



Funnel Experiments

Sheng Pin Kuan*

CSQ / QKC, Taipei, Taiwan

*Corresponding author: Sheng Pin Kuan, CSQ/QKC/ESG service team, Taipei, Taiwan; E-mail: pin12345@ms5.hinet.net

Abstract

In the book “Four Days with Dr. Deming”, Dr. Deming explained the problems of management and intervention with funnel experiments. Managers often interfere with the system due to lack of statistical thinking about system variation, causing the problem becomes more and more complex. For example, in the quality meeting, the management level in the factory requests the process with the highest defective percentage to propose an improvement plan; in the business meeting, the manager requests the salesperson who got a decline in sales volume to propose a countermeasure. However, in the long run, the defective percentage is still high or low; the monthly sales volume is still good or bad. In the past, mentors in the school ranked the students on a weekly examination basis, and warnings were given to the students who had stepped back (it should still be the same now). The students' rankings are still there. Much of the variation in these data is the normal variation of the system, which is the so-called Variation of the Common Cause. However, managers intervene on these variations and take corrective actions to make the system more complex. For example, process personnel hide defective products to make the defective percentage looks good; business personnel falsely report sales volume to make the book looks good; students go to the cram school to practice the examination topics first to make the ranking progress. These phenomena are common in our work or living environment. We should first understand whether the system variation is caused from the Special Cause or only the Common Cause, and then take appropriate actions.

Keywords: Control chart; Common cause; Special cause; Funnel experiments

Introduction

“Close to Academician”: Liu Yuanzhang: China's "factory doctor." In the article, Liu Yuanzhang, the father of Chinese quality, told a story [1]:

His first test was completed in 1957 at the Shanghai State-owned Second Textile Machinery Factory. The main product of this factory is the textile machine, one of which is the key component of the fine grinding process. Liu Yuanzhang saw in the workshop that the operator who worked on the grinding machine was an old master. Every time he finished grinding one piece, he handed it over to the young master. After the young master accurately measured the product size, he told the old master whether it was thick or thin. Liu Yuanzhang draws the data measured by the young master into a trend chart according to the processing order, and then asks the old master to process it alone without the help of the young master, and then draws the finished product data into

a trend chart. It is clear from the charts that the data of both processing fluctuates around the standard size. However, the fluctuation of the processing time of the old master alone is obviously much smaller than when they cooperate. The reason is that the old master is rich in experience, when the young master is on the side, he interferes with the old master's operation. Liu Yuanzhang explained through this small example that quality control is not a traditional simple statistical test. Instead, it controls the factors affecting product quality in the production process through the principle of mathematical statistics, so as to make the product quality fluctuate in every link as much small as possible. Ultimately achieve stable, high-quality production on the whole. In the book “Four Days with Dr. Deming” [2], Dr. Deming explained the problems of management and intervention with funnel experiments. Managers often interfere with the system due to lack of statistical thinking about system variation, causing the problem becomes more and more complex. For

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example, in the quality meeting, the management level in the factory requests the process with the highest defective percentage to propose an improvement plan; in the business meeting, the manager requests the salesperson who got a decline in sales volume to propose a countermeasure. However, in the long run, the defective percentage is still high or low; the monthly sales volume is still good or bad. In the past, mentors in the school ranked the students on a weekly examination basis, and warnings were given to the students who had stepped back (it should still be the same now). The students' rankings are still there. Much of the variation in these data is the normal variation of the system, which is the so-called Variation of the Common Cause. However, managers intervene on these variations and take corrective actions to make the system more complex. For example, process personnel hide defective products to make the defective percentage looks good; business personnel falsely report sales volume to make the book looks good; students go to the cram school to practice the examination topics first to make the ranking progress. These phenomena are common in our work or living environment. We should first understand whether the system variation is caused from the Special Cause or only the Common Cause, and then take appropriate actions.

Funnel Experiments

The so-called "funnel experiments" means that we have a funnel, which is mounted on a table about half a meter high, there is a target on the table. Suppose we put a marble into the funnel, regardless of the way we put it down, the marble will roll down the funnel in a random way. Then it will fall from the bottom of the funnel to the target and mark it with a pencil. We use some simple rules to aim the funnel at the target, these rules are quite equivalent to some of the rules we use in operating equipment, controlling processes or managing systems.

