constructed through a succession of optical and chemical processing stages. Along with a number of other compound semiconductor materials, silicon is one of the most widely utilized semiconductor materials.

Semiconductor is one of the most important components of many important modern industrial plants. Since the conductivity of semiconductors can be controlled, which may be used as an instrument material for information processing. Whether from the view of science or modern society development, semiconductors are very crucial. It is used in the fields such as mobile phones, automatic chemical plants, and automobile production. Today's mainstream semiconductors typically include four parts: sensors, optoelectronic components, discrete components, and integrated circuits. When broken down by integrated circuits, they can be divided into four categories: logic devices, memory, microprocessors, and analog devices. Semiconductor has an extremely broad market, and its rise and fall are closely related to customers and market demand. For a long time, the driving force behind the growth of the semiconductor industry has shifted from the traditional PC and related industries to the mobile product market including smartphones and tablets and may shift to wearable devices such as VR devices in the future.

Integrated circuits (ICS) made of silicon and other semiconductor materials are an important part of modern electronic devices, and such highly modern products are now widely used in modern commercial industries. In order to successfully perform basic logical calculations in a computer, the requirements that these circuit devices need to meet include that they must be able to be switched

electronically to meet the needs of performing basic mathematical calculations in a computer. In order for electronic devices to be ready to switch on and off, circuits often need to contain semiconductor materials. From this we can see the importance of semiconductor materials in industry, and the manufacture of these semiconductor materials often involves quite complex steps. Developing, designing, manufacturing, marketing and servicing a range of semiconductor products requires years of industry experience and research. Semiconductor companies typically deal with multiple product families at different stages of the lifecycle at the same time. After product release, some customer contracts may specify that the manufacturer will continue to supply the product for about ten years. During this period, the manufacturer must ensure the quality of its own products. Therefore, many companies actively collect various production data and use statistical methods to analyze the data to ensure that product quality meets requirements.

Although initially a small company, ABCtronics has finally grown into a medium-sized company through continuous efforts, and the company is still looking for further development. The company has a variety of semiconductor product lines and maintains competitiveness by providing customers with high quality products. ABCtronics relies on one major customer (XYZsoft) for the majority of its business. Additionally, it should be noted that semiconductor manufacturing is highly correlated with cyclical demand patterns. Therefore, during times of high product demand, semiconductor manufacturers like ABCtronics must ensure that they have sufficient manufacturing capabilities to meet customers' high demands while maintaining product quality.

In semiconductor manufacturing companies like ABCtronics, it is important to focus on the quality assurance process to avoid major scrap events and higher costs. To solve these problems, we must use the knowledge of statistics. Improve operational efficiencies, post-processing issues, customer feedback and revenue growth potential. Below, we provide some data collected by ABCtronics, analyze ABCtronics' production-related problems, and solve the problems related to customer feedback and sales model prediction.

2. Associated data

Related data on ABCtronics has been collected and shown below.

Table 1. Downtime Data

Month	Downtime
July, 2012	3 hrs 36 mins
August, 2012	4 hrs 48 mins
September, 2012	4 hrs 36 mins
October, 2012	6 hrs 40 mins
November, 2012	5 hrs 24 mins
December, 2012	5 hrs 40 mins
January, 2013	7 hrs 20 mins
February, 2013	9 hrs 24 mins
March, 2013	8 hrs 40 mins
April, 2013	5 hrs 06 mins
May, 2013	6 hrs 20 mins
June, 2013	4 hrs 40 mins

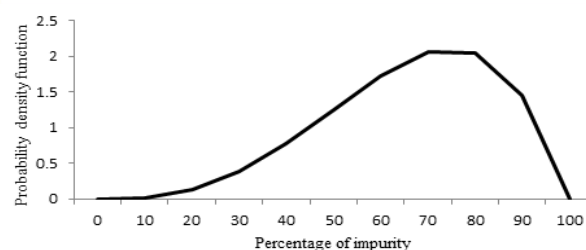


Figure 1. Chemical Impurity Found

Table 2. Rigorous Testing Report Portion

Time before failure (x)	Cumulative Chance to fail (%)
5	22.55
10	40
15	53.53
20	64.01
25	72.13
30	78.41

