UNIT III RESEARCH PROCESS

Research process consists of series of actions or steps necessary to effectively carry out research and the desired sequencing of these steps. These actions or steps are;

1. Formulating the Research Problem
2. Extensive Literature Survey
3. Developing the Research Hypothesis
4. Preparing the Research Design
5. Determining the Research Design
6. Collecting the Research Data
7. Execution of the Project
8. Analysis of Data
9. Hypothesis Testing
10. Generalization and Interpretation
11. Preparing of the Report or Presentation of the Result

1. Formulation of Research Problem

There are two types of research problems, *viz.*,

- those which relate to states of nature and
- those which relate to relationships between variables.

At the very outset the researcher must single out the problem he wants to study, *i.e.*, he must decide the general area of interest or aspect of a subject-matter that he would like to inquire into. Initially the problem may be stated in a broad general way and then the ambiguities, if any, relating to the problem be resolved. Then, the feasibility of a particular solution has to be considered before a working formulation of the problem can be set up. The formulation of a general topic into a specific research problem, thus, constitutes the first step in a scientific enquiry.

Essentially two steps are involved in formulating the research problem, *viz.*, understanding the problem thoroughly, and rephrasing the same into meaningful terms from an analytical point of view.

The researcher must at the same time examine all available literature to get himself acquainted with the selected problem. He may review two types of literature—the conceptual literature concerning the concepts and theories, and the empirical literature consisting of studies made earlier which are similar to the one proposed.

After this the researcher rephrases the problem into analytical or operational terms i.e., to put the problem in as specific terms as possible. This task of formulating, or defining, a research problem is a step of greatest importance in the entire research process.

2. **Extensive literature survey**

Once the problem is formulated, a brief summary of it should be written down. At this juncture the researcher should undertake extensive literature survey connected with the problem. For this purpose, the abstracting and indexing journals and published or unpublished bibliographies are the first place to go to. Academic journals, conference proceedings, government reports, books *etc*. must be tapped depending on the nature of the problem.

3. **Development of working hypotheses**

After extensive literature survey, researcher should state in clear terms the working hypothesis or hypotheses. Working hypothesis is tentative assumption made in order to draw out and test its logical or empirical consequences. As such the manner in which research hypotheses are developed is particularly important since they provide the focal point for research. They also affect the manner in which tests must be conducted in the analysis of data and indirectly the quality of data which is required for the analysis. Hypothesis should be very specific and limited to the piece of research in hand because it has to be tested.

4. **Preparing the research design**

The researcher will be required to prepare a research design, i.e., he will have to state the conceptual structure within which research would be conducted. The preparation of such a design facilitates research to be as efficient as possible yielding maximal information. In other words, the function of research design is to provide for the collection of relevant evidence with minimal expenditure of effort, time and money.

The preparation of the research design, appropriate for a particular research problem, involves usually the consideration of the following:

- the means of obtaining the information;
- the availability and skills of the researcher and his staff (if any);
- explanation of the way in which selected means of obtaining information will be organized and the reasoning leading to the selection;
- the time available for research; and
- the cost factor relating to research, i.e., the finance available for the purpose.

5. Determining sample design

The researcher must decide the way of selecting a sample or what is popularly known as the sample design. Sample design is a definite plan determined before any data is actually collected for obtaining a sample from a given population.

Samples can be either probability samples or non-probability samples. With probability samples each element has a known probability of being included in the sample but the non-probability samples do not allow the researcher to determine this probability. Probability samples are those based on simple random sampling, systematic sampling, stratified sampling, cluster/area sampling whereas non-probability samples are those based on convenience sampling, judgment sampling and quota sampling techniques.

The sample design to be used must be decided by the researcher taking into consideration the nature of the inquiry and other related factors.

6. Collecting the data

There are several ways of collecting the appropriate data which differ considerably in context of money costs, time and other resources at the disposal of the researcher.

Primary data can be collected either through experiment or through survey. In case of survey, data can be collected by any one or more of the following ways;

By observation,

- Through personal interview,
- Through telephonic interviews,
- By mailing of questionnaires or

- Through schedules

The researcher should select one of these methods of collecting the data taking into consideration the nature of investigation, objective and scope of the inquiry, financial resources, available time and the desired degree of accuracy.

7. Execution of the project

Execution of the project is a very important step in the research process. If the execution of the project proceeds on correct lines, the data to be collected would be adequate and dependable. The researcher should see that the project is executed in a systematic manner and in time. A careful watch should be kept for unanticipated factors in order to keep the survey as much realistic as possible.

