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The Model of Identification of the Problem Main Cause Set of Variation

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Abstract: *The term Lean has been widely used in today's product manufacturing and service delivery environments. In its fundamental nature the Lean Philosophy continuously strives for elimination of any kind of waste that exists in such environments. There are six basic strategies [1] related to the Lean Philosophy: Workplace Safety & Order & Cleanliness, JIT production, Six Sigma Quality, Empowered Teams, Visual Management and Pursuit of Perfection. On the journey of sustaining the lean supporting strategies there are many problems, or opportunities as Lean Practitioners call them. The value of some strategies highly depends on the efficiency of the problem solving techniques used to overcome the emerging issues. JIT production is difficult to imagine without a system that supports a high level of operational readiness with equipment uptime above 98%. Six Sigma level of quality, even when built into a product or system design, still undergoes the challenges of day to day operations and the variability brought with it. This variability is the source of waste and lean systems culture strives for continuous reduction of it.*

Empowered Teams properly trained to recognize the real cause of the problems and their Pursuit of Perfection culture are one of the corner stones of Lean Philosophy sustainability. Their ability to work with Problem Solvers and understand the difference between the "cure of the symptoms" approach versus "problem root cause identification" is one of the distinctions between Lean and Mass operations.

Among the series of Statistical Engineering Tools this paper will show one of the techniques that proved to be powerful in the identification of the Set of Variation that contains the Main Cause of the new problems that arise in daily operations. This technique is called Multi-Vari.

Multi-Vari is the statistical engineering method used to analyze the set of data acquired in an organized manner. The set could be analyzed graphically or analytically. There are two basic applications of this method: (1) Determine statistically the homogeneity of the data distribution [2] and (2)Identify the critical set of variation that contains the assignable cause of the variation.

This paper will focus on the second application of this method which gives the greatest return on investment in day to day operations in different working environments. Presented vision of the Multi-Vari method and application example should help readers to understand the essence, evaluate the value of this method and identify a potential for application in their areas of expertise.

Keywords: Lean Operations, Empowered Teams, Multi-Vari, Main Cause of Variation, Problem, Operational Environment, Variation, Set of Variation.

1. INTRODUCTION

The main *Lean Operation* premise is to operate in the customer oriented manner by eliminating anything that does not add value to the product or service. Customer, on the other side, values product or service based on the value received for investment or cost. Lean Operation Leaders understand those views and pursue the practices that will give to the customer the highest value in the product or the service for the cost that will turn the customer away from the competitor's products. To be able to do that, *lean operation leaders* need to implement, support and sustain lean operation practices in the way that will keep going and growing the business.

Regardless of the level of operational expertise, problems from day to day operation still arise and lean operations people have the urge to understand their root causes and eliminate them. This will keep the customers satisfied and lean operation profitable.

One of the parameters that will influence customer satisfaction is the variation of the working process *output* $\boldsymbol{Y_i}(t,x)$ (***t*** - *time* and ***x***- "*other variable*"[1] are an independent and nested or crossed variables in statistical terms) that is within or outside of the originally predetermined or expected range of variation. The "uncontrolled" *outputs* have negative impact on the performance of the operational environment which is, in most cases, closely related to the financial figures of the same. For better understanding of process *outputs* we need to better understand the sets of variation ($\boldsymbol{S_i}(t,\mathbf{x})$) that influence the distribution $N\ (0,\sigma^2_i)$ of the critical outputs.

We are specifically interested in the set that contains the *main cause of variation*[2] that influences the critical output to go out of control.

Statistical engineering has developed many techniques to help the operational environment deal efficiently with problems that arise.

However, the new set of expectations was set in front of the Statistical Engineering by the developing world of industry and related science. The value of statistical methods was not measured anymore by their statistical rigidity but rather the financial benefits that they will provide to industrial or any similar working environment.

This paper will show the benefits of Multi-Vari, the statistical engineering method, that has been underutilized for many years and which revival, in the most essential form, came with concepts of Lean Manufacturing and Six Sigma philosophies. Appendix shows the example of the Multi-Vari method application in manufacturing environment and benefits gained from it.

Main Aspects of the Multi-Vari Method

From *statistical* prospective the Multi-Vari method has originated from Shewhart's $\left(\overline{X},R\right)$ control charts which are used to monitor the variation within the statistical sample taken at the time instance as well as variation between the statistical samples at different time instances. Operations engineering was facing many process specific problems and they were looking for some tools that would help them to relate those problems to the process behavior depicted in the control charts. Statistical engineers recognized that the control charts concept can be used to monitor more than two sets of variation (example: batch production, different machines, different production shifts, additional product streams, …). Despite the number of additional sets of variation , statistics that are used for analysis are still range $\left(R\right)$ and mean $\left(\overline{Y}\right)$ of different sets of variation [3]. Like $\left(\overline{X},R\right)$ charts, the Multi-Very method is mostly recognized as a graphical tool apart from its ability to seek the set of variation, that contains the main cause of variation, in analytical form. The value and expedience of the analytical approach for simple problems analysis is presented in [3].

