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.

- Research design is the conceptual structure within which the research is conducted; constitutes for the blueprint for the collection, measurement and analysis of data.

- Once research project is identified and defined clearly, the next stage is to design the research.

Essence of research design:

- Selection of research approach
- Design of sampling plan
- Design of experiment
- Design of questionnaire

1.Selection of Research Approach

- Research approach - 2 types: exploratory & conclusive research for survey based researches.
- Based on requirements of study, the researcher should decide about the type of study to be conducted.

- The modeling research should be used to find the best result through a model which consists of an objective function and a set of constraints.

- The algorithmic research should be used to find the optimal or near optimal solution using either exact algorithm or heuristic, respectively.

2. Design of Experiment

- A study involves different response variables, each may be affected by many factors.

- To test the effect of these factors, a suitable experiment to be designed such that the necessary data for testing the significance of the effects of the factors on the response variable are collected & the inferences of the test are highly reliable.

- Two main steps of designing the experiment

a) Identify the response variable of the study

b) For each response variable repeat the following steps:

- Identify the factors affecting the response variable.

- Decide on the type of each of the factors (a factor may be either fixed factor or random factor)

- Fix the no. of levels (treatments) of each factor.

- Form the skeleton of the experiment

- Write the model of the experiment & define its components.

3. Design of Sampling Plan

- Sampling plan → mechanism by which the sampling units of study are selected from the sampling frame of the population.

- In turn affects cost & time to conduct the study, & reliability of inferences of the study.
- Should be selected with utmost care.

- Sampling plan – probability sampling plans & non-probability sampling plans.

- probability sampling plans : simple random sampling, systematic sampling, stratified random sampling, cluster sampling, multistage sampling etc.

- Non-probability sampling plans: convenience sampling, judgment sampling, quota sampling, snowball sampling etc.

4. Design of Questionnaire

- Data – primary or secondary data

- The data which is collected for the first time by direct observation – primary data.

- The data which is obtained from existing records, publications etc. – secondary data

- Different methods of primary data collection – personal interview, telephone interview, and mail survey.
- The success of survey methods depends on the strength of questionnaire used.
- Questionnaire – set of well-formulated questions to probe & obtain responses from the respondents.

Generalized steps of designing questionnaire:

i. Identification of research issues & finalization of the set of hypotheses.
ii. For each issue, formulation of a set of questions & then deciding about the contents & format of each question.
iii. Arrangement of questions in questionnaire in appropriate sequence.
iv. Pre-testing questionnaire
v. Review of questions for improvements.

Research Design :

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

a. *observational design* which relates to the conditions under which the observations are to be made.

c) *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 analyzed.

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

NEED FOR RESEARCH DESIGN

- 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.
- stands for advance planning of the methods to be adopted for collecting the relevant data and the techniques to be used in their analysis.

FEATURES OF A GOOD DESIGN

- ❖A good design is often characterized by adjectives like flexible, appropriate, efficient, economical and so on.

- ❖The design which minimizes bias and maximizes the reliability of the data collected and analyzed 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

- Thus, the question of good design is related to the purpose or objective of the research problem and also with the nature of the problem to be studied.
- A design may be quite suitable in one case, but may be found wanting in one respect or the other in the context of some other research problem.
- One single design cannot serve the purpose of all types of research problems.

IMPORTANT CONCEPTS RELATING TO RESEARCH DESIGN

1. 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.

- Phenomena which can take on quantitatively different values even in decimal points are called ‘continuous variables’.

- If they can only be expressed in integer values, they are non-continuous variables or in statistical language ‘discrete variables’. Age is an example of continuous variable, but the number of children is an example of non-continuous variable.

- 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.

- if we say that height depends upon age, then height is a dependent variable and age is an independent variable.

2. 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.

- Suppose the researcher wants to test the hypothesis that there is a relationship between children's gains in social studies achievement and their self-concepts.

- In this case self-concept is an independent variable and social studies achievement is a dependent variable. Intelligence may as well affect the social studies achievement, but since it is not related to the purpose of the study undertaken by the researcher, it will be termed as an extraneous variable.

- 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.*

3. Control: One important characteristic of a good research design is to minimize the influence or effect of extraneous variable(s). The technical term ‘control’ is used when we design the study minimizing the effects of extraneous independent variables.

