Unit 3- RESEARCH DESIGN AND ANALYSIS

SYLLABUS:

Meaning of research design - Need of research design - Different research designs - Basic principles of experimental design - Developing a research plan - Design of experimental set-up - Use of standards and codes. Overview of Multivariate analysis, Hypotheses testing and Measures of Association. Presenting Insights and findings using written reports and oral presentation. 9 Hours

3.1 MEANING OF RESEARCH DESIGN

(Q: Define research design. Explain the components and important features of research design. Q: Discuss the various types of research designs and their applications.
Q: Highlight the differences between exploratory and descriptive/ diagnostic type of research designs)

- The task of defining the research problem is the preparation of the design of the research project, popularly known as the "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** stands for advance planning of the methods to be adopted for collecting the relevant data, techniques for data analysis, keeping in view the objective of the research and the availability of staff, time and money.

3.1.1 The parts of research design:

(a) **Sampling design**: It deals with the method of selecting items to be observed for the given study;
(b) **Observational design**: It relates to the conditions under which the observations are to be made;
(c) **Statistical design**: It is concerned with the question of how many items are to be observed and how the information and data gathered are to be analysed.
(d) **Operational design**: It deals with the techniques of carrying out the procedures specified in the sampling, statistical and observational designs.

3.1.2 The important features of a research design:

(a) A clear statement of the research problem;
(b) Procedures and techniques to be used for gathering information;
(c) The population to be studied;
(d) Methods to be used in processing and analysing data.
(e) It includes the constraints time and cost budgets.

3.2 NEED (Importance) FOR RESEARCH DESIGN

- Facilitates the smooth sailing of the various research operations, making research as efficient as possible yielding maximal information with minimal expenditure.
- advance planning of the methods to be adopted for collecting the relevant data and the techniques to be used in their analysis
- Without proper research design many researches do not serve the purpose for which they are undertaken.
- The research design helps the researcher to organize his ideas in a form whereby it will

be possible for him to look for flaws and inadequacies.

- Ex: Better, economical and attractive construction of a house, needs a blueprint well thought out and prepared by an expert architect. Similarly, for the data collection and analysis, research project needs a research design.

3.3 DIFFERENT RESEARCH DESIGNS

Different research designs are:

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

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

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

Research design in case of exploratory research studies

- The 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.
- In this type of study the research design should be flexible.
- Generally, the following three methods are used.

(a) the survey of concerning literature

(b) the experience survey and

(c) the analysis of 'insight-stimulating' examples.

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.
- Diagnostic research studies determine the frequency with which something occurs or its association with something else.
- These studies must be rigid and not flexible.
- It includes:
  - (a) **Formulating the objective of the study with precision** – deals with what the study is about and why is it being made.
  - (b) **Designing the methods of data collection** –deals with what techniques of gathering data will be adopted. Observation, questionnaires, interviewing, examination of records, etc. are the methods available. Researcher should safeguard against bias and unreliability.
  - (c) **Selecting the sample** –deals with how much material will be needed. Researcher takes out sample(s) and then infers about the population on the basis of the sample analysis.
  - (d) **Collecting the data** –deals with where can the required data be found and with what time period should the data be related. As data then should be examined for completeness, comprehensibility, consistency and reliability.
  - (e) **Processing and analyzing the data**: This includes coding the interview replies, observations, tabulating the data; and performing several statistical computations. Coding should avoid errors, tabulation should be accurate, statistical operations and tests of significance should be appropriate to draw proper conclusions.
  - (f) **Reporting the findings**: To communicate the findings to others efficiently, the layout of the

report needs to be well planned to present in simple and effective style.

The difference between two types of research designs are summarized in Table 3.1:

Table 3.1

	Type of study	
Research Design	*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.

Research design in case of hypothesis-testing research (experimental studies) **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.

BASIC PRINCIPLES OF EXPERIMENTAL DESIGNS

(Q: What is meant by experimental design? What are its benefits
? Q: Differentiate between:
i. factors vs. levels ii. dependent vs. independent variables
iii. full factorial designs vs. fractional factorial
designs Q: Enumerate the principles of experimental
design.
Q: Classify the Formal experimental designs and illustrate each with
example Q: Clarify the use of orthogonal arrays and response surface
designs)

Experimental design: It provides a powerful framework for conducting research that can yield valid, reliable, and insightful results. It outlines how data is collected, what variables are manipulated, how results are interpreted and allows researchers to investigate cause-and-effect relationships between variables.

Benefits of experimental design:

- **Resource efficiency**: More information per experiment will be obtained when compared with unplanned experiments.
- **Control over variables**: Controls external variables (confounding factors) that might otherwise influence the dependent variable

- **Establishing causality**: Helps to draw conclusions about cause-and-effect relationships between variables.
- **Replicability**: Results can be tested in different contexts, strengthening reliability of the findings.
- **Random assignment**: Reduces bias, ensures random allocation.
- **Precision**: Facilitates accurate measurement of effects of an independent variable on a dependent variable

Important terms used:

- **Dependent and Independent variables:** Independent variables are the factors manipulated or controlled by the experimenter to observe their effect on outcomes. **Dependent variables** (response variable) are the outcomes measured in an experiment, and they depend on changes in the independent variables.
  Ex: In a study on medication effects, the **dosage of a drug** (e.g., 10 mg, 20 mg, 30 mg) is the **independent variable** (response variable, outcome) that is controlled, while **blood pressure levels** are the **dependent variables (factors)** measured to observe the drug's effect on lowering blood pressure.
- **Factors and Levels:** In experimental design, factors are the variables of interest, and levels are the specific values those variables take in the experiment:
  Factor: A factor is an independent variable that is expected to influence the outcome of an experiment. For example, in a chemical reaction study, factors might include temperature, pressure, and concentration.
  Level: A level is a specific value or setting of a factor. Each factor can have multiple levels. For example, if "temperature" is a factor, its levels might be 100°C, 150°C, and 200°C. Levels represent the different conditions under which the factor is tested.

