Discovering the 'Real' Data in Multi-Vari Analysis Charting

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Abstract

Multi-Vari Analysis Charts are distinct from multivariate control charts. A Multi-Vari Analysis Chart is graphical and is helpful in assessing variability due to three or more factors. It clarifies and simplifies the study of the spread of individual measurements in a sample. In contrast, the multivariate control chart is complex in construction and data interpretation. The Multi-Vari Analysis Chartiscurrently underutilized by practitioners. T the value of is discovering the 'hidden data' in the Multi-Vari Analysis Chart over both the multivariate and $\overline{X}$ R control charts.

Keywords: Multi-Vari Analysis Charts, Six Sigma Tools, multivariate control chart

1.0

Recent literature searches considered the value of Multi-Vari Analysis. Most variable data are only partially understood, even with the aid of $\overline{X}$R charts, box-whisker plots, and histograms. Examples of misunderstood measurements are variability in area surface thickness, even in Poisson samples. However, the Multi-Vari Analysis Chart clearly demonstrates the nature of data and elevates the findings to the status of useable information for understanding and root cause analysis. Multi-Vari Charts are of value analogous to the R portion of the control chart's variability, but at a broader view of the sample.

2.0

The Multi-Vari Analysis Charting must not be confused with the more restrictive multivariate control chart. The multivariate control chart, appropriately named Hotelling's T 2,is scalar and combines information from the dispersion and mean of several variables that lend to somewhat challenging interpretation of root causes.[1]Computations may be laborious and fairly complex and require some knowledge of matrix algebra. Acceptance of multivariate control charts has been slow while Multi-Vari Analysis Charting is simple and exposes the true array of data. Most measurement data are naturally diffuse and warrant a Multi-Vari Analysis Charting approach. The Multi-Vari Analysis Charting data profile of interest are evaluated at extremes (i.e., around diameters, along lengths, or across surfaces) and the measurements are plotted as vertical lines connecting the minimum and maximum values.

3.0

The resultant Multi-Vari Analysis provides the quality characteristic of interests plotted across three horizontal panels to represent:

- Variability on a single piece
- Piece-to-piece variability
- Time-to-time variability
- The quality characteristic of interest is plotted against upper and lower specifications rather than control limits.

4.0

Sneediscusses the 'Eight Essential Tools' used in Six Sigma methodology. Included in this list are Multi-Vari Analysis Charting studies. The author notes that Multi-Vari Analysis Charting contains valuable information. He explains the advantages and disadvantages of using a Multi-Vari Analysis Charting study as 'one of the most important and versatile Six Sigma tools…'[2] An additional comment on Multi-Vari Analysis Charting is, 'The objective is to find the input variables and the control and uncontrolled (noise) process variables that affect the process output variables.' Sanchez notes Multi-Vari Charting has gained popularity in Six Sigma problem solving.[3]

4.1 Negatives of multivariate control charts

The mantra of quality data evaluations is 'value added' information. Unfortunately, as Sneepointsout, the difficulty with multivariate control charts is that theydo not provide managers with the information most critical to the business.[4] There is considerable non-value added information as opposed to more inclusive information in Multi-Vari Analysis Charting. Alipour and Noorossanaattempted to modify some of the complexity of multivariate control chart by the use of fuzzy multivariate exponentially weighted moving average (F-MEWMA) control charts, but it has not been of significant value because of the complexity of the adjustment.[5]

4.2 Popularity of Multi-Vari Analysis Charting

Relative to Six Sigma, Ronald focuses on picking the right tool for the job.[6]In addition, Sang-Gyu Limstates,'In looking at Six Sigma project implementation using the DMAIC roadmap, the tools should be used strategically.[7] If the main problem is controllability, identifying the assignable noise identification is critical, and using the multi-vari chart is helpful.' He explains the differences between process capability and controllability and walks us through a case study which involves a service company wanting to decrease the number of customer claims they receive. After the data collection effort, the author suggests, '…the company's first effort should be to resolve the assignable causes using control charts and process noise analysis with multi-varicharts is helpful.'[8]

4.3

Snee, along with the development and use of models and regression analysis, suggests Multi-Vari Analysis plays a part in the process. 'The Six Sigma tools of multi-vari studies and design of experiments are used to develop models of this type. These tools rely heavily on the useof regression analysis to develop the models and interpret the results of the multi-vari studies and process experiments.'[9]Multi-VariAnalysis provides additional insight as to how this important tool can be used.

