Design of Experiments

INTRODUCTION:-

Design of Experiments (DOE) was first introduced in the 1920s when a scientist at an agricultural research station in England, Sir Ronald Fisher, showed how valid experiments could be conducted in the presence of many naturally fluctuating conditions such as temperature, soil condition, and rainfall. In 1935, Prof. R.A. Fisher laid the foundation for the subject matter of design of experiment.

DOE was a very useful tool traditionally used for improvement of product quality and reliability .The usage of DOE has been expanded across many industries as a part of decision-making process either along a new product development, manufacturing process or improvement. It is not used only in engineering areas but it has been used in laboratories and research in Natural sciences, in administration, marketing, hospitals, pharmaceutical, food industry, energy and architecture, and chromatography. DOE is applicable to physical processes as well as computer simulation models.

The subject matter of the Design of Experiment includes:-

1. **Planning of experiment.**
2. **Obtaining relevant information from it regarding the statistical hypothesis understudy.**
3. **Making a statistical analysis of the data.**

Experience has shown that proper consideration of the statistical analysis before the experiment is conducted, forces the experimenter to plan more carefully the DOE. The observations obtained from a carefully planned and well-designed experiment in advance give entirely valid inferences.

Design of experiment means how to design an experiment in the sense that how the observations or measurements should be obtained to answer a query in a valid, efficient and economical way. The designing of the experiment and the analysis of obtained data are inseparable. If the experiment is designed properly keeping in mind the question, then the data generated is valid and proper analysis of data provides the valid statistical inferences. If the experiment is not well designed, the validity of the statistical inferences is questionable and may be invalid.

One of the main objectives of designing an experiment is how to verify the hypothesis in an efficient and economical way. In the contest of the null hypothesis of equality of several means of normal populations having the same variances, the analysis of variance technique can be used. Note that such techniques are based on certain statistical assumptions. If these assumptions are violated, the outcome of the test of a hypothesis then may also be faulty and the analysis of data may be meaningless. So the main question is how to obtain the data such that the assumptions are met and the data is readily available for the application of tools like analysis of variance. The designing of such a mechanism to obtain such data is achieved by the design of the experiment. After obtaining the sufficient experimental unit, the treatments are allocated to the experimental units in a random fashion. Design of experiment provides a method by which the treatments are placed at random on the experimental units in such a way that the responses are estimated with the utmost precision possible.

It is important to understand first the basic terminologies used in the experimental design.

TERMINOLOGY in Experimental Design:-

1. EXPERIMENT:-

An experiment is a device of getting an answer to the problem under consideration. It may be classified into two categories:-

a. Absolute Experiment and

b. Comparative Experiment.

An absolute experiment is consist in determining absolute value of some characteristics like obtaining the average IQ of a group of people on the other hand comparative experiments are designed to compare the effects of two or more objects on some population characteristics:-

For eg:-Comparison of

Different fertilizer or manures;
Different cultivation processes;
Different kinds of varieties of a crop;
Different pieces of land in a field experiment;
Different medicines in medical experiment etc...

2. TREATMENTS:-

Various objects of comparison in a comparative experiment are called Treatments.

For e.g.:- In field experimentation different fertilizers or different varieties of crops are the treatments.

3. EXPERIMENTAL UNIT:-

The smallest division of the experimental material to which we apply the treatments and on which we make the observations on the variable understudy is known as an experimental unit.

For e.g.:- In field experimentation the plot of land (not the individual plant) is the experimental unit.

Experimental unit maybe a patient in a hospital or a student of a school etc…

4. BLOCKS:-

In agricultural experiment most of the time we divide the whole experimental unit (field) into relatively homogeneous subgroups or strata. These strata which are more uniform among themselves then the field as a whole are known as blocks.

5. YIELD:-

The measurement of the variable understudy on different experimental units is known as yields.

6. EXPERIMENTAL ERROR:-

Let us suppose that large heterogeneous field is divided into different plots of equal size and shape and different treatments are applied to these plots. If the yields from some of the treatments are different than those of the others, the experimenter is faced with the problem of deciding if the difference is really due to treatments or it is due to uncontrolled factors. Experience tells us that even if the same treatment is used on all the plot, the yields would still vary due to differences in soil. Such variation from plot to plot which is due to random or chance factor is known as experimental error. Experimental error does not mean a mistake but includes all type of variation due to:-

1. **Inherent variability in the experimental material to which treatments are applied.**
2. **Errors associated with the measurements made.**
3. **Lack of representativeness of the sample to the population understudy.**

The experimental error provides a basis for the confidence to be placed in the inference about the population. So it is important to estimate and control the experimental error.

7. REPLICATION:-

Replication means an execution of the experiment more than once, in other words repetition of treatments under investigation is known as replication.

8. PRECISION:-

Precision means the reciprocal of the variance of the mean. It is given by $1/V(\bar{x}) = r/\sigma^2$; Where r= common replication number and σ^2= error variance per unit.

9. Efficiency of a design:

Consider the designs D_1 and D_2 with error variances per unit σ_1^2 and σ_2^2 respectively and replications as r_1 and r_2 respectively. Then the variance of the difference between two treatment means is given by $2\sigma_1^2 / r_1$ and $2\sigma_2^2 / r_2$ for D_1 and D_2 respectively. Then the ratio $E = \frac{2\sigma_2^2}{r_2} \times \frac{r_1}{2\sigma_1^2} = \frac{r_1}{\sigma_1^2} \div \frac{r_2}{\sigma_2^2}$ is termed as efficiency of design D_1 w.r.to D_2. In other words it is defined as the ratio of the precisions of D_1 and D_2.