  Treatment (condition): A "treatment" refers to a specific combination of factors and their corresponding levels that are applied to the experimental group (group of units that receive the treatment) to observe its effect on the outcome being studied.

Principles of experimental designs

Three **principles of experimental design,** as per Professor Fisher:

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

(1) The Principle of Replication:

- As per this, the experiment should be repeated more than once and each treatment is applied in many experimental units to improve the statistical accuracy.
- For example, suppose we are to examine the effect of two varieties of rice.
- For this purpose, we may divide the field into two parts and grow one variety in one part and the other variety in the other part. We can then compare the yield of the two parts and draw conclusion on that basis.
- But if we are to apply the principle of replication to this experiment, then,
- we first divide the field into several parts, grow one variety in half of these parts and the other variety in the remaining parts. We can then collect the data of yield of the two varieties and draw conclusion by comparing the same. The result so obtained will be more reliable in comparison to the conclusion we draw without applying the principle of replication.
- The entire experiment can even be repeated several times for better results.

(2) The Principle of Randomization:

- It helps to protect experiments, from the influence of external factors by randomly assigning treatments.
- 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."
- For instance, if we grow one variety of rice, say, in the first half of the parts of a field and the other variety is grown in the other half, then it is just possible that the soil fertility may be different in the first half in comparison to the other half. If this is so, our results would not be realistic.
- According to principle of replication, assign the variety of rice to be grown in different parts of the field on the basis of some random sampling technique and protect ourselves against the effects of the extraneous factors (soil fertility differences in the given case).

(3) Principle of Local Control:

- Through this, one can eliminate the variability due to external factors reducing the 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. Dividing the field into several homogenous parts is known as 'blocking'.

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.

(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) Informal experimental designs: Informal experimental designs are those designs that normally use a less sophisticated form of analysis based on differences in magnitudes

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 design can be represented as

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. The design can be represented as

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. The design can be represented as

	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)		

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. due to lack of historical data, we prefer design 1 or design2.

Formal experimental designs: Offer better control and uses statistically designed experiments. They are classified as:

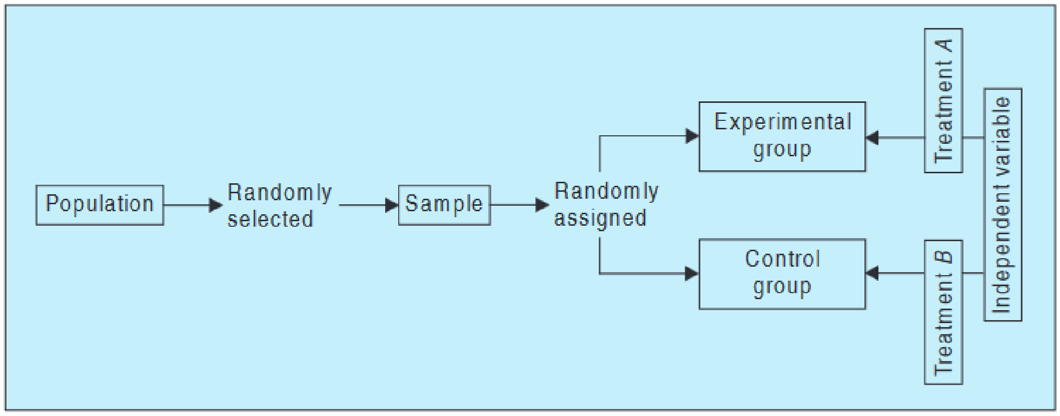
(i) Completely randomized design (C.R. Design).
(ii) Randomized block design (R.B. Design).
(iii) Latin square design (L.S. Design).
(iv) Factorial designs.

(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).
- For instance, 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.
- There are two forms of completely randomized designs
  - Two-group simple randomized design
  - Random replications design

(i) **Two-group simple randomized design**: In a two-group simple randomized design,

- first 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).
- this design yields two groups as representatives of the population. In a diagram form this design can be shown in this way 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.