5.0 Examples Using Multi-Vari Chart

Inthe Banuelas case study (film coating process waste reduction), they walk us through the project selection process as well as each of the five Six Sigma phases highlighting the tools that are used. The Multi-Vari chart is used during the analyze phase of the case study. The authors note that, 'Multi-Vari studies help associate key 'X' and the project 'Y', identify noise variables and reduce the number of 'X' for the improvement phase. In addition, they are helpful in obtaining and understanding the process during its natural variation.'[10]

5.1

Valles discusses a case study for assembly of automotive speakers. Each of the five Six Sigma phases isexplained and the tools used. The team uses a Multi-Vari chart during the Analyze phase of the project to isolate the cause of variation in the diaphragm height.[11]

5.2

Preliminary steps are taken to create the Multi-Vari chart:'To do the Multi-Vari Chart, a long term random sample of size 48 was selected, stratifying by diaphragm batch, speaker type and shift. The main causes of variation seem to be batch raw materials (diaphragm and coil) used, and the second work shift in which the operators had not been properly trained.'This is another example of dual discovery via the Multi-Vari Charting

Sneefocuses on Six Sigma and Multi-Vari charts.[12] The author says that one of the most important and versatile tools is the Multi-Vari study because it is useful in both manufacturing and non-manufacturing environments.

The objective is to find the input variables and controlled and uncontrolled (noise) variables that affect the process outputs. Analyses of Multi-Vari studies discover the presence of correlation among the process variables, known as multi-co-linearity. It is among the predictor variables (X's) that can lead to erroneous errors.

6.0

Goodman makes use of Dorian Shainin's Design of Experiments (DOE) in an industrial honing operation. The Red X is the most influential factor, which identifies the corrective actions.13The problem that is being solved is the out of roundness of cylinder bores after honing. Multi-Vari analysis is used to determine whether a variation pattern is positional, cyclical, or temporal (time related). After completion of the Multi-Vari graphs, it is possible to determine which family of variability that the honing process was most influenced. They were able to determine that positional variability is the major factor for the out of roundness condition.

7.0

Annastudied Multi-Vari analysis in a non-manufacturing setting. The study is a problem of daily discrepancies between the warehouse inventory and the receiving documents in the company.14 The goal of the team is to determine a method to reduce and eliminate the causes of discrepancies by eliminating the sources of variability in the process. They collected data where the variability is occurring in the process and completed a Multi-Vari analysis. Data are collected frequently enough to ensure that all possible sources of variation are measured. The Multi-Vari charts reveal that a large variation exists in the data depending upon the number of workers and when the samples were taken. They also gathered information such as the average proportion of mistakes during the day or with a specific number of works.

7.1 Measurement of data Dispersion

Banuelas contrasts and compares Multi-Vari Charting to,$\overline{X}$ R control charts and concludes that the Multi-Vari Analysis Charting presents an analysis of the variation, differentiating among three sources: (1) intrapiece, the variation within a piece, batch, lot, and so forth; (2) interpiece, the additional variation between pieces; (3) temporal variation, variation related to time. 'They also noted that historically, Seder (2) introduced the Multi-Vari Analysis Charting and compares it with the (, R) control chart.15

7.2

Snee focuses on improvement in the reduction of variations in process management. He explores the four most common Multi-Varistudies.16 The first study, called Type A, is designed to assess the effects of uncontrolled variables, which are the noise variables, such as human interaction. Type B is the design of the sampling schemes to monitor process performance. Type C is the process step study, which studies the different materials involved in a product, and the processes used to manufacture the product. Temporal variation studies are the Type D analysis. Sampling studies can be nested and used to estimate the sources in the variation of a process that is associated with time such as a month, week, day to day, or hour to hour, for example.

8.0 Software in Multi-Vari Analysis Charting

Goodman recommends (there is an updated version) the Multi-Vari software, Shain in Assistant for Windows.17 The software was developed by Marion Software located in Seattle, WA. It is made up of eight different modules with Multi-Vari Analysis Charting as one of the modules. This module, '….divides process variations into broad families to focus further research where it will do the most good.' The focus of the Rogers Corp is used to reduce the number of paper jams in its copy machines.