Table 3. Customer Sheet

Customer Name	Range
Customer A	Good
Customer B	Satisfactory
Customer C	Needs Improvement
Customer D	Good
Customer E	Good
Customer F	Satisfactory
Customer G	Satisfactory
Customer H	Needs Improvement
Customer I	Very Good
Customer J	Good
Customer K	Good
Customer L	Satisfactory
Customer M	Satisfactory
Customer N	Good
Customer O	Very Good
Customer P	Satisfactory
Customer Q	Needs Improvement
Customer R	Satisfactory
Customer S	Needs Improvement
Customer T	Satisfactory
Customer U	Good
Customer V	Very Good
Customer W	Good
Customer X	Satisfactory
Customer Y	Good
Customer Z	Satisfactory
Customer AA	Needs Improvement
Customer AB	Needs Improvement
Customer AC	Satisfactory
Customer AD	Good
Customer AE	Needs Improvement
Customer AF	Very Good
Customer AG	Good
Customer AH	Needs Improvement
Customer AI	Satisfactory
Customer AJ	Satisfactory
Customer AK	Good
Customer AL	Satisfactory
Customer AM	Satisfactory
Customer AN	Satisfactory

3. Analysis and results

3.1 Downtime and Chemical Impurity Problem

In some common areas such as process and plant engineering, plant engineers in charge of related areas must have a high degree of flexibility in the process of troubleshooting existing processes and

developing cutting-edge methods that can support the next generation of cutting-edge technologies. That is, being able to quickly make the right choice between goals and tasks. In addition to this, they must be able to handle large volumes of data, which may come from a variety of sources, and they are required to be able to make adjustments to processes quickly and accurately. Knowledge of data analysis allows companies to effectively monitor the process to ensure that the goods are of consistently standard quality. Validate and build new tools better and more efficiently and put them into practical use. Design experiments to develop new and more effective formulations. In addition, the relevant principles of data analysis can be used to manage and improve the quality of daily tasks.

Downtime is the duration in which a machine is idle or out of action. ABCtronics want to curtail it down to 5 hours. Thus, the data on the monthly duration of ion implantation for the last year has been collected, and we can see it in one table. Table 1 illustrates the data of ion implantation downtime in different months of 2012 and 2013, through which average downtime can be calculated and collected. Two men have different opinions on the issue of downtime, Stuart's idea was to reduce downtime from 6 hours to 5 hours to increase production time. However, Mark wanted the company to buy a new ion implanter because they didn't think five hours would be possible. Mark hold the belief that the data has a gamma distribution pattern while Stuart believes that it follows a uniform distribution.

People may have different views on distribution types as they take different factors into consideration. For example, someone might hold the belief that the monthly downtime of the ion implanter is independent and then he will find the gamma distribution. However, other people may argue that the data follow a uniform distribution, and this is because that they think the possibility of ion implantation can affect the overall production. This shows that every month of downtime will be influenced by replacing the ion implanter.

If we assume that the data follows uniform distribution

$$\text{Mean} = E(x) = \frac{a+b}{2}$$

$$\text{Variance} = \text{Var}(x) = \frac{(b-a)^2}{12}$$

We can obtain the value from Excel and solve the value of a and b

$$\frac{a+b}{2} = 6.01944$$

$$\frac{(a-b)^2}{12} = 2.76823$$

$$a = 3.1376, b = 8.9012$$

$$\text{So the pdf of } x \text{ is } f(x; a, b) = \frac{1}{b-a} = \frac{1}{8.9012-3.1376} = \frac{1}{5.7636}$$

The probability that the downtime will achieve 5 hours or less

$$p(x \leq 5) = \int_0^5 \frac{1}{b-a} dx = \int_0^5 \frac{1}{5.7636} dx = 0.8675$$

The probability is a big number, which means that the probability of the downtime less than 5 hours is big, so we can say that there is no need to change the ion implanter.

During production, certain chemical impurities are used, and some have been found to affect the chips if used above a certain level. Someone think it is reasonable to draw a conclusion that the company can successfully draw out of most of the useless impurities from the rare materials according to the calculations that based on Beta distribution after presenting the related analysis.

According to the Beta distribution data provided, we are able to find a chemical impurity more than 30% with a 96.9% probability. Because of which we can say that ABCtronics company has the ability to remove 96.9% of the chemical impurities that has been found in raw materials and not put them into the manufacturing process. In this case, I think it is safe to draw a conclusion that ABCtronics company can successfully draw out of most of the useless impurities from the rare materials with the current method.

3.2 Comparison of Quality Control Methods

A quality management technique called quality control is used to guarantee and continually enhance product quality. It discovers the law of quality differences, determines the factors that influence the quality differences, implements technical organizational measures, eliminates or controls the elements that result in defective or subpar products, and restores products as a whole production process through research and analysis of the distribution of product quality data. Every step in the process can be carried out naturally and optimally, allowing the product to ultimately acquire the natural qualities and traits required by people, including the product's applicability, dependability, and affordability. It has three characteristics: one is the use of quantitative statistical methods; The other is to focus on quality control throughout the production process; The third is the wide use of various quality data cards. The main functions of this law are: the design, manufacture and inspection personnel coordinate and cooperate in quality management; Development of quality management from simple carcass inspection to product quality control throughout the production process; The data recorded on the management chart is used to timely analyze the quality problems in the production process, so that measures can be taken quickly to eliminate the hidden dangers that cause quality problems and make the production in a stable state.