For the convenience to do the interpretation of the statistical model and the simulation of the data, we illustrate it in the time series of two dimension. With zero as the target value, Y_k : The drop point of the kth marble, $Y_k > 0$ means that the drop point is higher than the target value; $Y_k = 0$ means that the drop point is exactly at the target value on. u_k : The kth aim position, $u_k > 0$: means that aim over the target; $u_k = 0$: means that aim below the target; means that aim at the target value. Assume that each marble has a random error between the drop point and the aiming position, which is assigned as $N(0, \sigma_e^2)$. Here are the four rules of the funnel experiments:

Rule 1: At the beginning, aim at the target value, and then the aiming position is not adjusted every time. The statistical model is as shown in Figure 1 and the following formula (Figure 1):

$$u_0 = 0$$

$$Y_k = e_k, \quad u_k = 0, \quad k = 1, 2, \dots, n \dots \dots \dots (1)$$

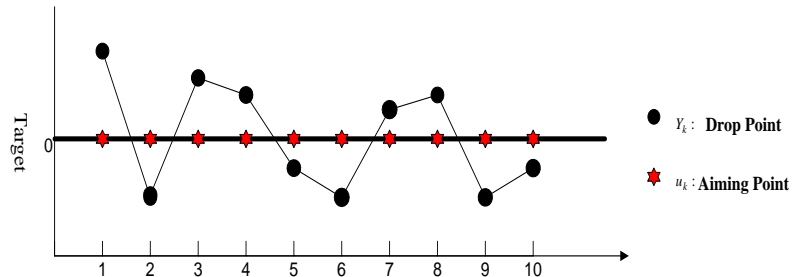


Figure 1: Rule 1.

Rule 2: According to the difference between the last drop point and the target value Y_{k-1} , the aiming position is adjusted in reverse by the previous aiming position $u_k = u_{k-1} - Y_{k-1}$; and its statistical model is shown in Figure 2 and the following formula (Figure 2):

$$u_0 = 0, \quad Y_0 = 0 + e_0, \quad u_1 = u_0 - Y_0 = -e_0, \quad Y_1 = u_1 + e_1 = -e_0 + e_1$$

$$u_2 = u_1 - Y_1 = -e_1, \quad Y_2 = u_2 + e_2 = -e_1 + e_2, \dots \dots \dots (2)$$

$$u_k = u_{k-1} - Y_{k-1} = -e_{k-1}, \quad Y_k = u_k + e_k = -e_{k-1} + e_k, \quad k = 1, 2, \dots, n$$

It can be obtained by 2

$$Y_k = -e_{k-1} + e_k$$



Figure 2: Rule 2.

Rule 3: Same as Rule 2, but before the adjustment return to the target value, the statistical model is shown in Figure 3 and the following formula (Figure 3):

$$\begin{aligned}
 u_0 &= 0, Y_0 = e_0, u_1 = 0 - Y_0 = -e_0, Y_1 = u_1 + e_1 = -e_0 + e_1 \\
 u_2 &= 0 - Y_1 = e_0 - e_1, Y_2 = u_2 + e_2 = e_0 - e_1 + e_2 \\
 u_3 &= 0 - Y_2 = -e_0 + e_1 - e_2, Y_3 = u_3 + e_3 = -e_0 + e_1 - e_2 + e_3 \dots\dots\dots (3) \\
 &\dots\dots\dots \\
 Y_k &= u_{k-1} + e_k, \\
 k &= 1, 2, \dots, n
 \end{aligned}$$

It can be obtained by 3

$$Y_k = \begin{cases} e_0 - e_1 + e_2 - e_3 + \dots\dots\dots + e_k, & k \text{ is even} \\ -e_0 + e_1 - e_2 + e_3 + \dots\dots\dots + e_k, & k \text{ is odd} \end{cases}$$

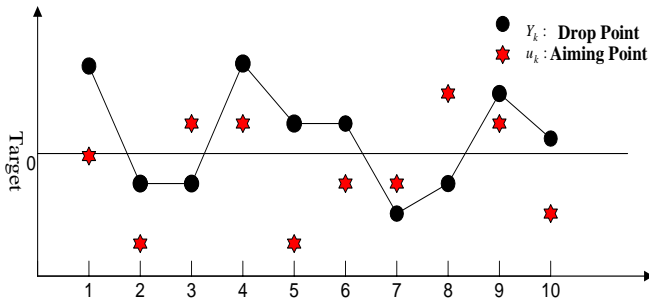


Figure 3: Rule 3.