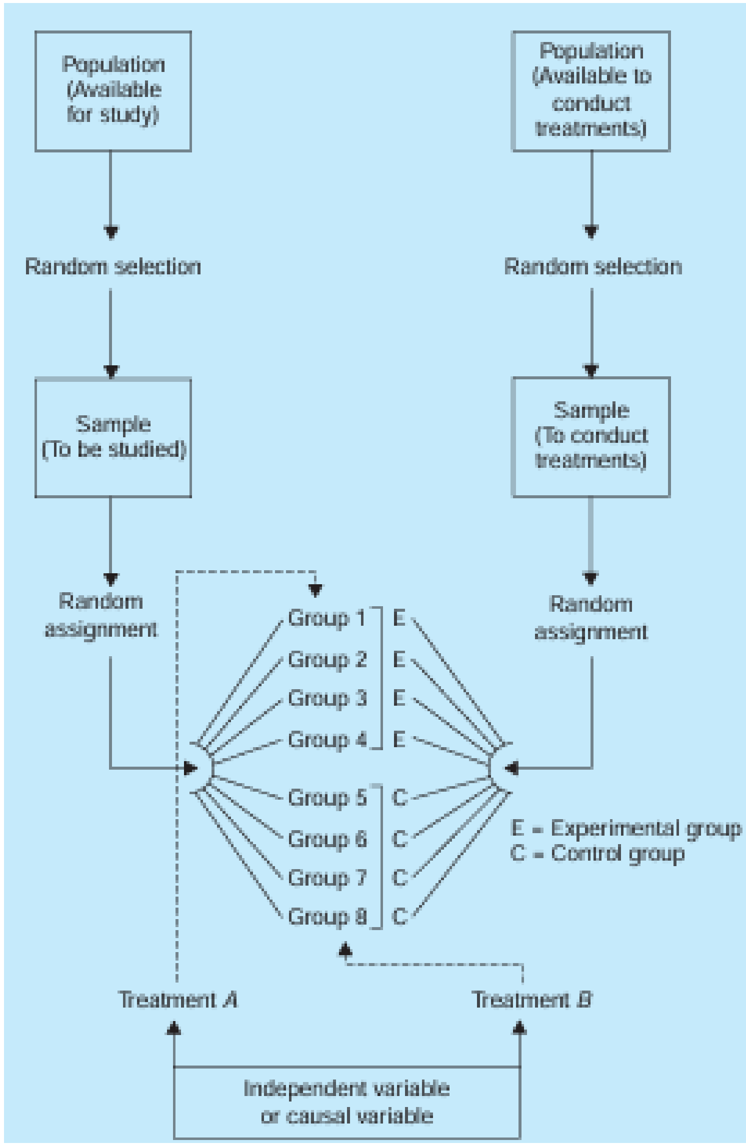
- The merit of such a design is that it is simple and randomizes the differences among the sample items. But the limitation of it is that the individual differences among those conducting the treatments are not eliminated, i.e., it does not control the extraneous variable.

(ii) **Random replications design:**

The limitation of the two-group randomized design is usually eliminated within the random replications design. In the illustration just cited above, the teacher 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 (or reduced) 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.
- It randomizes any individual differences among those conducting the treatments.



Randomized block design (R.B. design):
It is an improvement over the C.R. in this design all these basic principles of experimental design are used.
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.
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.

	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

Latin square design (L.S. design)

This type of 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 example, 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 majors' extraneous factors such as the varying soil fertility and varying seeds.

The two blocking factors may be represented through rows and columns. Fig shows diagrammatized from L.S design 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

Factorial designs:

Factorial designs are used in experiments where the effects of varying more than one factor is 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:

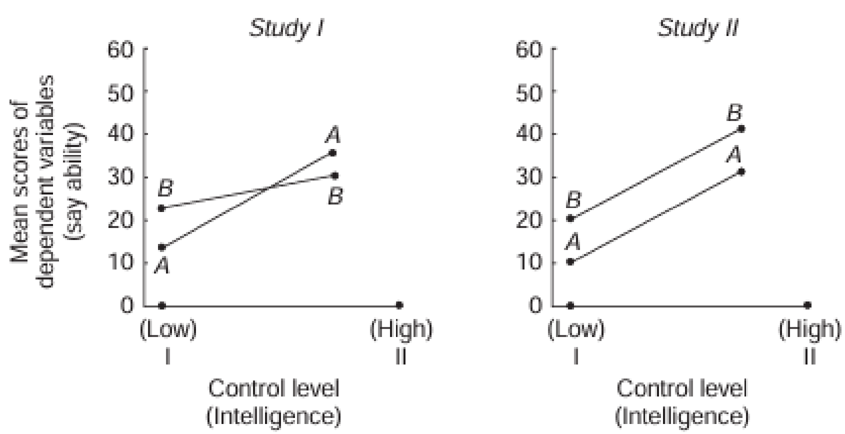
(i) simple factorial designs and

(ii) complex factorial designs. We take them separately

(i) **Simple factorial designs:** In case of simple factorial designs, we consider the effects of varying two factors on the dependent variable, but when an experiment is done with more than two factors, we use complex factorial designs. Simple factorial design is also termed as a 'two-factor-factorial design'.

2 × 2 SIMPLE FACTORIAL DESIGN

	Experimental Variable	
Control variables	Treatment A	Treatment B
Level I	Cell 1	Cell 3
Level II	Cell 2	Cell 4



(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.

Factorial designs are used mainly because of the two advantages.

(i) They provide equivalent Accuracy with less labour and as such are a source of economy.

(ii) They permit various other comparisons of interest.

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

DEVELOPING A RESEARCH PLAN

(Q: Define a research plan. What is its significance?)

'Research Plan': After identifying and defining the problem researcher must arrange his ideas in order and write them in the form of an experimental plan, known as 'Research Plan'.

3.6.1 Importance of Research Plan:

(a) It helps to organize the ideas and identify the inadequacies.
(b) It suggests what must be done further and to begin with which materials have to be collected.
(c) It is a document that can be given to others for comment.