- In experimental researches, the term ‘control’ is used to refer to restrain experimental conditions.

4. 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).

5. Research hypothesis: When a prediction or a hypothesized relationship is to be tested by scientific methods, it is termed as 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.

- Predictive statements which are not to be objectively verified or the relationships that are assumed but not to be tested, are not termed research hypotheses.

6. 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’ & a research in which an independent variable is not manipulated is called ‘non-experimental hypothesis-testing research

7. 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’.

8. Treatments: The different conditions under which experimental and control groups are put are usually referred to as 'treatments'.

9.Experiment: The process of examining the truth of a statistical hypothesis, relating to some research problem, is known as an experiment.

- For example, we can conduct an experiment to examine the usefulness of a certain newly developed drug.

- Experiments can be of two types, 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.

10. Experimental unit(s): The pre-determined plots or the blocks, where different treatments are used, are known as experimental units

DIFFERENT RESEARCH DESIGNS

(1) Research design in case of exploratory research studies;

(2) research design in case of descriptive and diagnostic research studies, and

(3) research design in case of hypothesis-testing research studies.

1. **Research design in case of exploratory research studies:** Exploratory research studies are also termed as formulative research studies. The main purpose 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 is on the discovery of ideas and insights.

- The research design appropriate for such studies must be flexible enough to provide opportunity for considering different aspects of a problem under study.

- Inbuilt flexibility in research design is needed because the research problem, broadly defined initially, is transformed into one with more precise meaning in exploratory studies, which fact may necessitate changes in the research procedure for gathering relevant data

3 methods:

(a)the survey of concerning literature;

(b) the experience survey and

(c) the analysis of ‘insight-stimulating’ examples *a. The survey of concerning literature* happens to be the most simple and fruitful method of formulating precisely the research problem or developing hypothesis.

- Hypotheses stated by earlier workers may be reviewed and their usefulness be evaluated as a basis for further research.

In this way the researcher should review and build upon the work already done by others, but in cases where hypotheses have not yet been formulated, his task is to review the available material for deriving the relevant hypotheses from it.

b. Experience survey means the survey of people who have had practical experience with the problem to be studied.

- The object of such a survey is to obtain insight into the relationships between variables and new ideas relating to the research problem.

- For such a survey people who are competent and can contribute new ideas may be carefully selected as respondents to ensure a representation of different types of experience (- interview) *c. Analysis of ‘insight-stimulating’ examples* 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.

- Attitude of the investigator, the intensity of the study and the ability of the researcher to draw together diverse information into a unified interpretation are the main features which make this method an appropriate procedure for evoking insights.

2. Research design in case of descriptive and diagnostic research studies: Descriptive research studies are those studies which are concerned with describing the characteristics of a particular individual, or of a group, whereas 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.

- The research design must make enough provision for protection against bias and must maximize reliability, with due concern for the economical completion of the research study.

- The design in such studies must be rigid & not flexible & must focus attention on the following:

(a) Formulating the objective of the study (what the study is about and why is it being made?)
(b) Designing the methods of data collection (what techniques of gathering data will be adopted?)
(c) Selecting the sample (how much material will be needed?)
(d) Collecting the data (where can the required data be found and with what time period should the data be related?)
(e) Processing and analyzing the data.
(f) Reporting the findings.

- In a descriptive/diagnostic study the first step is to specify the objectives with sufficient precision to ensure that the data collected are relevant.
- If this is not done carefully, the study may not provide the desired information.

Then comes the question of selecting the methods by which the data are to be obtained (methods: observation, questionnaires, interviewing, examination of records, etc.).

- In most of the descriptive/diagnostic studies the researcher takes out sample(s) and then wishes to make statements about the population on the basis of the sample analysis or analyses.
- Sampling designs are also used - samples may yield accurate information with a minimum amount of research effort

- To obtain data free from errors introduced by those responsible for collecting them, it is necessary to supervise closely the staff of field workers as they collect and record information.

- As data are collected, they should be examined for completeness, comprehensibility, consistency and reliability.”

- The data collected must be processed and analysed. This includes steps like coding the interview replies, observations, etc.; tabulating the data; and performing several statistical computations.

- Reporting the findings - task of communicating the findings to others and the researcher must do it in an efficient manner.