The *financial* aspect of the Multi-Vari method lies in it's ability to guide the statistical engineering practitioners to the critical set of variation in a cost effective way. As implied before, the existence of the working environment or business, mostly depends on its financial performance which is why it is very important to identify the controllable

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[1] "Other variable" refers to, for instance, machine 1,2,…,p; shift 1,2,3; process 1,2,…,q; etc.

[2] Assignable cause

parameters that may influence the financial performance. A change of the parameters may create the "uncontrolled" *output* that shows the level of variation that is outside of the predetermined or expected requirements. *We need to obtain the answer quickly to be able to reduce the impact of the uncontrolled output behavior on the business financial performance.*

As stated in *Abstract,* we will display the *second application* of this method at the operations level with all references made to requirements at that level in a ordinary industrial environment. The intent is also to simplify the relevant theory and help the lean philosophy practitioners to use the method at the lowest possible level of expertise at the same time maximizing the benefits of it.

2. STUDY PROCEDURE

The studies are initiated because of the observed *performance gap* that is usually presented at the management level in the financial or other *critical to business* form (example: customer dissatisfaction). The performance gap is the input in the problem resolution algorithm that at the specific level of branching defines the need for identification of the step in the processing stream that is directly related to the out of control conditions. The output that management or the customer is interested in is mostly variable that resulted from the interaction between the set of variables along the processing stream. When the performance gap occurs, statistical engineering practitioners are tasked to identify the downstream variable that has the main impact to one that is critical to performance gap. That is the variable that will be measured during the study. The next step in the procedure is to identify the *adequate measurement system* to monitor the critical variable. The critical output $\boldsymbol{Y_i}$(t,x) could be either attribute or variable data.

Selected measurement system must have the internal error significantly[3] smaller than the distribution of the critical variable. Gauge R@R or Isoplot are some of the methods used in operations to verify the suitability of the pre-selected measurement system [4]. If the pre-selected measurement system does not meet the pre-set criteria a new measurement system should be considered.

Once the adequate measurement system is selected the Multi-Vari analysis takes place (see Figure 1). The analysis consists of the following steps:

1. *Gain knowledge about the process* by learning or deploying the process experts. Quick elimination of non relevant sets of variation would reduce the study time significantly which is why it is very important that during the process we deploy the resources that have information and knowledge relevant to the working environment.
2. *Determine Sets of Variation*[4] $\boldsymbol{S_i}$ (**t**,**x**) that will be studied. This is a critical step that highly depends on the knowledge gained in the previous step. If we miss to identify the set within sets of variation that contains $\boldsymbol{S_{RX}}$ (**t**,**x**) (critical set of variation), process of problem identification may take much longer which will increase the cost related to the out of control condition. The sets of variation could be divided in three basic groups: Positional, Cyclical and Temporal [5]. Some of the most common sets of variation are "within observed object", "from object to object", "from set to set", "from tool to tool", "from equipment to equipment", "from working environment to working environment", "from man to man", "from shift to shift", … and "from time to time".
3. *Determine the size and form of the statistical sample* [3]. The sample size will need to provide the confidence in obtained conclusions and also to promote the study easiness .
4. *Prepare the data collection forms.* These forms will depend on the size and form of the statistical sample, the number of selected sets of variation and type of performed analysis (see Appendix). The behavior of the critical output ($\boldsymbol{Y_i}$(t,x)), influenced by

[3] Significant in statistical terms.

[4] Also called "Family of Variation".

different sets of variation, is monitored in predetermined *time* or "*other variable*" increments.

5. *Determine the control limits.* Statisticians [2] have developed the methods for calculation of control limits. These methods were developed to test the hypothesis of data homogeneity and they will not be used for this application. Instead, the process control limits are used as they are directly related to the studied process and customer satisfaction. (UCL- Upper Control Limit; LCL – Lower Control Limit).
6. *Decide on the type of analysis that will be performed.* Both graphical and analytical analysis can be performed.
7. *Collect the data and perform the analysis*. The study needs to be conducted "on the spot" where the problem exists. Proper observation is very important for identification of the critical set of variation. The analysis is based on the comparison between the point estimates of central tendency and dispersion of the measured critical output Y_i(t,x). The Multi-Vari method uses *range* as the measure of dispersion and *mean* as the measure of central tendency.

Once the S_{RX} (**t**,**x**) is identified the Multi-Vari study doesn't need to continue.
It is very important to understand that the set of variation that contributed to the out of control condition can be identified only if we monitor the impact of the predetermined set of sets of variation on the critical output without attempting to change any parameters within the considered sets during the observation.

The Multi-vari method will help us to isolate the critical set of variation S_{RX} (**t**,**x**) that has the main impact on the critical output (Y_i(t,x)) that went out of control but it will not identify the *assignable cause of variation*.

The identification of the assignable cause within identified set of variation S_{RX} is the next step towards the problem solution. Statistical engineering methods used to identify the assignable cause are outside of the scope of this paper.

3. TYPE OF ANALYSIS

As the Multi-Vari method originated from the $(\overline{X}, R)$ control charts the *graphical type* of analysis was the preferred one for use. Process that takes place for the graphical type of the Multi-Vari method is equivalent to the Analytical type.