3.6.2 Research plan must contain the following items:

1. A clearly stated research objective, outlining what the researcher is expected to do.
2. An explicitly stated research problem stating what information is needed to solve the problem.
3. Each major concept (to be measured) defined in operational terms.
4. An overall description of the approach to be adopted.
5. The details of the techniques to be adopted. For instance, if interview method is to be used, detailed interview procedure, if tests are to be given, the conditions under which they are to be administered and the nature of instruments to be used.

3.7 DESIGN OF EXPERIMENTAL SET-UP

(Q: Identify and explain the phases in the process of designing an experimental setup.)

The experimental set-up depends on objective of the research.

- Process is divided into three main phases: conceptual, substantive and detail design.
- During the **conceptual phase** one should avoid thinking about physical hardware and should concentrate on functional requirements. The approaches are: (i) literature search (ii) known technical systems (iii) analogies (iv) previous experimental studies (v) design catalogues (vi) discussion with colleagues and experts etc.
- In the **substantive or embodiment phase**, the researcher should concentrate on how to convert the conceptual set-ups into physical or simulated structures. Here, the main emphasis is identification and assessment of equipment, instruments, software available, sources of supply, their method of functioning, efficacy, precision, cost etc.

- In **detailed design phase**, each of the alternative experimental set-up has to be thoroughly evaluated considering the study objective, expected outcome, feasibility, cost involved and time frame required etc. and most feasible one should be selected for adoption.

3.8 USE OF STANDARDS AND CODES

(Q: Give an overview of codes and standards used by the researcher in the design of the experimental set-up.)

- The **codes and standards** are an important source of documents to help the researcher in the design of the experimental set-up. If these standardized procedures are adopted, the credibility of the approach gets enhanced.
- Standards specify the number of specimens to be taken, the statistical tools to be used and cover instrument accuracy, test apparatus, testing methods and environment.
- Many countries have their national standards organizations, which ensure coordination and preparation of standards and codes and publish them for the benefit of industry and public. Ex: American National Standards Institute (ANSI) of USA, British Standards (BS) of UK, DIN standards of Germany, Bureau of Indian Standards (BIS) of India. The International Standards Organization (ISO)
  examines the standards prepared by member countries and evolves common standards.
- The professional bodies are also involved in the preparation of specification, standards and codes on various aspects. Ex: the American Society for Testing Materials (ASTM), Society of Automotive Engineers (SAE), American Concrete Institute (ACI), Institute of Electrical and Electronic Engineers
  (IEEE), Association of Computing Machinery (ACM) and Indian Road Congress (IRC) etc.

3.9 OVERVIEW OF MULTIVARIATE ANALYSIS

(Q: Throw light on the important techniques used in Multivariate Analysis)

3.9.1 Definition

Multivariate analysis is a powerful statistical tool that enables researchers to investigate and understand complex data sets by considering multiple variables simultaneously. Unlike univariate analysis, which examines one variable at a time, multivariate analysis explores the relationships and interactions among several variables.

3.9.2 Purpose

The main goals of multivariate analysis include:

- Understanding complex relationships among variables.
- Identifying patterns and trends in data.
- Reducing data dimensionality while retaining essential information.
- Making predictions based on multiple inputs.

3.9.3 Common Techniques

1. **Multiple Regression Analysis**: Examines the relationship between one dependent variable and multiple independent variables to predict outcomes. Ex: researchers might investigate how various factors, such as age, income, education level, and lifestyle choices, impact individuals' health outcomes (the dependent variable).
2. **Factor Analysis:** Identifies underlying factors that explain the correlations among multiple observed variables, useful for data reduction. Ex: Researchers might collect survey data on responses to questions about consumer preferences for various smartphone features such as battery life, camera quality, screen size, brand reputation, and price.
   Through factor analysis, the researchers could identify:
   Performance: includes battery life and processing speed. Camera Quality: encompasses camera resolution and features. Value: combines brand reputation and price sensitivity.
3. **Principal Component Analysis (PCA):** Transforms correlated variables into a set of uncorrelated variables (principal components) to simplify data analysis. These variables represent the directions of maximum variance in the data.
   Ex: In analyzing air quality data, researchers collect data on various air pollutants, including levels of carbon monoxide, nitrogen dioxide, sulfur dioxide, ozone etc. across multiple cities. Using PCA, the researchers can reduce the complexity of this data as follows:
   Component 1: Represents overall pollution levels (combining effects of all pollutants).
   Component 2: Distinguishes between traffic-related pollutants (e.g., carbon monoxide and nitrogen dioxide) and industrial pollutants (e.g., sulfur dioxide).
4. **Cluster Analysis:** Groups similar observations or variables into clusters, helping to identify natural groupings within data.
   Ex: A retail company collects data on various customer attributes, such as age, income, shopping frequency, and preferences for product categories (e.g., electronics, clothing, groceries).
   Using cluster analysis, the company can identify:
   Cluster1 Younger customers with high incomes frequently buy electronics. Cluster2: Middle-aged customers with moderate incomes look for discounts.
   Cluster3: Young adults interested in clothing and accessories, shop regularly for latest trends.
5. **MANOVA (Multivariate Analysis of Variance):** Tests differences in multiple dependent variables across groups based on independent variables.
   Ex: A study is investigating the effects of three teaching methods (traditional, online, and hybrid) on student performance across multiple subjects, such as math, science, and language arts.
   The independent variable would be the teaching method, while the dependent variables would be the test scores in math, science, and language arts. Using MANOVA, the researchers can determine if there are any statistically significant differences in student performance across the three teaching methods for the combined scores in all subjects.