- Thus, the research design in case of descriptive/diagnostic studies is a comparative design throwing light on all points narrated above and must be prepared keeping in view the objective(s) of the study and the resources available.

- it must ensure the minimization of bias and maximization of reliability of the evidence collected.

Research Design	Type of study	
	Exploratory of 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 maximise reliability)
(i) Sampling design	Non-probability sampling design (purposive or judgement sampling)	Probability sampling design (random sampling)
(ii) Statistical design	No pre-planned design for analysis	Pre-planned design for analysis
(iii) Observational design	Unstructured instruments for collection of data	Structured or well thought out instruments for collection of data
(iv) Operational design	No fixed decisions about the operational procedures	Advanced decisions about operational procedures.

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.

BASIC PRINCIPLES OF EXPERIMENTAL DESIGNS

R. A. Fisher, a British statistician and professor, has enumerated three principles of experimental designs:

(1)the Principle of Replication;
(2)the Principle of Randomization; and
(3)the Principle of Local Control.

- *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.

- The *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.”

- The *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.

- This means that we should plan the experiment in a manner that we can perform a two-way analysis of variance, in which the total variability of the data is divided into three components attributed to treatments (varieties of rice in our case), the extraneous factor (soil fertility in our case) and experimental error.

- In other words, according to the principle of local control, we first divide the field into several homogeneous parts, known as blocks, and then each such block is divided into parts equal to the number of treatments. Then the treatments are randomly assigned to these parts of a block.

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, informal experimental designs and formal experimental designs.

- Informal experimental designs are 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.

1. **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

effect of the treatment would be equal to the level of the phenomenon after the treatment minus the level of the phenomenon before the treatment.

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

Test area:	Level of phenomenon before treatment (X)	Treatment introduced →	Level of phenomenon after treatment (Y)

Treatment Effect = (Y) – (X)

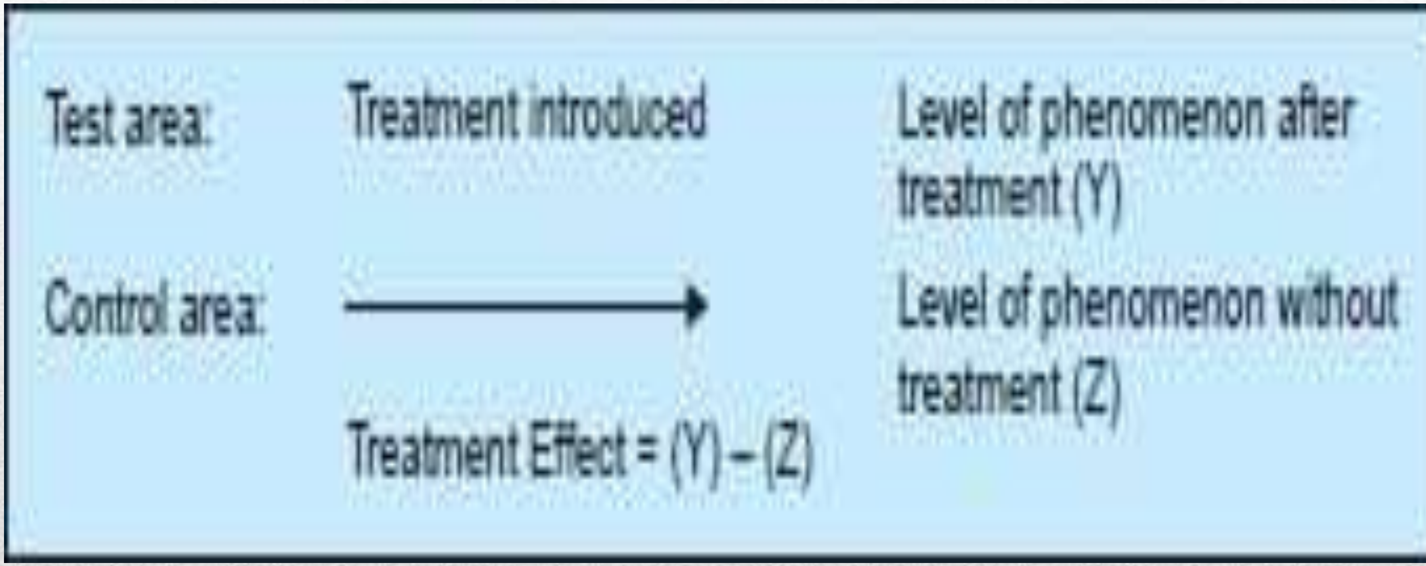
2. After-only with control design:

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. Treatment impact is assessed by subtracting the value of the dependent variable in the control area from its value in the test area.