8. Analysis of data

After the data have been collected, the researcher turns to the task of analyzing them. The analysis of data requires a number of closely related operations such as establishment of categories, the application of these categories to raw data through coding, tabulation and then drawing statistical inferences. *Tabulation* is a part of the technical procedure wherein the classified data are put in the form of tables. Analysis work after tabulation is generally based on the computation of various percentages, coefficients, etc., by applying various well defined statistical formulae.

9. Hypothesis-testing

After analysing the data as stated above, the researcher is in a position to test the hypotheses, if any, he had formulated earlier. Do the facts support the hypotheses or they happen to be contrary? This is the usual question which should be answered while testing hypotheses. Various tests, such as Chi square test, t-test, F-test, have been developed by statisticians for the purpose. Hypothesis-testing will result in either accepting the hypothesis or in rejecting it.

10. Generalisations and interpretation

If a hypothesis is tested and upheld several times, it may be possible for the researcher to arrive at generalisation, i.e., to build a theory. As a matter of fact, the real value of research lies in its ability to arrive at certain generalisations. If the researcher had no hypothesis to start with, he might seek to explain his findings on the basis of some theory. It is known as interpretation. The process of interpretation may quite often trigger off new questions which in turn may lead to further researches.

11. Preparation of the report or the thesis

Finally, the researcher has to prepare the report of what has been done by him. Writing of report must be done with great care.

The layout of the report should be as follows: (i) the preliminary pages; (ii) the main text, and (iii) the end matter

In its *preliminary pages the report* should carry title and date followed by acknowledgements and foreword. Then there should be a table of contents followed by a list of tables and list of graphs and charts, if any, given in the report.

The *main text of the report* should have the following parts:

- Introduction
- Review of Literature
- Materials and Methodology
- Results and Discussion
- Summary and Conclusion

At the *end of the report*, appendices should be enlisted in respect of all technical data. Bibliography, i.e., list of books, journals, reports, etc., consulted, should also be given in the end. Index should also be given specially in a published research report.

UNIT III RESEARCH DESIGN

Structure

3.1 MEANING OF RESEARCH DESIGN

"A research design is the arrangement of conditions for collection and analysis of data in a manner that aims to combine relevance to the research purpose with economy in procedure." In fact, the research design is the conceptual structure within which research is conducted; it constitutes the blueprint for the collection, measurement and analysis of data. More explicitly, the design decisions happen to be in respect of:

- What is the study about?
- Why is the study being made?
- Where will the study be carried out?
- What type of data is required?
- Where can the required data are found?
- What periods of time will the study include?
- What will be the sample design?
- What techniques of data collection will be used?
- How will the data be analysed?
- In what style will the report be prepared?

Keeping in view the above stated design decisions, one may split the overall research design into the following parts:

The *sampling design* which deals with the method of selecting items to be observed for the given study;

The *observational design* which relates to the conditions under which the observations are to be made;

The *statistical design* which concerns with the question of how many items are to be observed and how the information and data gathered are to be analysed.

The operational design which deals with the techniques by which the procedures specified in the sampling, statistical and observational designs can be carried out.

In brief, research design must, at least, contain—

- ✓ a clear statement of the research problem;
- ✓ procedures and techniques to be used for gathering information;
- ✓ the population to be studied; and
- ✓ methods to be used in processing and analysing data.

3.2 NEED FOR RESEARCH DESIGN

Research design is needed because it facilitates the smooth sailing of the various research operations, thereby making research as efficient as possible yielding maximal information with minimal expenditure of effort, time and money.

Just as for better, economical and attractive construction of a house, we need a blueprint (or what is commonly called the map of the house) well thought out and prepared by an expert architect, similarly we need a research design or a plan in advance of data collection and analysis for our research project.

The design helps the researcher to organize his ideas in a form whereby it will be possible for him to look for flaws and inadequacies. Such a design can even be given to others for their comments and critical evaluation.

3.3 CHARACTERISTICS OF A GOOD RESEARCH DESIGN

- ✓ A good design is often characterised by adjectives like flexible, appropriate, efficient, economical and so on.
- ✓ Generally, the design which minimises bias and maximises the reliability of the data collected and analysed is considered a good design.
- ✓ The design which gives the smallest experimental error is supposed to be the best design in many investigations.

- ✓ Similarly, a design which yields maximal information and provides an opportunity for considering many different aspects of a problem is considered most appropriate and efficient design in respect of many research problems.

A research design appropriate for a particular research problem, usually involves the consideration of the following factors:

- ➢ the means of obtaining information;
- ➢ the availability and skills of the researcher and his staff, if any;
- ➢ the objective of the problem to be studied;
- ➢ the nature of the problem to be studied; and
- ➢ the availability of time and money for the research work.

3.4 IMPORTANT CONCEPTS RELATING TO RESEARCH DESIGN

Before describing the different research designs, it will be appropriate to explain the various concepts relating to designs so that these may be better and easily understood.