9.0 Getting the Most Value of Multi-Vari Analysis Charting Work

Annanotes,'Multi-Vari divides the many variations in a process into broad families. A variable belonging to any family, except the family containing the largest variation can then be eliminated, focusing further research where it will do the most good. The module allows the user to construct data hierarchies that can accommodate most manufacturing processes.'18

9.1

Schultzpraises Mult-VariAnalysis Charting as it sorts through all the extraneous clutter to find the pertinent variables and eliminate insignificant variables in finding a solution to a particular issue, as the Red X, which is the largest cause of variation in the Shainin system.

Multi-Vari Analysis Charting divides the many variations of a process into broad families. Any variable that belongs to the family and containing the largest variations (RED X), can be eliminated. It concludes that the module allows the user to construct data hierarchies that can accommodate most manufacturing processes.19

10.0

Ledolter introduces another quality improvement tool called a statistical engineering (SE) algorithm.20The need to isolate and eliminate the dominant cause of the variation in a process is evaluated. The focus of the case study presented in this article was the reduction of variation in key crossbar measurements. The Multi-Vari Chart is used during the define phase of the project. 'The Multi-Vari chart shows that the dominant cause acts hour to hour with some evidence of day-to-day differences.'

11.0

Figure 1 Three Views of the Same Surface Noting the Disparity of Variable Data
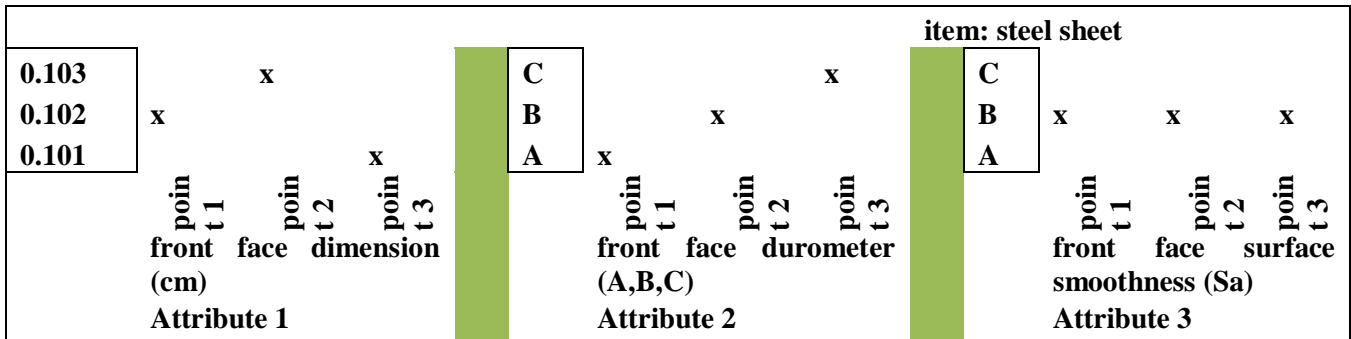
The premise of a Multi-Vari Analysis Chart utilizes graphics to understand where the variation in a process exists. Is it excessive variation within a single piece, excessive variation from piece to piece, or is the variation excessive from time to time.22If relating to service delivery, substitute service delivery to customers, service delivery from customer to customer, and service delivery from time to time. Multi-Vari Analysis Chartstudies are often classified as either a 'nested design' or a crossed design. In the nested design, the data are collected without making changes to the process to investigate where the variation is coming. It could be positional which is within piece variation, it could be cyclical which is a consecutive piece-to-piece variation,or it could be temporal which is time-to-time variation such as day-to-day, or week-to-week. The following graphic is an example in finding the source of process variation with regard to warp in a glass container.

Figure 2: Multi Vari Analysis Hourly for Warp on Same Product (Permission Granted from Educate Virtually)[22]
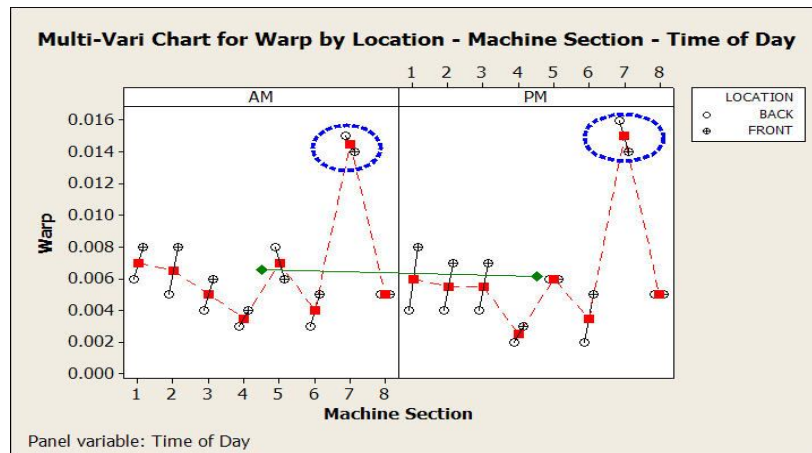
11.1