- The basic assumption in such a design is that the two areas are identical with respect to their behaviour towards the phenomenon considered. If this assumption is not true, there is the possibility of extraneous variation entering into the treatment effect.

- data can be collected in such a design without the introduction of problems with the passage of time. In this respect the design is superior to before-and-after without control design.


Test area:
Treatment introduced
Level of phenomenon after treatment (Y)
Control area:
Level of phenomenon without treatment (Z)
Treatment Effect = (Y) – (Z)

3. 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. But at times, due to lack of historical data, time or a comparable control area

	Time Period I		Time Period II
Test area:	Level of phenomenon before treatment (X)	Treatment introduced →	Level of phenomenon after treatment (Y)
Control area:	Level of phenomenon without treatment (A)		Level of phenomenon without treatment (Z)

Treatment Effect = (Y – X) – (Z – A)

4. Completely randomized design (C.R. design):

- Involves only two principles, 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).

Eg. - if we have 10 subjects and if we wish to test 5 under treatment A and 5 under treatment B, the randomization process gives every possible group of 5 subjects selected from a set of 10 an equal opportunity of being assigned to treatment A and treatment B.

One-way analysis of variance is used to analyse such a design. Even unequal replications can also work in this 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.

2 forms of C R Design

(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 (Such random assignment of items to two groups is technically described as principle of randomization).

- Thus, this design yields two groups as representatives of the population.