I. Dependent and independent variables

A concept which can take on different quantitative values is called a variable. As such the concepts like weight, height, income are all examples of variables. If one variable depends upon or is a consequence of the other variable, it is termed as a *dependent variable*, and the variable that is antecedent to the dependent variable is termed as an *independent variable*. For instance, if we say that height depends upon age, then height is a dependent variable and age is an independent variable.

II. Extraneous variable

Independent variables that are not related to the purpose of the study, but may affect the dependent variable are termed as extraneous variables. Whatever effect is noticed on dependent variable as a result of extraneous variable(s) is technically described as an 'experimental error'. A study must always be so designed that *the effect upon the dependent variable is attributed entirely to the independent variable(s), and not to some extraneous variable or variables.*

III. Control

One important characteristic of a good research design is to minimise the influence or effect of extraneous variable(s). The technical term 'control' is used when we design the study minimising the effects of extraneous independent variables. In experimental researches, the term ‘control’ is used to refer to restrain experimental conditions.

IV. **Confounded relationship**: When the dependent variable is not free from the influence of extraneous variable(s), the relationship between the dependent and independent variables is said to be confounded by an extraneous variable(s).

V. Research hypothesis

The research hypothesis is a predictive statement that relates an independent variable to a dependent variable. Usually a research hypothesis must contain, at least, one independent and one dependent variable.

VI. Experimental and non-experimental hypothesis-testing research

When the purpose of research is to test a research hypothesis, it is termed as hypothesis-testing research. It can be of the experimental design or of the non-experimental design. Research in which the independent variable is manipulated is termed ‘experimental hypothesis-testing research’ and a research in which an independent variable is not manipulated is called ‘non-experimental hypothesis-testing research’.

VII. Experimental and control groups

In an experimental hypothesis-testing research when a group is exposed to usual conditions, it is termed a ‘control group’, but when the group is exposed to some novel or special condition, it is termed an ‘experimental group’.

VIII. **Treatments:** The different conditions under which experimental and control groups are put are usually referred to as ‘treatments’.

IX. Experiment

The process of examining the truth of a statistical hypothesis, relating to some research problem, is known as an experiment. Experiments can be of two types viz., absolute experiment and comparative experiment. If we want to determine the impact of a fertilizer on the yield of a crop, it is a case of absolute experiment; but if we want to determine the impact of one fertilizer as compared to the impact of some other fertilizer, our experiment then will be termed as a comparative experiment.

X. Experimental unit(s)

The pre-determined plots or the blocks, where different treatments are used, are known as experimental units. Such experimental units must be selected (defined) very carefully.

3.5 TYPES OF RESEARCH DESIGN

In the subsections below, we elucidate the different types of research designs to comprehend the matter more clearly.

3.5.1 Exploratory Research Design

Exploratory research studies are also termed as formulative research studies. The main purpose of such studies is that of formulating a problem for more precise investigation or of developing the working hypotheses from an operational point of view. The major emphasis in such studies is on the discovery of ideas and insights. As such the research design appropriate for such studies must be flexible enough to provide opportunity for considering different aspects of a problem under study. Generally, the following three methods in the context of research design for such studies are talked about: (a) *the survey of concerning literature;* (b) *the experience survey* and (c) *the analysis of 'insight-stimulating*' examples.

a. The survey of relevant literature: literature review helps in formulating a research problem and developing hypotheses. Hypotheses can either be reviewed from earlier works or their validity can be appraised for future research. The investigator also has to see if the present hypotheses can reveal a new hypothesis. Thus the researcher should evaluate and construct her/his hypotheses on earlier work done by others and if such a situation is not possible, then earlier published material is to be reviewed to build a new hypothesis from scratch.

It is in fact the bibliographical study which aids the researcher to formulate the problem accurately. It is essential for the researcher to use notions and theories built in various research settings to the thematic area s/he is working. Creative writing can also be looked into to devise hypothesis.

b. The Experience Survey: in exploratory studies, it is essential that those persons should be surveyed who have already done some work in the field under study. These people have the knowledge to guide and explain practical difficulties. These might be the persons who might be senior officials, social workers and professionals, having a lot of untapped material at their disposal on the hand and opportunity of viewing the problem from different angles on the other. They also know policy implications of a problem. They have insight and are in close contact with the people of an area knowing their habits, limitations and also possess the method of approaching them. The administrators have real advantage of viewing the problem from close quarters and can definitely provide fruitful clues for solving many such prolems which otherwise appear to be difficult.