3.9.4 Applications

- Market Research: Understanding consumer preferences and behavior.
- Healthcare: Analyzing patient data to identify risk factors for diseases.
- Social Sciences: Studying relationships between socioeconomic factors and outcomes.
- Finance: Portfolio management and risk assessment.

3.7 HYPOTHESIS TESTING OVERVIEW

(**Q:** What is a hypothesis? Describe the characteristics of a good hypothesis and explain the process of hypothesis testing.

Q: Differentiate between: i. Null hypothesis and alternative hypothesis ii. Type I and Type II errors iii. Two-tailed and One-tailed tests

Q: Explain: The level of significance and decision rule for testing of hypothesis)

Hypothesis testing is a statistical technique used to draw conclusions about an entire population based on a representative sample. It involves formulating a hypothesis, collecting sample data, and evaluating the evidence to determine whether the null hypothesis (expected result) or the alternative hypothesis (the proposed change) is more likely.

3.7.1 What is hypothesis? Research hypothesis is a predictive statement, capable of being tested by scientific methods. They state the variables of concern, the relationships among them, and the target group being studied.

Ex: 1. "Students who receive counselling will show a greater increase in creativity than students not receiving counselling"

2. "The automobile A is performing as well as automobile B."

3.7.2 Importance of Hypothesis Testing:

- It provides a framework for making informed decisions based on data.
- It helps to avoid Type I and Type II errors.
- It enables researchers to draw conclusions about populations based on sample data.

By understanding hypothesis testing, researchers can effectively evaluate evidence, make data- driven decisions, and communicate their findings to stakeholders.

3.7.3 Characteristics of hypothesis:

(i) Hypothesis should be clear, precise and specific.

(ii) Hypothesis should be capable of being tested.

(iii) Hypothesis should state relationship between variables, if it is a relational hypothesis.

(iv) Hypothesis should be stated in most simple terms so that it is easily understandable.

(v) Hypothesis should be consistent with most known facts, reasonable, credible, supported by existing evidence and most likely prediction.

(vi) Hypothesis should be agreeable to testing within a reasonable time.

(vii) Hypothesis must explain the facts that gave rise to the need for explanation.

3.7.4 Basic concepts related to testing of hypotheses

(a) Null hypothesis and alternative hypothesis:

Null hypothesis refers to the default assumption that there is no significant difference or relationship between variables.

Ex1: If method A is to be compared with method B for superiority, then null hypothesis assumes that both methods are equally effective, and is denoted by H_0.

In contrast, alternative hypothesis assumes that method A is superior or method B is inferior, and is denoted by Ha.

Ex2: If it is needed to test the hypothesis that the population mean (μ) is equal to the hypothesized mean (μH0)= 100.

Then **null hypothesis:** 'The population mean is equal to the hypothesized mean 100' and $H0 : \mu = \mu H0 = 100$.

If sample results do not support this null hypothesis, researcher should conclude that something else is true. Rejecting the null hypothesis is known as accepting alternative hypothesis. If we accept H0, then we are rejecting Ha and if we reject H0, then we are accepting Ha.

For $H0 : \mu = \mu H0 = 100$, there are three possible alternative hypotheses:

Alternative hypothesis	*To be read as follows*
$H_a : \mu \neq \mu_{H_0}$	(The alternative hypothesis is that the population mean is not equal to 100 i.e., it may be more or less than 100)
$H_a : \mu > \mu_{H_0}$	(The alternative hypothesis is that the population mean is greater than 100)
$H_a : \mu < \mu_{H_0}$	(The alternative hypothesis is that the population mean is less than 100)

The null hypothesis and the alternative hypothesis are chosen before the sample is drawn.

Important points related to hypothesis testing:

- The **null hypothesis** represents the default assumption that is being tested and is typically assumed to be true until evidence suggests otherwise. It is the hypothesis that researchers aim to **reject**.
- The **alternative hypothesis** is the hypothesis that the researcher seeks to **prove** or support. It encompasses all other possible outcomes that are considered if the null hypothesis is rejected based on the evidence.
- If the rejection of a certain hypothesis when it is actually true involves great risk.
- Null hypothesis should always be specific hypothesis i.e., it should not state approximately a certain value.

(b) **The level of significance:**

The significance level is the maximum value of the probability of rejecting H_0 when it is true and is determined in advance before testing the hypothesis with great care, thought and reason.

The factors affecting the level of significance: (a) the magnitude of the difference between sample means; (b) the size of the samples; (c) the variability of measurements within samples; and (d) whether the hypothesis is directional or non-directional.

Ex: 5 % level of significance means that researcher is willing to take maximum 5 per cent risk of rejecting the null hypothesis when it (H_0) it is true.

(c) **Decision rule for testing of hypothesis:** Given a hypothesis H_0 and an alternative hypothesis H_a, researcher makes decision rule according to which he accepts H_0 (i.e., reject H_a) or reject H_0 (i.e., accept H_a).