From this Nested Design Multi-VariAnalysis Chart we can see that Machine Section 7 is very different from any other section on the machine. Section 7 becomes the target for variation reduction. The question becomes, 'Why is it so different from the rest of the machine?'.In the Crossed Design, the plan is to test changes to the process in a balanced manner following an on or off strategy. In the Crossed Design either two or three potential variation contributor process variables are studied at two different settings. Analysis of Variance is often added as part of the study to provide detailed statistics that support what the graphic analysis portrays. An ANOVA provides the verdict of 'guilty beyond a shadow of a doubt' to support what we see graphically. The following graphic is an example where we are trying to minimize the time it takes to boil a cup of water in a microwave oven.

Figure 3 Multi Vari Analysis of Same Solution at Different Points X (Educate Virtually-Permission Granted)[23]
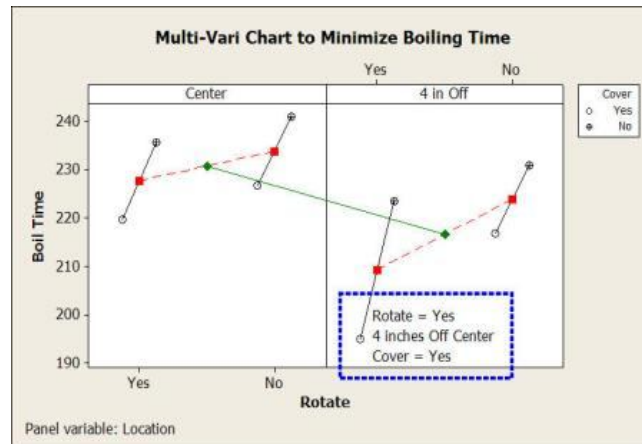
From this Crossed Design Multi-VariAnalysis Chart, it can be observed that to minimize the time to boil a cup of water in a microwave oven, the container should be rotated, located four inches off center, and covered. To add further proof to this graphic's finding an analysis of variance (ANOVA)confirmed the graphical results. The sources of variation are Cover, Rotate, and Location. Each are significant with p values that are less than 0.0009 (assume worst case for the unknown 4th digit to be 9) which equates to a confidence level of at least of 99.91%.

12.0 Key Eruditions

1. Multivariate control charts have not provided managers the information most critical to the business.
2. Once the causes for the failures are identified, Multi-Vari analysis is used to further define the reason for the failures. By reducing variances in the data, it is easier to identify the root cause of the problem and to develop a viable solution.
3. A Multi-VariAnalysis Chart during the Six Sigma analyze phase of the project isolates the cause of variation in diaphragm height.
4. By using Multi-VariAnalysis Charts and Six Sigma methodology, the billing and receiving processes are improved, thus showing that Multi-VariAnalysis Charting is not just valuable for manufacturing, but can be applied to many different industries.

The literature repeatedly describes the difficulty in control charting via the multivariant function. It, along with the $\bar{X}$R chart, actually maskssome of the true nature of the dimensional variable. The R chart explains much about the $\bar{X}$ chart, and the Multi-VariAnalysis Chart explains much about the $\bar{X}$ R chart—all are important in determining the total picture. The Multi-Vari Analysis Chartingis finding an important role in the Six Sigma cadre of tools as well as in general data analysis.

13.0 Discussion and Conclusion

Based on the literature and the intuitive thinking that more than one factor describes a variable's dimensional characteristics, the Multi-Vari Analysis Charting has merit. In addition to the ease of use, its visual representation leads to a more accurate interpretation of the data.

The technique can be used by practitioners for improved design, root cause evaluations, and clearer representation of any data set.

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