An important thing which ought to be kept in mind in this regard is that there are many people in every country who have rich and firsthand knowledge of a particular problem proposed to be studied, but their work may not available in a published form. These people are store house of knowledge.

c. **Analysis of 'insight-stimulating'**: is also a fruitful method for suggesting hypotheses for research. It is particularly suitable in areas where there is little experience to serve as a guide. This method consists of the intensive study of selected instances of the phenomenon in which one is interested. For this purpose the existing records, if any, may be examined, the unstructured interviewing may take place, or some other approach may be adopted. The investigator's assertiveness, the passion towards the study and the capacity of the researchers to bring together varied information into a single significant interpretation are the key features by which this method becomes an apt process to evoke discernment.

3.5.2 Descriptive/Diagnostic Research Design

Descriptive research studies are those studies which are concerned with describing the characteristics of a particular individual, or of a group, while diagnostic research studies determine the frequency with which something occurs or its association with something else. The studies concerning whether certain variables are associated are examples of diagnostic research studies. As against this, studies concerned with specific predictions, with narration of facts and characteristics concerning individual, group or situation are all examples of descriptive research studies. Most of the social research comes under this category. From the point of view of the research design, the descriptive as well as diagnostic studies share common requirements and as such we may group together these two types of research studies.

The research design must make enough provision for protection against bias and must maximise reliability, with due concern for the economical completion of the research study. The design in such studies must be rigid/exact and not flexible and must focus attention on the following:

- Formulating/Devising the objective of the study (what the study is about and why is it being made?)
- Designing the methods of data collection (what techniques of gathering data will be adopted?)
- Selecting the sample (how much material will be needed?)
- Collecting the data (where can the required data be found and with what time period should the data be related?)

- Processing and analysing the data.
- Reporting the findings

In a descriptive and diagnostic investigation, the first step that needs to be taken into consideration is to identify the objectives. This is to be done with adequate exactness so that the data collected are applicable. After this, the methods for collecting the data are to be selected. Usually in descriptive and diagnostic studies, the researcher first makes a sample study. Based on the analysis of the sample study s/he makes statements about the population. Such a sample obviously has to be designed as well.

A researcher has to accumulate the following qualities to collect authentic and useful data. S/he should be honest and should work without prejudice. Her/his level of dedication towards collecting data should be viewed in terms of completeness, comprehensibility, consistency and dependability.

The difference between research designs in respect of the above two types of research studies can be conveniently summarised in tabular form as under:

Table: Difference between exploratory and descriptive/diagnostic research design

Research Design	**Type of Study**	
	Exploratory/Formulative	**Descriptive/Diagnostic**
Overall design	Flexible design (design must provide opportunity for considering different aspects of the problem)	Rigid design (design must make enough provision for protection against bias and must maximize reliability)
Sampling design	Non-probability sampling design (purposive or judgment sampling)	Probability sampling (random sampling)
Statistical design	No pre-planned design for analysis	Pre-planned design for analysis
Observational design	Unstructured instruments for collection of data	Structured or well thought out instruments for collection of data
Operational design	No fixed decisions about the operational procedures	Advanced decisions about operational procedures

3.5.3 Research design in case of hypothesis-testing research studies: Hypothesis-testing research studies (generally known as experimental studies) are those where the researcher tests the hypotheses of causal relationships between variables. Such studies require procedures that will not only reduce bias and increase reliability, but will permit drawing inferences about causality. Usually experiments meet this requirement. Hence, when we talk of research design in such studies, we often mean the design of experiments.

Professor R.A. Fisher's name is associated with experimental designs. Beginning of such designs was made by him when he was working at Rothamsted Experimental Station (Centre for Agricultural Research in England). As such the study of experimental designs has its origin in agricultural research. Professor Fisher found that by dividing agricultural fields or plots into different blocks and then by conducting experiments in each of these blocks, whatever information is collected and inferences drawn from them, happens to be more reliable.

3.5.3.1 BASIC PRINCIPLES OF EXPERIMENTAL DESIGNS

Professor Fisher has enumerated three principles of experimental designs: (1) the Principle of Replication; (2) the Principle of Randomization; and the (3) Principle of Local Control.

1. **Principle of Replication:** According to the Principle of Replication, the experiment should be repeated more than once. Thus, each treatment is applied in many experimental units instead of one. By doing so the statistical accuracy of the experiments is increased.

2. **Principle of Randomization:** provides protection, when we conduct an experiment, against the effect of extraneous factors by randomization. In other words, this principle indicates that we should design or plan the experiment in such a way that the variations caused by extraneous factors can all be combined under the general heading of "chance." As such, through the application of the principle of randomization, we can have a better estimate of the experimental error.

3. **Principle of Local Control**: is another important principle of experimental designs. Under it the extraneous factor, the known source of variability, is made to vary deliberately over as wide a range as necessary and this needs to be done in such a way that the variability it causes can be measured and hence eliminated from the experimental error.