Ex: if H_0 is that a certain lot is good (=there are very few defective items in it) against H_a, that the lot is not good (=there are too many defective items in it), then the researcher must decide the number of items to be tested (say, test 10 items in the lot) and the criterion for accepting or rejecting the hypothesis (say, if there is only 1 defective item per 10 items, then accept H_0 otherwise reject H_0.

(d) **Type I and Type II errors:** While testing of hypotheses, the researcher can make two types of errors.

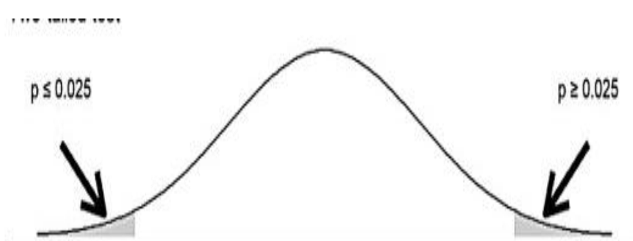
- **Type I error (Alpha error):** rejecting H_0 when H_0 is true. It means rejection of hypothesis which should have been accepted and denoted by μ (alpha).
- **Type II error (Beta error):** Accepting H_0 when H_0 is not true. In other words, accepting the hypothesis which should have been rejected and is denoted by μ (beta).

For more clarity consider the table below:

	Decision	
	Accept H_0	Reject H_0
H_0 (true)	Correct decision	Type I error (α error)
H_0 (false)	Type II error (β error)	Correct decision

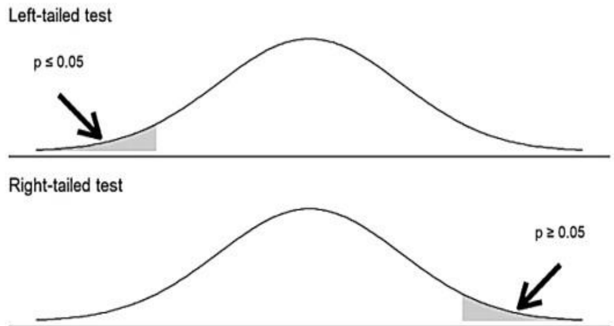
(e) Two-tailed and One-tailed tests (see fig. 3.1):

- Two-tailed test rejects the null hypothesis if, the sample mean is significantly higher or lower than the hypothesised value of the mean of the population. Such a test is appropriate when the null hypothesis is some specified value and the alternative hypothesis is a value not equal to the specified value of the null hypothesis. Symbolically, the two tailed test is appropriate for
- $H_0 : \mu = \mu_{H0}$ and $H_a : \mu \neq \mu_{H0}$ ($= \mu > \mu_{H0}$ or $\mu < \mu_{H0}$)



Two-Tailed Test

- A one-tailed test would be used when we are to test, whether the population mean is either lower than or higher than some ypothesized value.
- Ex: if $H_0 : \mu = \mu_{H0}$ and $H_a : \mu < \mu_{H0}$, then we are interested in left-tailed test (wherein there is one rejection region only on the left tail). In case $H_0 : \mu = \mu_{H0}$ and $H_a : \mu > \mu_{H0}$, we are then interested in what is known as right tailed test.



One-tailed Test

Procedure for Hypothesis Testing:

Hypothesis testing means to tell on the basis of the data the researcher has collected whether or not the hypothesis seems to be valid.

In hypothesis testing the main question is: whether to accept the null hypothesis or not to accept the null hypothesis.

(i) **Making a formal statement:** This step consists of making a formal statement of the null hypothesis (H_0), alternative hypothesis (H_a), one-tailed test or a two-tailed test. If H_a is of the type greater than or of

lesser than, we use a one-tailed test, but when H_a is of the type "whether greater or smaller" then we use a two-tailed test.

Ex: 1. A researcher of the Civil Engineering Department wants to test the load bearing capacity of an old bridge which must be more than 10 tons; The hypotheses as under:

Null hypothesis H_0: $\mu = 10$ tons

Alternative Hypothesis Ha: $\mu > 10$ tons

2. The average score in an aptitude test administered at the national level is 80. To evaluate a state's education system, the average score of 100 of the state's students selected on random basis was 75. The state wants to know if there is a significant difference between the local scores and the national scores. Then the hypotheses:

Null hypothesis H_0: $\mu = 80$

Alternative Hypothesis H_a: $\mu \neq 80$

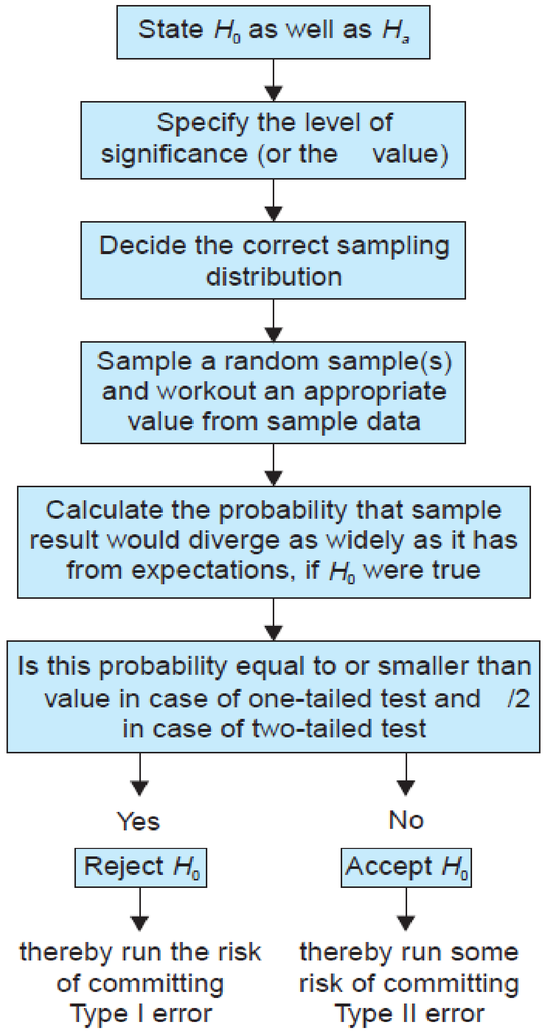
(ii) Selecting a significance level: The hypotheses are tested on a pre-determined level of significance either 5% level or 1% level and should be specified based on the purpose and nature of enquiry.