Rule 4: Aiming for the last drop, the statistical model is as shown in Figure 4 and the following formula (Figure 4):

$$\begin{aligned}
 u_0 &= 0, Y_1 = e_1, u_1 = Y_1 = e_1, Y_2 = u_1 + e_2 = e_1 + e_2 \\
 u_2 &= Y_2 = e_1 + e_2, Y_3 = u_2 + e_3 = e_1 + e_2 + e_3 \\
 &\dots\dots\dots (4) \\
 Y_k &= u_{k-1} + e_k = e_1 + e_2 + e_3 + \dots + e_k, \\
 k &= 1, 2, \dots, n
 \end{aligned}$$

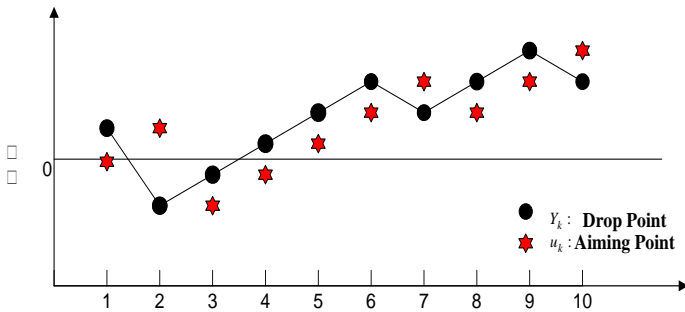


Figure 4: Rule 4.

It can be obtained by 4

$$Y_k = e_1 + e_2 + e_3 + \dots\dots\dots + e_k$$

From the statistical models 1, 2, 3, and 4, the variation of Rule 1 is $\sqrt{\text{VAR}(Y_i)} = \sqrt{\text{VAR}(e_i)} = \sigma_e$; the variation of Rule 2

$$\sqrt{\text{VAR}(Y_k)} = \sqrt{\text{VAR}(-e_{k-1} + e_k)} = \sqrt{\sigma_e^2 + \sigma_e^2} = \sqrt{2}\sigma_e$$

is about 41% larger than Rule 1; the variation of Rule 3 is up and down around the target value, the more observation point is, the

bigger the variation is; the variation of Rule 4 is random walks, and the variation is getting bigger and bigger.

Data Simulation

Assume that each marble has a random error e_k between the drop point and the aiming position, which is assigned as $N(0, \sigma_e^2)$. In this way, we can easily simulate the four adjustment rules. The following is the result of our simulation, as shown in Figure 5 and Figure 6. Assuming $\sigma_e = 2$, the specification is 0 ± 20 (Figure 5,6).

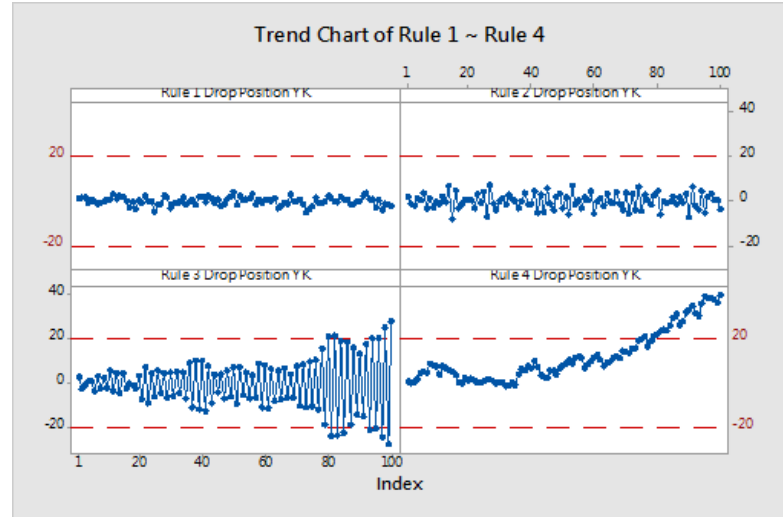


Figure 5: Trend Chart of Rule 1 ~ Rule 4.

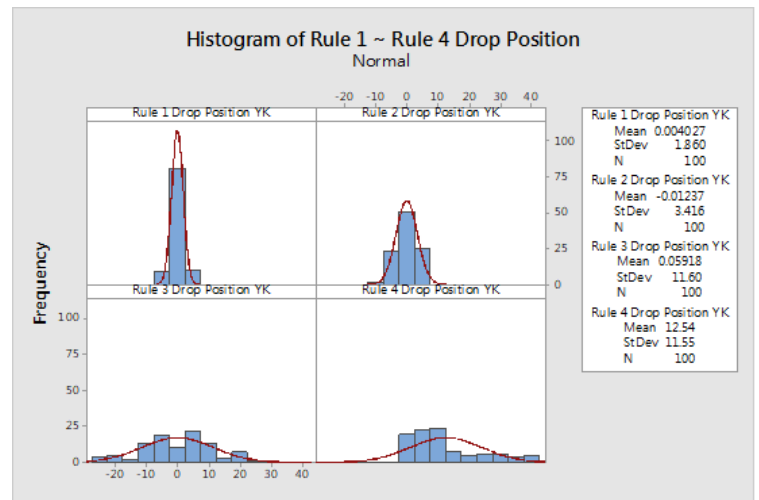


Figure 6: Histogram of Rule 1 ~ Rule 4.