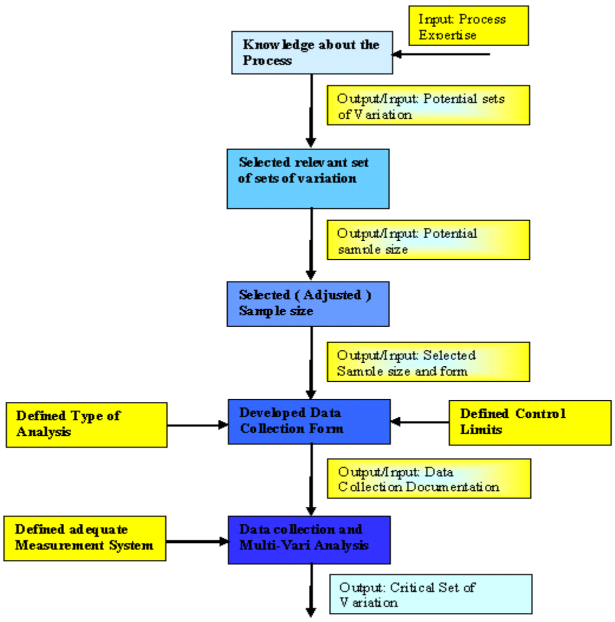

Figure 1. *Multi-Vari Analysis Model*

The only difference is that data entered on the previously prepared blank forms with identified sets of variation are then transferred into some statistical software that performs Multi-Vari analysis and draws the chart or it is manually plotted on the graph paper in scaled format with identified sets of variation and control limits. The critical output values are plotted on y-axes and sets of variation on x-axes (see Appendix).

Data collected during the study should be tabulated in ascending order of ***t and/or x***. The measurement starts with critical outputs related to the set of variation that covers the ***x*** at ***t*** or lowest time increment Δt and then passing through the sets of variation that cover multiple ***x*** or ***t*** increments usually up to the set of variation of time S_T simply measured in units of time increments (see Figure 2).Plotted values will define the ranges for each set of variation either directly as for "within observed object" set of variation or indirectly through calculated means. Simple comparison of the *ranges* will determine the largest one which is associated to the set of variation S_{RX} (**t,x**) that contains the main cause of out control output which justifies the main purpose of this type of Multi-Vari chart application.

The analytical type of analysis uses the same tabulated values. The *ranges* and *means* are calculated and noted directly in the table used to collect the data. (The table should contain the fields for those numbers). The highest range number is associated with critical set of variation.

Meas. 1																	
Meas. 2																	
Meas. 3								Measured Values									
.																	
.																	
.																	
Meas. *n*																	
	Part 1	Part 2	Part 3	...	Part *j*	Part j+1	Part j+2	Part j+3	...	Part *2j*	Part 2j+1	Part 2j+2	Part 2j+3	...	Part *3j*	...	
Δ R WP	Δ R 11	Δ R 12	Δ R 13	. . .	Δ R **1*j***	Δ R 21	Δ R 22	Δ R 23	. . .	Δ R ***2j***	Δ R 31	Δ R 32	Δ R 33	. . .	Δ R ***3j***	...	**R A**
Mean WP	Mean 11	Mean 12	Mean 13	. . .	Mean ***1j***	Mean 21	Mean 22	Mean 23	. . .	Mean ***2j***	Mean 31	Mean 32	Mean 33	. . .	Mean ***3j***	...	
Δ R PP	Δ R **B1**					Δ R **B2**					Δ R **B3**					...	**R B**
Mean PP	Mean **B1**					Mean **B2**					Mean **B3**					...	
Δ R BB	Δ R C1															...	**R C**
Mean BB	Mean C1															...	.
.								.								...	.
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																	R max
Legend																	
WP	" Within Part" set of variation																
PP	" Part to Part" set of variation																
BB	" Batch to Batch" set of variation																
.																	
.																	
TT	" Time to Time" set of variation																

Figure 2: MultiVari Chart Data Recording Table – Generic Form

4. CONCLUSION

Different from control charts that are used to monitor the process behavior in time domain this method is used for the analysis of process behavior when out of control output condition due assignable cause is present or when repeated out of control conditions occur.

This method has great importance in today's fast paced production environment that requires quick problem main cause identification and solution implementation. Despite the fact that some statistical methods, like F-test or ANOVA, can provide similar conclusions to ones developed from Multi-Vari, they are much more difficult to understand and apply by non-statisticians. Rather than calculating data homogeneity, Multi-Vari, in the very essence, provides quickly the clue to which set of variation contains an assignable cause of variation. Its graphical nature sometimes allows engineers and statistical engineering practitioners to perform the studies and come to valuable conclusions "on the spot", which we would consider one of the main advantages of this method. In many situations properly prepared tables for data collection can be easily used for simple calculations of *range* and *mean* which would lead to the same conclusion as ones developed from properly designed graph.

Simplicity and value of the Multi-Vari method are two factors that will promote and extend its application beyond the production environment.

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