(iii) **Deciding the distribution to use:** It includes determining the appropriate sampling distribution based on the rules for selection.

(iv) Selecting a random sample and computing an appropriate value: This refers to select a random sample and compute an appropriate value from the sample data concerning the test statistic utilizing the relevant distribution.

(v) **Calculation of the probability**: Then calculate the probability that the sample result would diverge as widely as it has from expectations, if the null hypothesis were true.

(vi) **Comparing the probability:** It refers to comparing the probability thus calculated with the specified value for μ, the significance level. If the calculated probability =< μ value in case of one-tailed test and =< μ /2 in case of two-tailed test, then reject the H_0 (i.e., accept the H_a). but if the calculated probability is greater, then accept the null hypothesis.



Flow diagram of Hypothesis Testing

3.8 MEASURES OF ASSOCIATION

(Q: Explain the concept of measures of association, highlighting its importance and types.)

3.8.1 Definition:

Measures of association are statistical tools used to quantify the strength and direction of relationships between two or more variables. They help researchers understand how variables interact and can indicate whether changes in one variable are associated with changes in another. By understanding

these associations, researchers can draw meaningful conclusions and inform practical applications across various disciplines.

3.8.2 Importance:

Understanding measures of association allows researchers to:

- Identify patterns and relationships in data.
- Inform decision-making and policy development.
- Design interventions and strategies based on identified associations.

3.8.3 Types of Measures:

1. **Correlation Coefficients**:
    - **Pearson's Correlation Coefficient (r)**: Measures the linear relationship between two continuous variables, ranging from -1 to +1. A value close to +1 indicates a strong positive relationship, while a value close to -1 indicates a strong negative relationship.
    - **Spearman's Rank Correlation Coefficient**: Used for ordinal data or non-normally distributed continuous data, measuring the strength and direction of a monotonic relationship.
2. **Contingency Coefficients**:
    - **Chi-Square Test of Independence**: Assesses the association between two categorical variables in a contingency table(A contingency table is a matrix that displays the frequency distribution of the variables; how often each combination of categories occurs). It indicates whether the observed frequencies differ from expected frequencies under the assumption of independence.
    - **Cramér's V**: A measure derived from the Chi-Square statistic, providing a value between 0 and 1 to indicate the strength of association between categorical variables.

3.8.4 Applications

Measures of association are widely used in various fields, including:

- **Market Research**: To evaluate the association between consumer preferences and purchasing behavior.
- **Social Sciences**: To analyze relationships between demographic variables and social behaviors.
- **Medicine**: To assess the relationship between risk factors and health outcomes.

3.9 PRESENTING INSIGHTS AND FINDINGS

(Q: Discuss the importance of both written and oral presentations in research methodology. Q:

3.9.1 Written Reports

- A quality presentation of research findings can have an excessive effect on a reader's perceptions of a study's quality. Hence a researcher to make a special effort to communicate skillfully and clearly.
- Research reports contain findings, analysis, interpretations, conclusions, and sometimes recommendations.
- The writer of research reports should be guided by four questions:
    - ✓ What is the purpose of this report?
    - ✓ Who will read it?

- ✓ What are the circumstances and limitations under which it is written?
- ✓ How will the report be used?

Reports should be clearly organized, physically inviting, and easy to read. Most statistics should be placed in tables, charts, or graphs based on the specific data and presentation purpose.

3.9.2 Types of Reports

(Q: Explain the different types of report)

They may be **short**, informal format typical of memoranda and letters, or they may be **longer** and more complex.

i. Short Reports: Short reports are appropriate when the problem is well defined, is of limited scope, and has a simple and straightforward methodology. The purpose is to distribute information quickly in an easy-to-use format. Informational, progress, inexpensive research projects and interim reports are of this kind. Ex: a report of cost-of-living changes for upcoming labor negotiations. Short reports are about five pages. It should have a brief statement about the authorization for the study, the problem examined, and its important details, the conclusions and recommendations and the findings that support them. The report should be direct, make ample use of graphics to show trends.

ii. Long Reports: Long reports are of two types, the technical (or base) report and the management report

A technical report is written for an audience of researchers. Completeness is a goal. It should include full documentation and detail. This includes sources of data, research procedures, sampling design, data gathering instruments, index construction, and data analysis methods.