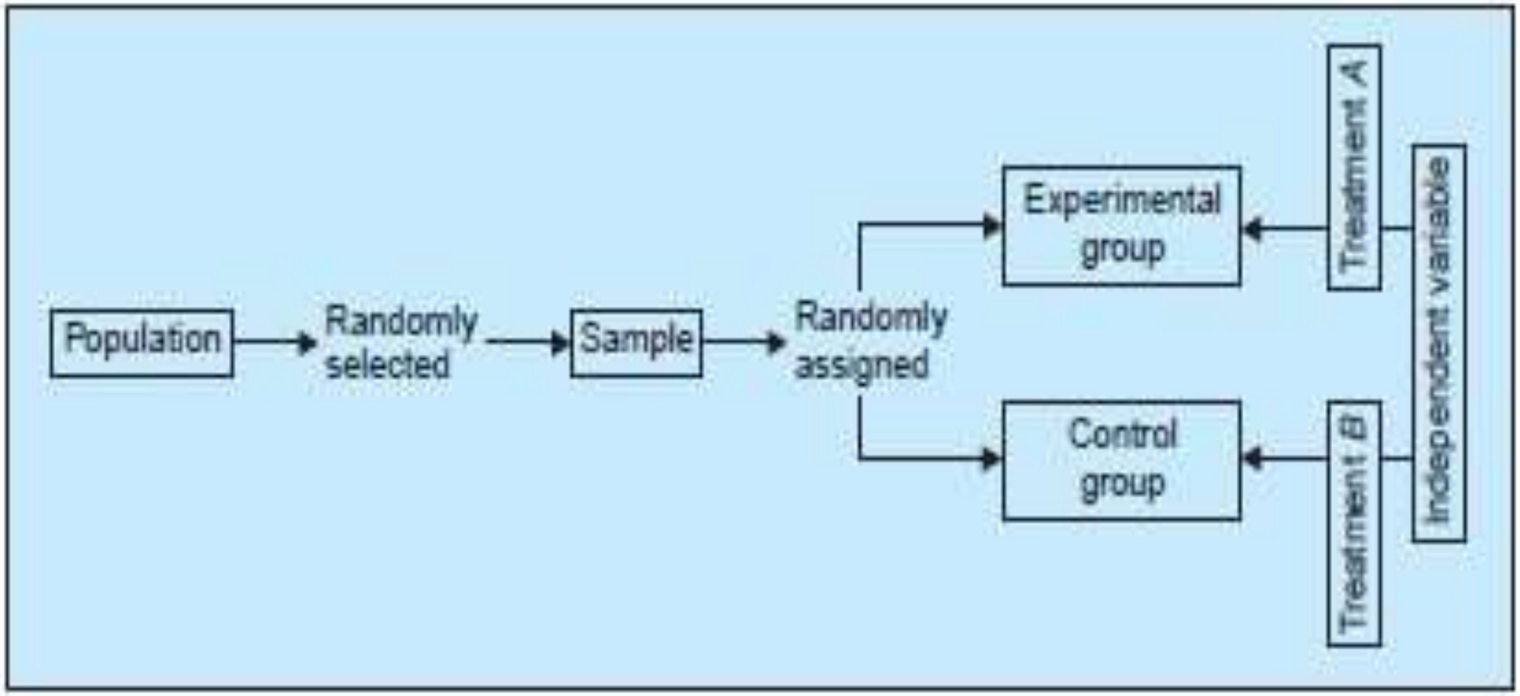


Fig. 3.4: Two-group simple randomized experimental design (in diagram form)

- Since in the sample randomized design the elements constituting the sample are randomly drawn from the same population and randomly assigned to the experimental and control groups, it becomes possible to draw conclusions on the basis of samples applicable for the population.

- The two groups (experimental and control) 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., in the above design, the *differences on the dependent variable were ignored, i.e., the extraneous variable* was not controlled. But in a random replications design, the effect of such differences are minimised by providing a number of repetitions for each treatment.

- Each repetition is technically called a ‘replication’.

- Random replication design serves two purposes, it provides controls for the differential effects of the extraneous independent variables and secondly, it randomizes any individual differences among those conducting the treatments.