3.5.3.2 Important Experimental Designs

Experimental design refers to the framework or structure of an experiment and as such there are several experimental designs. We can classify experimental designs into two broad categories, viz., informal experimental designs and formal experimental designs. Informal experimental designs are those designs that normally use a less sophisticated form of analysis based on differences in magnitudes, whereas formal experimental designs offer relatively more control and use precise statistical procedures for analysis. Important experiment designs are as follows:

A. Informal experimental designs:

i. Before-and-after without control design

ii. After-only with control design

iii. Before-and-after with control design

B. Formal experimental designs:

i. Completely randomized design (C.R. Design)

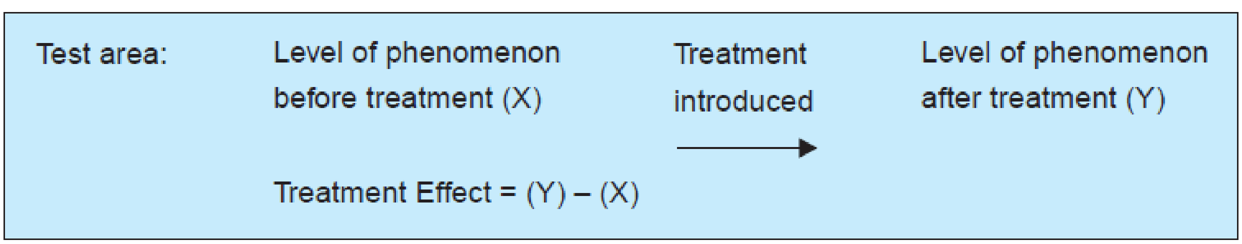
ii. Randomized block design (R.B. Design)

iii. Latin square design (L.S. Design)

iv. Factorial designs

A.i. Before-and-after without control design

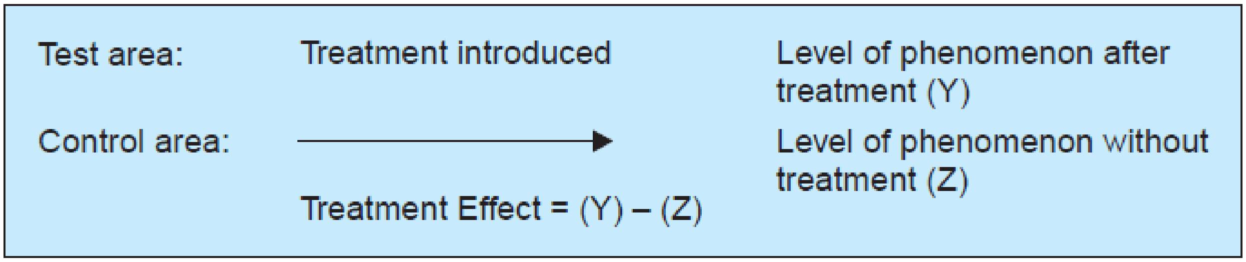
In such a design a single test group or area is selected and the dependent variable is measured before the introduction of the treatment. The treatment is then introduced and the dependent variable is measured again after the treatment has been introduced.



The main difficulty of such a design is that with the passage of time considerable extraneous variations may be there in its treatment effect.

A.ii. After-only with control design

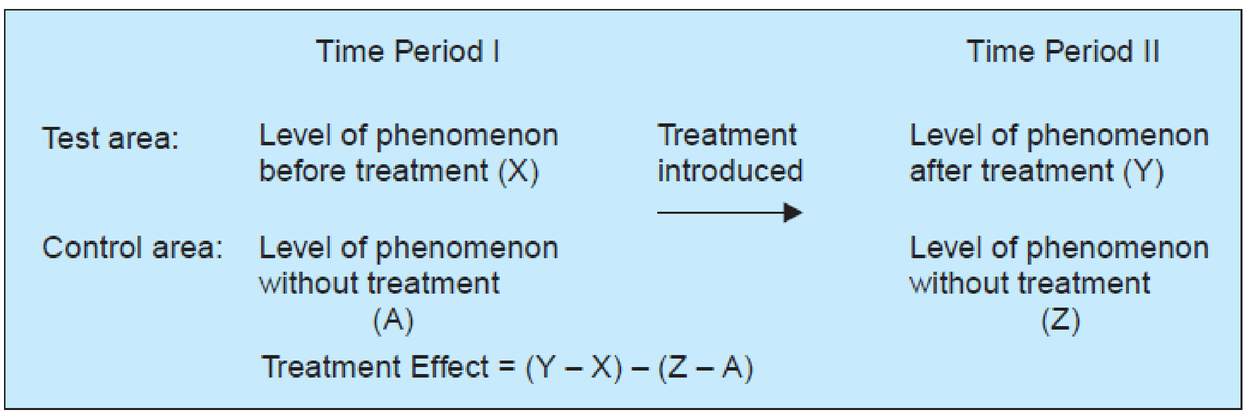
In this design two groups or areas (test area and control area) are selected and the treatment is introduced into the test area only. The dependent variable is then measured in both the areas at the same time.