The Lot Acceptance Testing Process (LATM) quality control policy is inefficient. This is because the method uses a technique where a machine takes twenty-five IC chips for testing without swapping. The size of the chips is reduced by twenty-five, which means the output size is less than twenty-five chips, and if the sample has less than two defective chips, it is accepted. If there are two bad chips, it means there are probably others in the batch that haven't been tested. Because of this, customers complain about the high number of IC chips defective due to their inefficient test control method.

The LATM method draws 25 samples from 500 chips without replacement, here we can randomly sample a sample without replacement using the hypergeometric distribution. In Excel, we could enter "`=HYPERGEOM.DIST(1, 25, 2, 500, 1)`". Among them, "1" indicates that there are one or several defects in the sample; "25" is the sample size; "2" is calculated as 500×0.004 , that is, the number of successful people; "500" is the total population size; another "1" indicates the cumulative probability. and received a result of 0.9976. For ICTM, it randomly draws 25 chips with replacement. The Poisson distribution can then be used, "`=POISSON.DIST(1, 1, 1)`", with numbers representing one chip, 500×0.002 and cumulative, respectively. and received a result of 0.7358. Therefore, LATM has a defect that the pass rate is too high and too many IC chips pass through. Therefore, in comparison, the pass rate of ICAM is higher than that of LATM. This new approach achieves ABCtronic's goal of becoming a reliable brand and maintaining a positive relationship with its largest customer, XYZsoft. Hence, this will increase the company's market share.

It appears that operating effectively in the yield and quality areas necessitates utilizing a variety of data sets, including everything from customer acceptance data to statistical process control data and everything in between. The identification of problems' underlying causes, the formulation of corrective measures, and the identification of improvement possibilities that can boost productivity and cut waste all depend on data analysis. Create interactive wafer maps with ease. Create alternatives for reporting and visualization as soon as possible to better spot issues before they evolve into anomalies. Create a data collecting strategy quickly to direct investigations. Use artificial intelligence and machine learning to better direct root cause analysis. Manage and handle various datasets from various sources effectively.

3.3 Analysis on Client Interfaces

Basing the argument on the RP report it is evident that the chips produced by ABCtronic would last more than six years. PQR systems had requested IC chips that would work for six years, none stop. The chips produced by ABCtronics have been found to last for even forty years or more. That is why the mark was so confident that PQR systems expectations would be met, and the order would be secured. Since XYZsoft changed its testing policy ABCtronic has been on the receiving end. The

new policy of XYZsoft stated that if one defective chip was found, the whole lot was to be sent back to ABCtronic.

According to Figure 2 and Table 2, we can calculate the probability of time less than 6 years by first calculating λ using the probability density function. Then we can put "5 years" and the "cumulative distribution function of 22.5% failure time" into function=1-, which results in $\lambda=0.05$. Then using the Excel function for the exponential distribution, calculate the probability that the time is less than 6 years" = exponential distance(6, 0.05, 1) = 0.2592. Finally, $1 - 25.92\% \approx 75\%$ represents the percentage of the company that will meet the criteria. This is also Mark The reason for such confidence.

Hypothetical tests can be used regarding SHVP (Susceptible High Voltage Problems) and testing if electronics are overestimating the output of their chips. Then set the null hypothesis as $\mu=2.7V$ and the alternative hypothesis as . The z-score was calculated to be -2.22, which is less than -1.64 ($\alpha = 0.05$), and the P value was 0.0132, so we concluded that the IC chip produced a high-signal average voltage of less than 2.7V. Therefore, they are likely to overestimate the output of the IC chip.

3.4 Customer Feedback

Customer feedback reveals the benefits customers have experienced, their difficulties, and their pain areas, as well as why customers like and dislike your company's products. Generally speaking, we can comprehend the customer's perspective of the product from their feedback and take specific action to increase customer happiness. Focusing on client feedback and basing business choices on it can help the company optimize products and services, increase referral rates, increase customer retention, and provide a host of other advantages. These benefits are plain to see. When customer retention is enhanced, the customer retention rate can rise quickly; by increasing the number of referrals, we can find more new clients and the company can expand.

Table 3 in this article shows that most customers are satisfied with IC chips made by ABCtronic. People who consider themselves good or very good make up 80% of him in the entire sample population. 20% want his ABCtronic to improve the chip. The data are normally distributed with an expected value of 56.9 and a variance of 360.1948718. So, Robert's analysis of customer ratings can be agreed as the company has produced the chips for a long time and most customers acknowledge the standard of its chips. Since the customer scores follow a normal distribution and we know the sample variance, we use the Z distribution to find the confidence interval: $\bar{x} \pm z_{\frac{\alpha}{2}} \cdot \frac{s}{\sqrt{n}}$ and there is 90% confidence that the space is [51.9636645, 61.8363355].