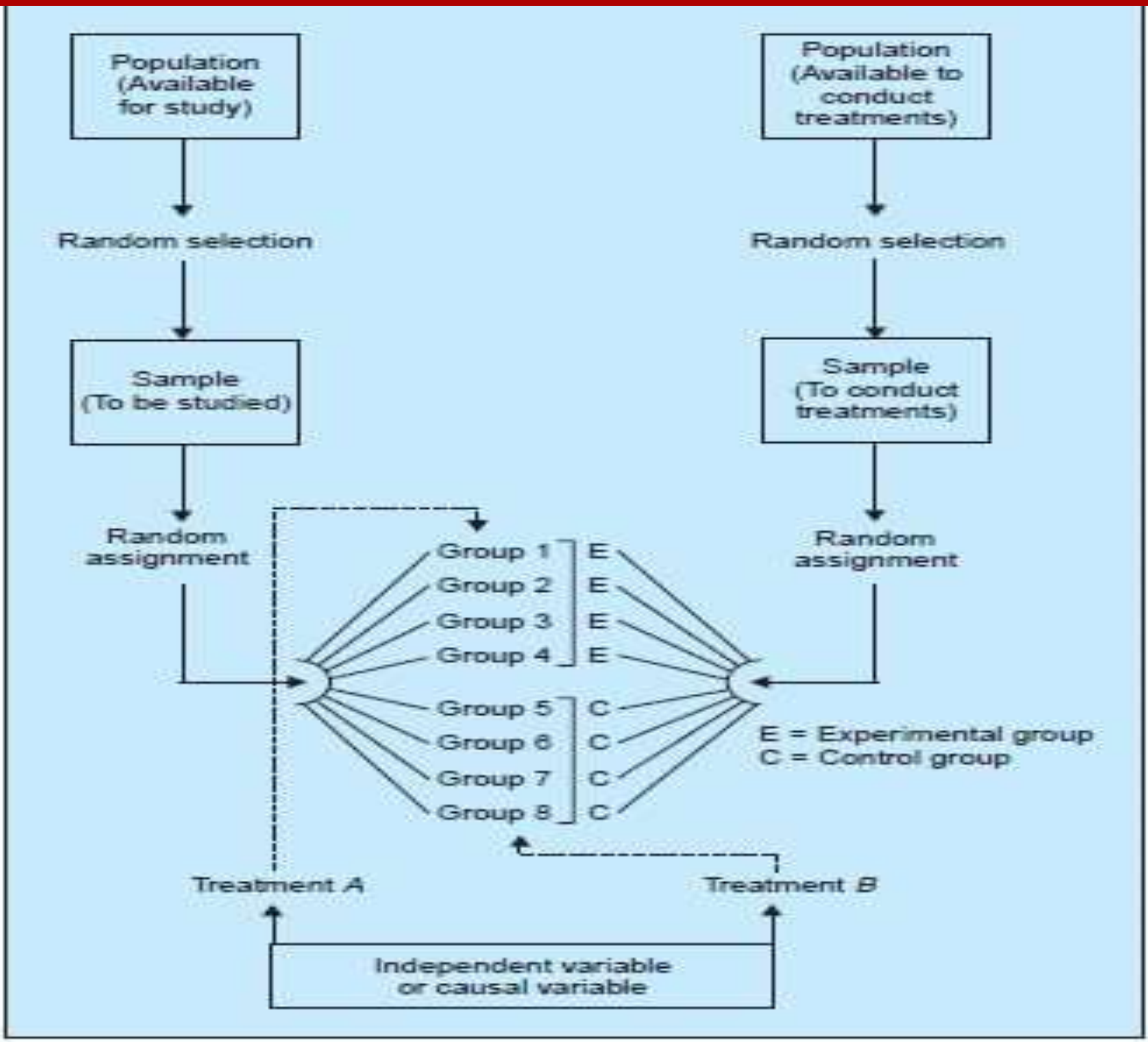


Fig. 3.5: Random replication design (in diagram form)

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, 4 experimental and 4 control groups. Similarly, sample is taken randomly from the population available to conduct experiments (because of the 8 groups 8 such individuals be selected) and the 8 individuals so selected should be randomly assigned to the 8 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.

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

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.

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- 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.

	Very low I.Q.	Low I.Q.	Average I.Q.	High I.Q.	Very high I.Q.
	Student A	Student B	Student C	Student D	Student E
Form 1	82	67	57	71	73
Form 2	90	68	54	70	81
Form 3	86	73	51	69	84
Form 4	93	77	60	65	71

- If each student separately randomized the order in which he or she took the four tests (by using random numbers or some similar device), we refer to the design of this experiment as a R.B. design.

- The purpose of this randomization is to take care of such possible extraneous factors (say as fatigue) or perhaps the experience gained from repeatedly taking the test.

6. Latin square design (L.S. design)

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 eg., 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 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).

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

- The merit of this experimental design is that it enables differences in fertility gradients in the field to be eliminated in comparison to the effects of different varieties of fertilizers on the yield of the crop.
- But this design suffers from one limitation, and it is that although each row and each column represents equally all fertilizer varieties, there may be considerable difference in the row and column means both up &across the field.

- This, means that in L.S. design we must assume that there is no interaction between treatments and blocking factors. This defect can, however, be removed by taking the means of rows and columns equal to the field mean by adjusting the results.

- Another limitation of this design is that it requires number of rows, columns and treatments to be equal.

7. Factorial designs:

Factorial designs are used in experiments where the effects of varying more than one factor are to be determined.

-important in several economic and social phenomena where usually a large number of factors affect a particular problem.