The basic assumption in such a design is that the two areas are identical with respect to their behaviour towards the phenomenon considered.

A.iii. Before-and-after with control design

In this design two areas are selected and the dependent variable is measured in both the areas for an identical time-period before the treatment. The treatment is then introduced into the test area only, and the dependent variable is measured in both for an identical time-period after the introduction of the treatment. The treatment effect is determined by subtracting the change in the dependent variable in the control area from the change in the dependent variable in test area.

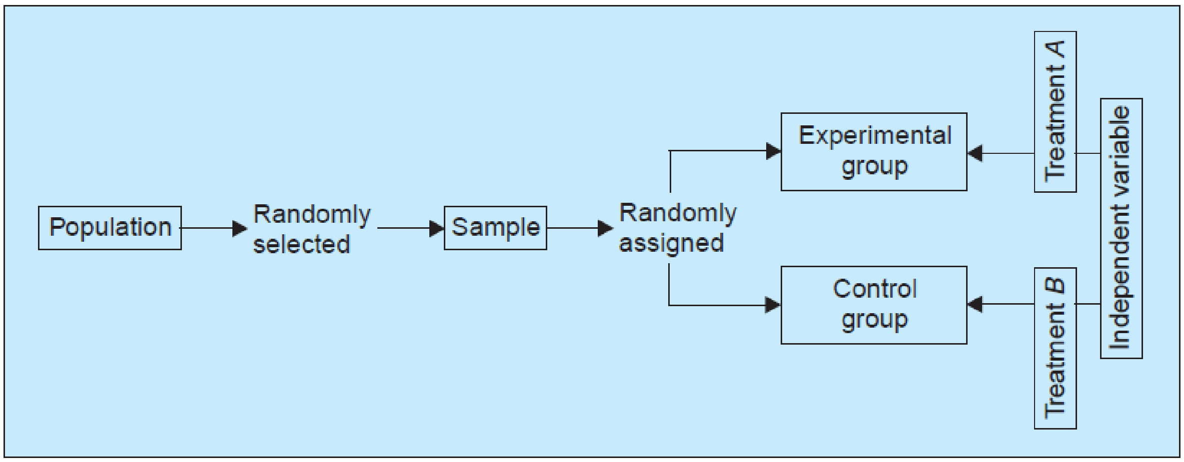


This design is superior to the above two designs for the simple reason that it avoids extraneous variation resulting both from the passage of time and from non-comparability of the test and control areas.

B.i. Completely randomized design (C.R. design)

Involves only two principles viz., the principle of replication and the principle of randomization of experimental designs. It is the simplest possible design and its procedure of analysis is also easier. The essential characteristic of the design is that subjects are randomly assigned to experimental treatments (or vice-versa). One-way analysis of variance (or one-way ANOVA) is used to analyse such a design. It provides maximum number of degrees of freedom to the error. Such a design is generally used when experimental areas happen to be homogeneous. brief description of the two forms of such a design are presented below.

I. **Two-group simple randomized design**: In a two-group simple randomized design, first of all the population is defined and then from the population a sample is selected randomly. Further, requirement of this design is that items, after being selected randomly from the population, be randomly assigned to the experimental and control groups. Thus, this design yields two groups as representatives of the population. In a diagram form this design can be shown in this way:



The two groups (experimental and control groups) of such a design are given different treatments of the independent variable. This design of experiment is quite common in research studies concerning behavioural sciences. The merit of such a design is that it is simple and randomizes the differences among the sample items. But the limitation of it is that the individual differences among those conducting the treatments are not eliminated, i.e., it does not control the extraneous variable and as such the result of the experiment may not depict a correct picture.

II. **Random replications design:** The limitation of the two-group randomized design is usually eliminated within the random replications design. Random replication design serves two purposes viz., it provides controls for the differential effects of the extraneous independent variables and secondly, it randomizes any individual differences among those conducting the treatments.

From the diagram it is clear that there are two populations in the replication design. The sample is taken randomly from the population available for study and is randomly assigned to, say, four experimental and four control groups. Similarly, sample is taken randomly from the population available to conduct experiments (because of the eight groups eight such individuals be selected) and the eight individuals so selected should be randomly assigned to the eight groups. Generally, equal number of items are put in each group so that the size of the group is not likely to affect the result of the study. Variables relating to both population characteristics are assumed to be randomly distributed among the two groups. Thus, this random replication design is, in fact, an extension of the two-group simple randomized design.

