Design of Experiments

In the previous topic, you described the tools and deliverables of the Improve phase. Before implementing any changes to a process to improve it, if needed, you should conduct experiments to understand the effect of these changes on the process. Many times, you may know the factor that impacts a CTQ parameter, but you may not know the settings in which that factor will provide desirable results. This is where DOE comes in handy. In this topic, you will perform DOE.

Before implementing any changes to a process to improve it, you need to test if the factors produce the desired response in the process. If there is any variability, you can make the necessary changes to ensure that the improvements made meet the envisioned objectives.

What is the need for experimentation?

An experiment is a series of changes made to inputs to obtain the desired performance or value on outputs. Experiments help you:

- Find out which Xs, or variables, have impact on Ys, or outputs
- Quantify the impact of Xs on the variability of output
- Offset the impact of uncontrollable variables by setting controllable variable
- And, discover how two variables jointly have an impact on output

What are the approaches to experimentation?

There are two different approaches to experimentation: traditional and structured.

Approach	**Description**
Traditional	• Adopts a trial and error method to make inferences. • Only one factor at a time can be varied to study the impact.
Structured	• Adopts a structured and statistically valid method. • More than one factor can be varied at a given time to study the impact.

What are the disadvantages of traditional experimentation?

Traditional experimentation approaches cannot capture the interaction between factors, that is, the impact that two Xs jointly have on Y, while individually these Xs may or may not have an impact. Traditional approaches can only capture main effects. They are also less efficient than statistically designed structured experiments. Therefore, the number of experiments will be more in traditional approaches than structured experiments. The interpretation of results is also logical rather than scientific.

What is structured experimentation?

Structured experimentation is a series of planned experiments where the outcomes of all experimental trials are studied together rather than just studying a single trial outcome. In a structured experiment, more than one factor are varied at a given time. Structured

experiments are also called factorial experiments or DOE. A number of terms are used while describing or performing DOE. These include factor, level, response, treatment, and block.

What do you understand by factors in DOE?

A *factor* is an item that can affect the outcome of an experiment when changed. In simple terms, all the Xs identified in the Measure phase are indeed factors. In the context of DOE, factors are measurable and are chosen to change systematically when an experiment is being conducted to identify how the response is affected by the factors. Factors that affect the response in an experiment are called independent variables or predictor variables. A factor can either be a categorical variable or a continuous variable. If it is continuous, it has to be converted to categorical and then used in DOE. It can also be controlled to study how the factor influences a response in an experiment. Factors are widely used in DOE.

Define DOE

Design of Experiments (DOE), also known as experimental design, is a method of discovering and validating the effect of factors on responses in a process. DOE uses a series of tests or experimental runs where input variables or factors are changed deliberately to observe how they affect the output variables or responses. DOE also considers the settings or levels of each factor to analyze its effect on responses.

In DOE, more than one factor can be changed at a time to draw inferences about how interactions between factors influence the response. Therefore, DOE is an ideal tool to use in circumstances where the effect of multiple factors needs to be studied. It can also be used in the Improve phase to test solutions to ensure that unexpected problems do not arise during implementation. Based on conclusions drawn from the experimental runs, Six Sigma practitioners can formulate an efficient process improvement strategy.

Example: DOE in a Mobile Phone Manufacturing Firm

Ristell Corp., a leading mobile phone manufacturer, recently implemented the Six Sigma methodology to improve its process. One of the major concerns of customers was that the company's products did not efficiently receive signals either at the top of hills or within buildings located below sea level. Therefore, the Six Sigma team applied the DMAIC methodology to improve the product to meet customer requirements. As part of the Improve phase, the Six Sigma team conducted DOE to analyze the impact of the input variables on the output variables of the process. The team considered shape, size, and weight as input variables and analysed how they affect the signal reception process. The levels or settings for each factor included the height of the towers and the climate in each problem area.

What do you understand by levels in DOE?

A *level* is the set of values that a factor may have through the course of an experiment. For example, different settings, such as 50° or 100° Fahrenheit, are the levels for the factor temperature. The factor level can be quantitative—such as 50°, 100°, or 200° Fahrenheit—or qualitative—low, medium, or high. The levels of factors are changed during different trials inane experiment. The entire set of all the possible combinations of factors and levels in an experiment is known as a *full factorial.*

What do you understand by Response in DOE?

A response is a variable that is measured or observed in an experiment. It is also referred to as a dependent variable. CTQs of a Six Sigma project are usually the response variables. Generally, predictor variables, also known as factors, are plotted on the X-axis, and response variables are plotted on the Y-axis. Through response optimization, you can identify the factor level combination that can optimize a single response or a group of responses. This also helps you assess the impact that multiple inputs have on a response.

What do you understand by treatments in DOE?

While conducting an experiment, different settings are applied in an organized manner. A level assigned to a single factor during a trial in an experiment is called a *treatment.* It can also mean a particular combination of factor levels while comparing their influence with other treatments. The set of levels for all the factors in an experiment is called a treatment combination.

What are different experiment types of DOE?

Different types of DOE are used depending on the number of treatments in an experiment. This is determined by the number of factor levels to be studied in the experiment.

DOE Type	**Description**
One factor design	• Only one factor is studied • Can be continuous or discrete • A structured one factor design is ANOVA

Factorial design	• Multiple factors are studied at the same time during the experiment
	• Can be continuous or discrete, or both
	• Factorial designs can be further divided into:
	  ○ General full factorial design
	  ○ Two-level full factorial design
	  ○ Two-level fractional factorial design
	  ○ Plackett-Burman design
	  ○ Taguchi's orthogonal arrays

Response surface method design	• The settings of factors are studied to identify those settings that will enable a response to deliver the optimal value
Reliability DOE	• Traditional experimental designs are combined with reliability methods • Studies the effects of different factors on a response