For a confidence interval with a minimum error of 4, we use the formula of margin of error: $E = z_{\frac{\alpha}{2}} \cdot \frac{s}{\sqrt{n}}$, then we find the sample sizes is $n= 60.91$. Since the sample size must be an integer, the minimum sample size must also be 61. So at least it would be more useful to analyze data from a customer base of 61+ customers.

3.5 Sales Prediction Models

In the field of reliability, building sales production models from existing data is a challenging problem that requires unique insights into equipment physics, statistics, probability, and modeling. For companies like ABCtronics, the establishment of sales forecast models can have important guiding significance for actual production and cost forecasts. Therefore, ABCtronics collected various sales data from 2004 to 2013 and used different models to analyze the data. Modeling analysis.

ABCtronic's sales production model is a simple linear regression model. The model cannot predict next year's sales as it is based on ABCtronic's sales in previous years (Adhikari, Biswas & Bisi, 2016). SMT interns recommend using more sophisticated sales forecasting methods such as B. the multiple linear regression. Multiple regression methods have better explanatory power and do not have multicollinearity problems. The model also allows ABCtronic to plan ahead as it explains forecasts for the next year.

Yet I think the SMT interns' scheme is not very good. Here, R is used to carry out this multiple linear regression. Model: $\bar{y} = 8.860711 - 0.005239x_1 - 5.505411x_2 + 1.130183x_3$. The data can be simulated through multiple linear regression.

Due to three variables, I choose to use adjusted R square to judge the linear regression model. Through Examine variance inflation factor: $VIF = \frac{1}{1-R_j^2}$, we get that VIF is equal to 7.209367189, which is greater than 5. If the value of VIF is greater than 5, then it indicates multicollinearity, and the overall regression model gets affected by it. This is the reason why I think the plan is not very good. According to Phil, the expected sales are 2.063 million chips per year. Using the law of total probability, their probability of reaching 3million chips is 0.08, which is almost 0, so it can be said that it is impossible to happen.

4. Conclusions

There are several difficulties in analyzing each unit process in a semiconductor operation simultaneously. Companies must use more cutting-edge technologies if they are to adapt these processes to the requirements of the most demanding clients and industries on the planet. Potential revenue increases for both new and existing items can be quickly realized with a business analysis understanding. With data-driven root cause analysis investigations, waste can be reduced along with recovery attempts for sudden exceptions. Create interactive wafer maps with ease. Utilize an effective split plan to obtain the information you need to quickly address consumer requests. efficiently create useful insights from diverse datasets. Offer customers and decision-makers attractive data insights.

If the following suggestions are adopted, ABCtronics may have the opportunity to become one of the leading chip manufacturers in the market. First, they must check the quality control test and adopt the new ICTM system. Second, they should reduce the production cost as much as possible to ensure that they can obtain substitutes for R & D, which will reduce R & D expenditure and ensure that the research team is committed to improving the existing IC chips. The chemical impurities in the chip should be appropriate, because these chemicals may damage the quality of the chip. In addition, abctronics should be committed to expanding the customer market and should develop a new long-term customer base similar to XYZ software as the main buyer. The research team should focus on improving the existing IC chips and developing efficient and portable modern chips. The chemical impurities in the chip should be limited because these chemicals can damage the quality of the chip. Finally, it is important to adopt a new sales production model, and they need to be ready for the market to produce more chips. And the chip should always be enhanced to meet customer needs.

Here are some suggestions for the company. The company needs to consider finding more long-term partners instead of relying on one major customer. And the company's machine resources are overloaded to develop the maximum performance, which reduces the quality of production. The average machine down time should be 6 hours, but from the context it is clear that ABCtronic only allows a machine down time of 3 to 4 hours and if the machine is overloaded again and again its productivity will decrease over time. So I recommend the company to increase the downtime from 3 hours to 6 hours to give the machine enough downtime to get the quality and expected results. High financial investments in research that do not drive new inventions can also have a negative impact on companies. The research is right, but if it doesn't lead to new designs, its funding should be cut and reallocated to other departments. The quality testing process should be edge-locked to ensure all chips are made compliant to avoid complaints from XYZsoft. Chemical contamination is also a factor affecting the ABCtronic. The chemicals used in the manufacturing process should be controlled to avoid producing defective chips. I think the development of a company is inseparable from technical requirements, improving product quality and teamwork. Obviously, there are contradictions in the company, there is no consensus and no clear understanding of the problem. In my opinion, we should not only improve technical quality and plan for financing, but also strengthen teamwork and make them aware that teamwork can maximize the impact of the solution.

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