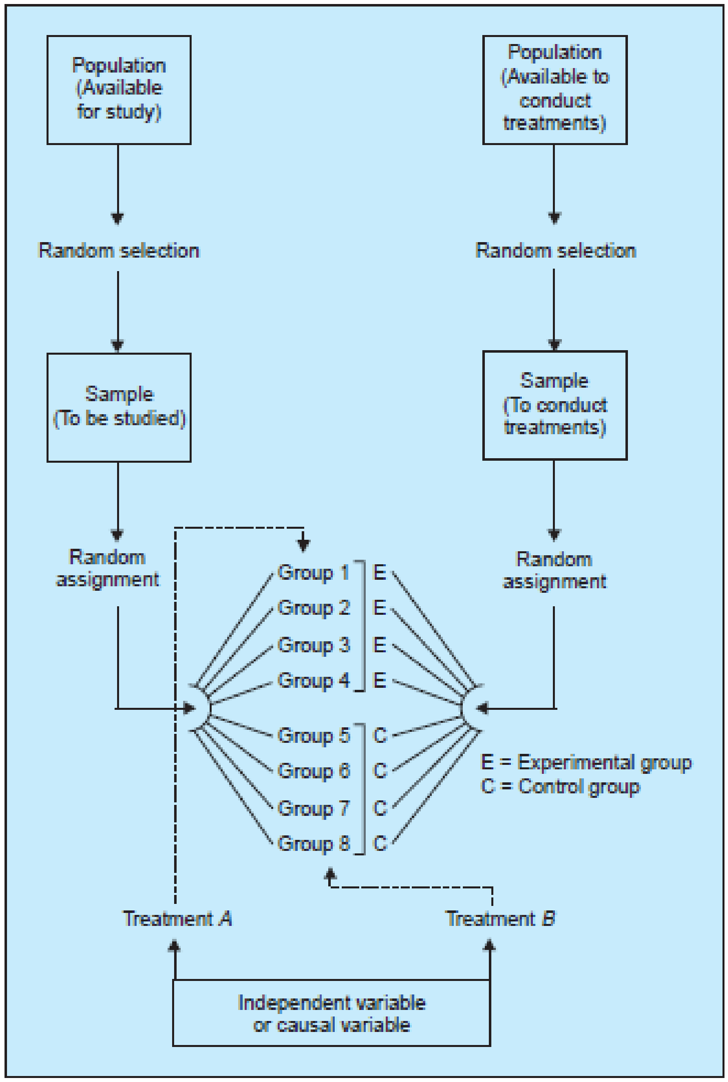


Fig.: Random replication design (in diagram form)

B.ii. Randomized block design (R.B. design)

It is an improvement over the C.R. design. In the R.B. design the principle of local control can be applied along with the other two principles of experimental designs. In the R.B. design, subjects are first divided into groups, known as blocks, such that within each group the subjects are relatively homogeneous in respect to some selected variable. The variable selected for grouping the subjects is one that is believed to be related to the measures to be obtained in respect of the dependent variable. The number of subjects in a given block would be equal to the number of treatments and one subject in each block would be randomly assigned to each treatment. In general, blocks are the levels at which we hold the extraneous factor fixed, so that its contribution to the total variability of data can be measured. The main feature of the R.B. design is that in this each treatment appears the same number of times in each block. The R.B. design is analysed by the two-way analysis of variance (two-way ANOVA)* technique.

B.iii. Latin square design (L.S. design)

It is an experimental design very frequently used in agricultural research. The conditions under which agricultural investigations are carried out are different from those in other studies for nature plays an important role in agriculture. For instance, an experiment has to be made through which the effects of five different varieties of fertilizers on the yield of a certain crop, say wheat, it to be judged. In such a case the varying fertility of the soil in different blocks in which the experiment has to be performed must be taken into consideration; otherwise the results obtained may not be very dependable because the output happens to be the effect not only of fertilizers, but it may also be the effect of fertility of soil. Similarly, there may be impact of varying seeds on the yield. To overcome such difficulties, the L.S. design is used when there are two major extraneous factors such as the varying soil fertility and varying seeds. The Latin-square design is one wherein each fertilizer, in our example, appears five times but is used only once in each row and in each column of the design. In other words, the treatments in a L.S. design are so allocated among the plots that no treatment occurs more than once in any one row or any one column. The two blocking factors may be represented through rows and columns (one through rows and the other through columns). The following is a diagrammatic form of such a design in respect of, say, five types of fertilizers, viz., A, B, C, D and E and the two blocking factor viz., the varying soil fertility and the varying seeds:

FERTILITY LEVEL

Seeds differences

	I	II	III	IV	V
X_1	A	B	C	D	E
X_2	B	C	D	E	A
X_3	C	D	E	A	B
X_4	D	E	A	B	C
X_5	E	A	B	C	D

L.S. design of orders (5 × 5) to (9 × 9) are generally used.