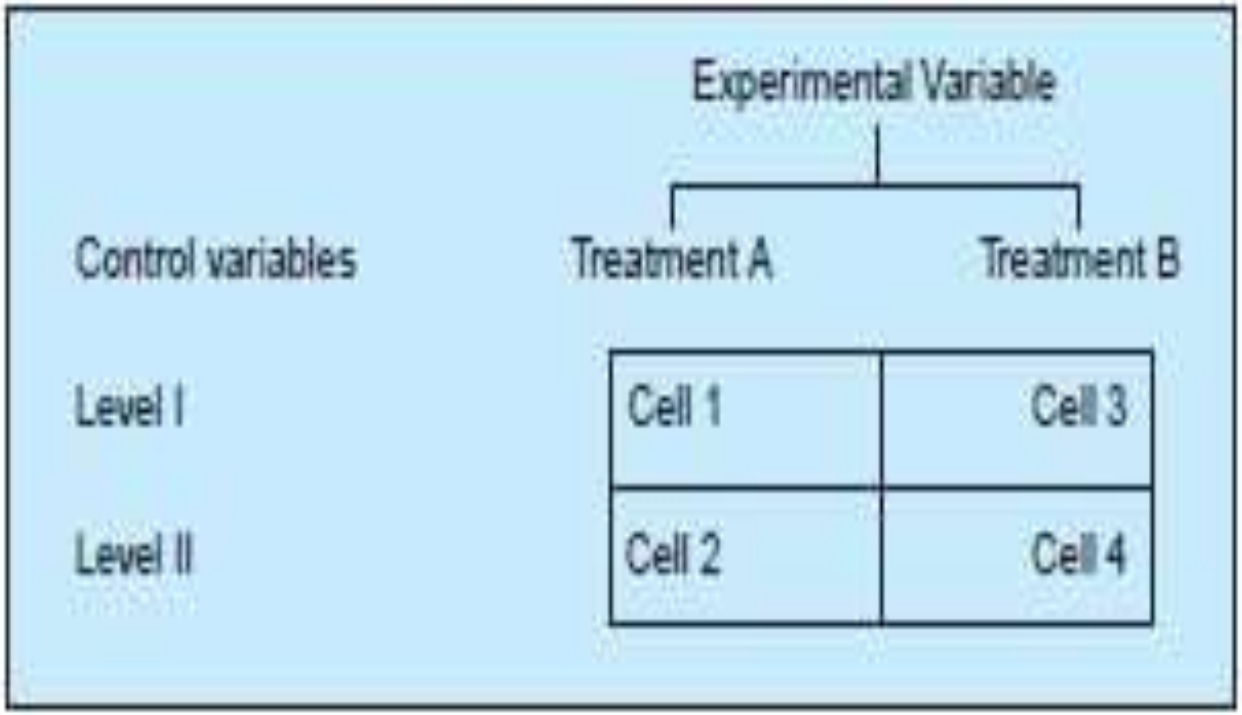
-Factorial designs - two types:

(i) simple factorial designs and (ii) complex factorial designs.

(i)Simple factorial designs: This considers the effects of varying two factors on the dependent variable.

- -Also termed as a ‘two-factor-factorial design’, whereas complex factorial design is known as ‘multifactor- factorial design.’

2 × 2 SIMPLE FACTORIAL DESIGN



The extraneous variable to be controlled by heterogeneity is called the control variable and the independent variable, which is manipulated, is called the experimental variable.

- So two treatments of the experimental variable and two levels of the control variable. As such there are four cells into which the sample is divided. Each of the four combinations would provide one treatment or experimental condition

- Subjects are assigned at random to each treatment in the same manner as in a randomized group design. The means for different cells may be obtained along with the means for different rows and columns.

- Means of different cells represent the mean scores for the dependent variable and the column means in the given design are termed the main effect for treatments without taking into account any differential effect that is due to the level of the control variable.

Similarly, the row means in the said design are termed the main effects for levels without regard to treatment. Thus, through this design we can study the main effects of treatments as well as the main effects of levels.

- An additional merit of this design is that one can examine the interaction between treatments and levels, through which one may say whether the treatment and levels are independent of each other or they are not so.

(ii) *Complex factorial designs:*

- Experiments with more than two factors at a time involve the use of complex factorial designs.

- A design which considers three or more independent variables simultaneously is called a complex factorial design.

- In case of three factors with one experimental variable having two treatments and two control variables, each one of which having two levels, the design used will be termed 2 × 2 × 2 complex factorial design which will contain a total of eight cells.

2 × 2 × 2 COMPLEX FACTORIAL DESIGN

		Experimental Variable			
		Treatment A		Treatment B	
		Control Variable 2 Level I	Control Variable 2 Level II	Control Variable 2 Level I	Control Variable 2 Level II
Control Variable 1	Level I	Cell 1	Cell 3	Cell 5	Cell 7
	Level II	Cell 2	Cell 4	Cell 6	Cell 8

Factorial designs are used mainly because of the two advantages.

(i) They provide equivalent accuracy (as happens in the case of experiments with only one factor) with less labour and as such are a source of economy. Using factorial designs, we can determine the main effects of two (in simple factorial design) or more (in case of complex factorial design) factors (or variables) in one single experiment.

(ii) They permit various other comparisons of interest. For example, they give information about such effects which cannot be obtained by treating one single factor at a time.

- The determination of interaction effects is possible in case of factorial designs.