A Six Sigma Control Chart

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ABSTRACT

A Six Sigma control chart is proposed as a cross functional management tool and illustrated with an example. The benefits of using this control chart and the role of SAS programming are described. The fundamentals of Defects Per Million Opportunities (DPMO) and Defects Per Million Units (DPMU) are introduced, and the relationships between these units for attribute and variable data are discussed. In addition, the methods to achieve six sigma quality are elaborated with two prevention approaches.

INTRODUCTION

There are generally three levels of reporting structure for most organization regardless the nature of business. The structure consists of operational, middle management and executives levels. From quality information perspective, the ability to measure improvement over time and to report that improvement to these levels is a key feature of any good quality information system. Apparently, a tool or mechanism to achieve this goal is a necessity for any world class organization.

The traditional control charts such as X-bar and R control charts are excellent in providing trending and tracking information. However, they are ineffective to be used as a reporting tool. The measurement units used in these control charts are meaningful most of the time only to the affected department and personnel. This implies a lack of a common communication language exists across different functional areas. To circumvent this problem, Motorola Corporation proposes a unique measurement unit, and it is named Defects Per Million Opportunity (DPMO) or Defects Per Million Units (DPMU). Although these units have different applications, they are conceptually equivalent. The significance of the measurement unit is that it provides a single communication language, and thus saves unnecessary duplicating information stored in either paper or computer system.

The purpose of this paper is to incorporate DPMO or DPMU measurement unit into a control chart format for better utilization. The control chart is named Six Sigma control chart, and it provides the same functionality as the traditional control chart. In other words, it provides only the monitor function. The term "control" is used mainly to emphasize the fact that the monitoring function will provide the necessary information for any subsequent control actions. In a way, the corrective control action is the by product of the monitoring activity.

WHAT IS SIX SIGMA

To understand the concepts of Six Sigma, the concepts of Defects Per Unit (DPU) and Defects Per Opportunities (DPO) need to be introduced. DPU and DPO have different implications from attribute and variable data perspectives:

Attribute Data

DPU is the counting of defects per unit of product, however, a better unit to use is Defects Per Million Units (DPMU). Since the DPMU deals with similar products, it is an excellent tool for tracking trends but will be inappropriate for comparing the quality of dissimilar products. To compare dissimilar products, the Defects Per Million Opportunities (DPMO) unit should be used. The DPMO allows the quality of a wide variety of products and services to be compared on an equivalent basis. Similar to the DPMU unit, the DPMO is the ratio of number of defects to all defect opportunities.

Table 1 shows the relationship between the sigma value and the defect level. From the table, it indicates that a six sigma quality requires 3.4 DPMO which is the quality level targeted by a world class organization. Nevertheless, this quality level should be used only as a guide since benchmarking may be required in some extreme cases. Under those cases, it is possible that a six sigma quality process or service may not be a world class quality.

Since most products or processes have multiple defect opportunities, the DPMU will be somewhat higher even for the same six sigma quality. In general, the higher the number of defect opportunities, the higher is the DPMU number. Table 2 shows the relationship between the

Number of Defect Opportunities (NDO) and the DPMU for the same six sigma quality level.

Variable Data

Six sigma quality for variable data means any process or service that has an average of less than 3.4 DPMO. This implies that the process average must remain at least 4.5 standard deviations from the nearest specification limit. Table 3 shows the relationships between the lower tail of normal process curve and its corresponding percentage in tail.

The other way of interpreting six sigma quality is to use the process capability index (Cpk). For six sigma quality process or service, this index should always be at or above 1.5 at all times.

Since variable data deal with the shape of process distribution, proper targeting and variation control become a major issue. Under six sigma quality, process average will have a +/- 1.5 sigma window and process variation will be allowed to vary among +/- 4.5 sigma, assuming that the specification limits are at least +/- 6 sigma wide. This implies that as long as the process average does not deviate from the target by more than +/- 1.5 sigma and the process variation does not vary more than +/- 4.5 sigma, the process is a six sigma process.

HOW TO ACHIEVE SIX SIGMA

Six Sigma quality is achieved through defect prevention and therefore some fundamental changes of the process are usually required. The method of prevention is through two approaches: (1) mistake proofing and (2) optimization and variation reduction. These two approaches can be applied to fixing existing problems and preventing new problems.

Mistake proofing is normally used for attribute data and it is especially efficient when the problem is error or omission. The optimization and variation reduction approach is normally used for variable data under the improper average or excessive variation situation. However, both approaches have many exceptions. To select either approach, one should keep an open mind and concentrate on the underlying defect cause rather than its current measurement method. One should also be ready to switch one approach to another as new evidence arises.

In some situations, multiple causes can exist and each of them should be treated individually. It is important to identify all contributing causes and select one or ones to tackle, and then apply the appropriate prevention method to each targeted cause. In general, mistake proofing is to identify all potential problems and improper average or excessive variation is to drive the average to target and also reduce the variation.

SAS EXAMPLE

Figure 1 illustrates the format of a Six Sigma control chart. The significance of this control chart is that it provides a standardized format for all applications. The vertical axis of the control chart will always be fixed, ranging from o to 6 sigma. The quality level of the process or service may require more than 6 sigma in some extreme cases, only then should the vertical axis be modified. The required modification poses no difficulty with SAS programming. On the other hand, the horizontal axis will require changes in most cases.

The SAS statement used to create the Six Sigma control chart is the PROC PLOT statement. This may not be the most efficient way to generate the chart, it is however not the intention of this paper to illustrate the best SAS programming practice. Furthermore, since the SAS system provides an integrated system environment, the automation of this control chart will require some minor efforts. This is a significant advantage of SAS in comparison to most statistical packages for quick application prototyping or development.

Although Figure 1 shows only one trend line, multiple trend lines with different color coding would be the normal case. The different lines can compare each other for short or long term periods under one control chart. Comparison of multiple control charts is also possible as they are all using one standardized scale. This is usually not the case when the traditional line or bar chart is used.

Another advantage of using this control chart is that a common language "sigma" is used in this control chart. Since sigma levels are not in proportional magnitude, the move from one sigma level to another level implies a change of large magnitude of DPMO or DPMU. The use of DPMO or DPMU in this case will obviously create an awkward presentation. The use of sigma unit however will create a clear and concise quality image for all products or services.

CONCLUSION

There are many ways to attain world class quality and the proposed Six Sigma control chart provides another tool to achieve this objective. Like most other tools, some business practices need to be changed in order to fully grasp the benefits of this control chart. In this case, the major challenge would be the training in terms of interpreting and communicating in sigma unit.

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Table 1. Sigma Versus Defect Level

Sigma	Letter Grade	Defect Level (defects per million opportunities)
6.0	A	3.4
5.5	A-/B+	32
5.0	B	233
4.5	B-/C+	1350
4.0	C	6210
3.5	C-/D+	22,750
3.0	D	66,810

Table 2. Number of Defect Opportunities Versus DPMU

Number of Defect Opportunities	Defects / Million Units
1	3.4
2	6.8
3	10.2
4	13.6
5	17
10	34
15	51
20	68
30	102
40	136
50	170
100	340
200	680
400	1,359
1,000	3,398
1,500	5,097
2,000	6,794
5,000	16,988
10,000	33,977

Table 3. Top of Lower Tail Versus Percentage in Tail

Top of Lower Tail	Percentage in Tail
-5	0.3 per million
-4.5σ	3.4 per million
-4σ	31 per million
-3.5σ	233 per million
-3σ	0.135%
-2.5σ	0.6%
-2σ	2.3%
-1.5σ	6.7%
-1σ	15.8%
-0.5σ	30.9%
0	50%

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