B.iv. Factorial designs:

Factorial designs are used in experiments where the effects of varying more than one factor are to be determined. They are especially important in several economic and social phenomena where usually a large number of factors affect a particular problem. Factorial designs can be of two types: (i) simple factorial designs and (ii) complex factorial designs.

SUMMARY

There are several research designs and the researcher must decide in advance for the collection and analysis of data as to which design would prove to be more appropriate for her/his research. S/he must give due importance to various points such as type of universe and its nature, the objectives of her/his study, the resource list or the sampling frame desired standard of accuracy and the like when taking decision in respect of the design for her/his research. From the lesson above a learner can elucidate that there are different kinds of research designs which make research possible and feasible. The research design assists the investigation in being pragmatic and scientific

Ethical aspects of animal experimentation (Biomedical Research)

A predominant view within the current ethical discussion on human dealings with animals is that humans are vested with the basic moral right to use animals for their own ends. This right, however, is subject to limits where animals are significantly harmed by human actions or are killed without sufficient reason. In the established system of normative positions on animal ethics, this position is classified as **"pathocentric"**. This means that a living organism's ability to suffer entails an obligation to protect it. On the other hand, a position is defined as **"anthropocentric"** if it categorically makes humans "the measure of all things", including when it comes to the treatment and protection of animals. A third relevant position here is the **"biocentric"** view, which assigns ethical value to all living organisms, including lower animals and plants. Whilst the extreme versions of these three positions are incompatible with one another, their more moderate forms are generally regarded as reconcilable.

The Three Rs principle

Although animal experimentation cannot be completely avoided in research, there is a general consensus that it must be restricted to the necessary minimum. The Three Rs principle, devised by W. Russell and R. Burch in 1959, can be taken as the guideline for animal experiments. The Three Rs stand for

- ✓ refinement,
- ✓ reduction and
- ✓ replacement

1. Refinement

The aim of the principle is to avoid animal experiments where possible, to reduce their number and to limit the harm caused to animals during the experiments to the necessary minimum. The consistent and responsible implementation of the Three Rs principle accommodates ethical concerns against the use of animals, and also improves the quality of the test results.

The refinement of animal experiments has the objective of minimizing the adverse effects of research procedures on animals. An animal's capacity for suffering is central to this assessment. The human obligation to minimise stressful animal experiments must be guided by the extent to which animals are capable of suffering based on their respective level of neuronal development. Particularly important to the gradation of ethically grounded animal protection is the animal's capacity for self-perception. The strongest protection should therefore be given to animals presumed to have the greatest capacity for experience due to their advanced stage of development, such as primates. However, it must also be considered that less developed animals occasionally react to an experimental setup with greater stress than those able to adapt to the stress through training.

By carefully selecting the animal models, alleviating pain using analgesia and anesthesia, improving the technology used in measurement procedures and developing non-invasive research methods, it has been possible to make great progress in the refinement of animal experiments.

2. Reduction

Statistical and methodological improvements help to reduce the number of laboratory animals. In addition to carefully selecting suitable animal models and determining the absolutely necessary number of test animals, this entails the consistent application of statistical methods. Even centrally registering and recording results from animal experiments can reduce the need for them.

3. Replacement

Replacement seeks to substitute animal experiments with alternative methods as much as possible, or to avoid them completely. If the research question permits, simple organisms such as bacteria or invertebrates, cell and tissue cultures, computer models, or other alternative methods will be used.

Alternatives to animal experimentation

Cell lines that have been harvested from animal or human tissue are often used and then bred further in a laboratory culture. These experimental methods outside the organism – known as “in vitro methods” (in vitro = in the test tube) – are of major importance and are widely used, particularly to elucidate cellular processes or the effect of medications on cell metabolism.

Another method for avoiding experiments on live animals comes from regenerative medicine and is known as ***“body on a chip”***. This method was developed from tissue engineering or bioprinting, whereby replacement organs for humans are grown from human tissue and created using a 3D printer. These mini-organs are placed on a microchip and supported by an artificial maintenance system. Sensors on the microchip measure certain parameters, such as organ temperature and oxygen content, and record changes in the system. The “body on a chip” method is used for testing the toxicity or pharmacological properties of biological and chemical substances.

“***In silico methods***” *(in silico* = on a computer) are also becoming increasingly important as alternatives to animal experimentation. These computer- controlled analysis and simulation techniques are used for assessing risk when researching tolerance to substances or theoretically modelling life processes, among other purposes.