Examples of Management

Rule 1: Aim at the target value each time



The purpose of process control is to economically and effectively control product or process quality. In other words, when the process has only common cause variation, do not adjust or tamper with the process; when there are special because variations in the process, do not ignore the corrective action. The purpose of process control is to make the process under the statistical control, as shown in Figure 1, so that its variation only originates from the common cause of the process. In this way, it is possible to monitor the process that can be perceived when special causes arise, and to remove the bad effects of the product or process quality, and to retain the benefits of the product or process quality.

Rule 2: Adjusted in reverse by the previous aiming position

It can be regarded as the system under the common cause of variation, due to the operations and management personnel lack of understanding of the system, interfere with the system, and make the system structural changed. Unless the system itself is influenced by some predictable factors, rule 2 can be applied to adjust the system to reduce its variation. For example, the air conditioner's automatic temperature control system adjusts the amount of cold air as the room temperature changed so that the room temperature is at a fixed temperature. MacGregor once explained that the average change in the system is predictable, and Rule 2 will have less variation than Rule 1. Therefore, when interpreting Rule 2, we must assume that the system is under the common causes of variation. The following examples illustrate [3]:

- Automatic process control often adjusts the process by the results of the previous process status;
- Operators always adjust the process compensatory with the difference between measurement result and the target value;
- The teacher of the junior high school in Taiwan always determines the severity of the penalty by the student's test score;
- When cooking, it is customary to taste salty, add water or salt to neutralize salty, making the dishes that are served each time differently.

Rule 3: Adjustment return to the target value

As the compensatory adjustment of Rule 2, the adjustment returns to the target value and then adjusts the difference. When there are common causes in the system, the variation will be greater than the adjustment method in Rule 2.

- The salesman's performance in the month is lower than the target of 100,000 yuan, and the next month's performance must reach the target plus 100,000;

- Political ideology, in accordance with public opinion or votes, reverse adjustment of governance;
- Loss of gambling or stock investment, double gambling investment or investment, hope to win back the money, the result is not a big lose or is a big win, usually a big lose;
- The current budget of the public agency has not been used up, in the next period, we should use more to make up for it.

Rule 4: Aiming for the last drop

This is the most common mode of intervention and is visible in almost all industries, governments, and academic institutions. The following examples can illustrate:

- The operator takes previous production result as the standard, and follows the standard to produce, omits the original standard;
- When the engineering change, only refer to the last version as the basis for the change, without tracing the original design;
- In the education and training situation, the old students teach new students or a elder students lead his younger students, but those student teachers without well-trained;
- Budgeting is based on the result of the previous period and multiplied by some percentage, without any plans;
- A kind of TV program, the host gives the first performer a title, the first performer is shown by hands without talking to the second performer, the second performer do the same way to the next performer, and so on. After a long run the final performer announces the title which he thinks what is, usually very far away.

Conclusion

The funnel experiment emphasizes that managers must use statistical thinking ways to distinguish the variation of the process system caused by common causes or special causes. If there are special causes, the managers should detect and correct it. If the variation of process system due to common causes, the managers do not interfere it, just study the process system capability is large enough to improve it. These are traditional SPC methods such as, Shewhart Control Chart, CUSUM Chart, and EWMA Chart, which are used to monitor the process or system. However, engineering process control often uses some control methods to adjust the process system when the process system is floating, so that the process system does not deviate from the target or increase the yield of the process system. In the field of automatic control has been applied for a long time, generally referred to as Engineering Process Control (EPC). These two areas are originated from different industrial patterns. SPC uses the component industry as the object of application, while EPC uses the process flow industry as the object. In recent years, the quality methods of these two industries have not had much difference



based on the development of mixed industries. For example, in the IC industry, the pre-process is a process flow industry, and the post-process is a component industry. Therefore, the integration of SPC and EPC applications will be the trend of future process control [4].

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