TERMINOLOGIES USED IN DESIGN OF EXPERIMENTS

Design of an experiment

Designing an experiment simply means planning an experiment so that the information collected will be relevant to the problem under investigation. This is therefore the complete sequence of steps taken ahead of time to ensure that the appropriate data will be obtained in a way which permits objective analysis leading to valid references or conclusions with respect to the stated problem. This definition shows that the person formulating the design clearly understands the objectives of the proposed investigation or experiment.

Experimental unit

These are objects upon which measurements are taken i.e on which variable understudy is measured. In an agricultural field experiment, the plot of land will be the experimental unit. In a feeding experiment of cows, the cow is the experimental unit, etc.

Factors

These are independent experimental variables and could be quantitative or qualitative. A quantitative factor is one that can take on values corresponding to points on the real line, factors that are not quantitative are said to be qualitative. For example height, weight, temperatures are quantitative factors. Examples of qualitative factors include; car types, manufacturers, halls of residence, sex, they can’t be quantified.

Level

This is the intensity setting of a factor e.g the 3 temperatures 100℃, 200℃, 300℃ represent 3 levels of the quantitative factor temperature. Similarly Benz, V/W, BMW, Corolla represent 4 levels of the qualitative factor type.

Treatment

This is the specific combination of factor levels. The experiment may involve only a single factor and will therefore have one-way ANOVA. The experiment could also be composed of levels of 2 or more factors in which case we have two-way ANOVA......... n-way ANOVA where n is the number of factors. In other words what one does to the experimental unit that makes it differ from one population to another is called a treatment e.g for one-way ANOVA, no of treatments = no of levels of a factor.

Experimental error

This is the unexplained random part of the total variation and it is caused by a number of factors, most important of which are the following;

1. Variability in experimental units.
2. Errors associated with the measurements made.
3. Lack of representativeness of the sample to the population under study.

The experimental error provides a basis for the confidence to be placed in the conclusions of inferences about the population so it is important to estimate and control the experimental error.

Replication
A treatment is of replication 'n' if it is tried on 'n' experimental units. **N = rcn , N = rc**

Advantages of replicating
i) It makes the experiment more precise.
Precision = $\frac{1}{\delta_{\bar{x}}^{2}}$; reciprocal of the variance of the mean. As n increases, the precision also increases.
ii) Replication gives an estimate of the error.
iii) It guards against accidents and with many replications, the investigator is in position to identify outliers.

Randomisation
Each individual experimental unit has a known probability of being subjected to each treatment and the advantages include;
i) It reduces on the bias.
ii) It helps to increase the induction scope of the experiment i.e the conclusions are made more powerful.
iii) We can generate random variables whose distribution we know and it is possible to use the F-test for all practical purposes.

Fixed, random and mixed effects/models
It should be noted that in the planning stages of an experiment, the experimenter must decide whether the levels of factors considered are to be set at fixed values or are to be chosen at random from many possible levels. This will depend on the objectives of the experiment and the question to be asked is:

Are the results to be judged for those levels alone fixed or are they to be extended to more levels of which those in the experiment are a random sample.

In the case of quantitative factors such as time, weight, etc it is usually desirable to pick fixed levels, some at the extremes and some at intermediate points because a random choice might not cover the range in which the experimenter is interested e.g $0℃,\ 100℃,\ 200℃, 300℃, 400℃$. Other factors such as days of the week, halls of residence, locations, etc may often be a small sample of all possible days, possible halls of residence, etc. In such cases the particular day or particular hall may not be very important. What is important is whether or not days, halls, etc. in general increase the variability of the experiment.

Once the decision has been made as to whether to consider the levels random or fixed, if random levels are to be used then they must be chosen from all possible levels by a random process. When all levels are fixed, the mathematical model of the process is called a fixed model. When all levels are chosen at random, then we have a random model. When more than one factor is involved, some factors may be at fixed levels and others at random levels and the model would be a mixed model. Suppose we have a single factor experiment, the model is;

$$y_{ij}= \mu+\alpha_i +\epsilon_{ij}$$

Where; γ_{ij} is the j^{th} observation in the i^{th} treatment

μ is the general mean about which the observations are supposed to fluctuate.

α_i is the effect of the i^{th} treatment

$\in_{ij}$ is the experimental error/ error term

$\epsilon_{ij} \cong NID\ (0,\delta_\epsilon^2)$ Normally and independently distributed with 0 mean and variance δ_ϵ^2

Steps in designing an experiment

i) Selection of factors to be included in the experiment and specification of population parameters of interest e.g. mean, variance, etc.
ii) Deciding how much information is required pertinent to the parameters of interest identified above. How accurately do you wish to estimate these parameters (level of significance)?
iii) Selection of the treatments to be employed in the experiment and deciding on the number of experimental units to be assigned to each i.e. replications. Are the factor levels going to be fixed, random or mixed.
iv) Deciding on how the treatments are going to be applied to the experimental units. Should the treatments be randomly assigned to the experimental units or should some semi-random pattern be employed.

Therefore designing an experiment means deciding how the observations or measurements should be taken to answer a particular question in a valid, efficient and economical way. The design and the final analysis go together. They are inseparable in a sense that if the experiment is properly designed then there will exist an appropriate way of analysing the data. The application of the technique of ANOVA is appropriate if the data conforms to the basic set up of the ANOVA. The lay out and the method of analysis are coordinated in the design of experiments.