Management report is written for the nontechnical client and the manager and should make liberal use of visual displays such as pictures and graphs. The reader has little time to absorb details and needs an exposure to the most critical findings; thus the report's sections are in an inverted order. After the prefatory and introductory sections, the conclusions with recommendations are presented to grasp quickly. Individual findings are presented next, supporting the conclusions already made. The appendices present any required methodological details.

3.9.3 Research Report Components

(Q: Discuss the components of a research report that assist the reader in understanding the structure and context of the report)

1. Prefatory Items: These assist the reader in using the research report.

2. Letter of Transmittal: It should refer to the authorization for the project, instructions, limitations, state the purpose and the scope of the study.

3. Title Page: It should include four items: the title of the report, the date, and for whom and by whom it was prepared. The title should be brief but include the following three elements: (1) the variables included in the study, (2) the type of relationship among the variables, and (3) the population to which the results may be applied. **Ex:**

Descriptive study: The Five-Year Demand Outlook for Consumer Packaged Goods in India.

Correlation study: The Relationship between Relative National Inflation Rates and Household Purchases of Brand X in International Markets.

Causal study: The Effect of Various Motivation Methods on Retail Sales Associates' Attitudes and

Performance.

4. Authorization Letter: When the report is sent to a public organization, this letter is included which not only shows who sponsored the research but also defines the original request.

5. Executive Summary: It is of 2 pages and serve two purposes. It may be a report covering all the aspects in the body of the report in abbreviated form, or it may be a concise summary of the major findings and conclusions, including recommendations.

6. Table of Contents: A report of several sections should have a table of contents, list of tables, charts, or other exhibits.

7. Introduction: It describes the parts of the project: the problem statement, research objectives, and background material.

8. Problem Statement: It contains the need for the research project and represented by a management question.

9. Research Objectives: These objectives are research questions and associated investigative questions. They address the purpose of the project. In correlational or causal studies, the hypothesis statements are included.

10. Background: Background material may be of two types. It may be the preliminary results of exploration from an experience survey, focus group, or another source. It could be secondary data from the literature review. The background includes definitions, qualifications, and assumptions. It gives the reader the information needed to understand the remainder of the research report.

11. Methodology: For technical report, the methodology is an important section.

11.1 Sampling Design: This includes the target population being studied, uniqueness of the chosen parameters and the sampling methods used.

11.2 Research Design: The coverage of the design must be adapted to the purpose. In an experimental study, the materials, tests, equipment, control conditions, and other devices should be described. Also cover the rationale for using one design instead of competing alternatives.

12. Data Collection: This part describes the specifics of gathering the data. How many people were involved? When were the data collected? etc. The use of standardized procedures and protocols, the administration of tests, manipulation of the variables etc. used in the experiment should be explained.

13. Data Analysis: This section summarizes the methods used to analyze the data and describes data handling, preliminary analysis, statistical tests, computer programs, and other technical information.

The rationale for the
choice of analysis, approaches, assumptions and appropriateness of use should be presented.

14. Limitations: Acknowledging limitations helps readers assess the study's validity and understand the context of the findings.

15. Findings: The objective is to explain the results9facts) rather than draw interpretations or conclusions. It is useful to present findings in numbered paragraphs with the quantitative data supporting the findings presented in a small table or chart on the same page.

16. Conclusions:

16.1 Summary and Conclusions: The summary is a brief statement of the essential findings. Findings state facts; conclusions represent inferences drawn from the findings.

16.2 Recommendations: In this section, researchers offer ideas for corrective actions and suggestions for further research initiatives that broaden or test the understandings of a subject area.

17. Appendices: They include complex tables, statistical tests, supporting documents, copies of forms and questionnaires, detailed descriptions of the methodology, instructions to field workers, and other evidence important for later support.

18. Bibliography: It documents the sources used by the writer and requires to be adhered to specific citation styles and formats, which can vary based on the instructor, program, or institution. Recommended style manuals include the APA Publication Manual, Kate L. Turabian's manual, and the MLA Handbook.

3.10 ORAL PRESENTATION IN RESEARCH METHODOLOGY

(Q: Explain the significance of oral presentations in research methodology. Discuss the key elements involved in preparing an effective oral presentation, including the structure, audience engagement, and delivery techniques that contribute to a successful presentation.)

- It involves the effective communication of research findings to an audience, in a structured and concise format. It is a vital skill for researchers, as it allows them to share their work, engage with other scholars, and receive feedback.
- A successful oral presentation not only communicates the research effectively but also builds the presenter's credibility and helps establish professional networks in the academic community.
- The presentation includes an introduction to the research problem, review related literature and research gap, objectives, methodology, results, and conclusions.
- Preparing for an oral presentation requires organizing key points logically, selecting visuals such as slides to enhance understanding, and practicing clear and confident delivery.
- Audience engagement is also crucial, often achieved through interactive elements, such as Q&A sessions. Good time management during the presentation is essential to ensure that all main points are covered within the allotted time.
- Attention to the tone, body language voice modulation and avoiding fillers ("ah," "um," "you know," "like,") can make the presentation more effective. Anticipating potential questions from the audience allows the presenter to prepare informed responses.

References:

1. Ganesan R, Research Methodology for Engineers, MJP Publishers, Chennai. 2011
2. Cooper, Donald R. and Schindler, Pamela S., Business Research Methods, Tata McGraw-hill Publishing Company Limited, New Delhi, India. 2012
3. Internet resources

(Note: Questions are given for illustrative purpose only)