RESEARCH METHODOLOGY

INDIAN INSTITUTE OF MATERIALS MANAGEMENT
IIMM

Research Methodology

ISBN: 978-93-91540-95-1

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Course Outcomes

The course on "Research Methodology" aims to equip students with a comprehensive understanding of research design, data collection, and analysis techniques. It provides practical skills for developing, conducting, and presenting research, enabling students to tackle complex research problems and contribute valuable insights across various fields. The book comprises the following twelve chapters:

Chapter 1: Fundamentals of Research - The chapter provides an overview of research, starting with an introduction to the fundamental principles of research. It then delves into the concept of research, explaining its importance and applications. The chapter concludes by outlining the research process, detailing the steps involved in conducting systematic and structured research.

Chapter 2: Defining and Formulating a Research Problem - The chapter begins with the concept of management dilemmas and their significance in the research context. Then it covers the importance and methodology of conducting a literature review. The chapter concludes with an in-depth discussion on formulating and understanding research problems.

Chapter 3: Research Design - This chapter introduces the concept of research design, highlighting its necessity and key features. It categorises the various types of research designs, providing examples and applications for each. The chapter concludes by detailing the essential components of an effective research design, enabling students to structure and plan their research projects systematically.

Chapter 4: Sampling - This chapter elucidates the concept of sampling, emphasising its importance in research methodology. Then it discusses common errors in measurement and sampling, as well as non-sampling errors that can impact research validity. The chapter concludes by exploring various methods of sampling, equipping students with the knowledge to select appropriate sampling techniques for their research projects.

Chapter 5: Measurement and Scaling - This chapter provides an understanding of measurement concepts and their application in research. Then the chapter introduces various scaling techniques, explaining their importance and use in quantifying variables. At the end, the chapter discusses bases of scale classification and techniques of scale construction.

Chapter 6: Data Collection Techniques - This chapter begins with the concept of data collection. Then it explores the methods of data collection. At the end, the chapter explores the factors affecting the selection of data collection methods.

Chapter 7: Introduction to Questionnaire Designing - This chapter introduces the concept of questionnaire designing. Then it covers the different types of questions used in questionnaire designing, and the steps involved in designing a questionnaire. At the end, the chapter discusses designing of an effective questionnaire.

Chapter 8: Data Processing and Analysis - This chapter provides an overview of data processing and analysis techniques essential for interpreting research data. Then it covers the concepts of data processing and analysis, including measures of central tendency, dispersion, skewness, and relationship. At the end, the chapter also explores various charts and visual tools used in data analysis.

Chapter 9: Concept of Hypothesis - This chapter delves into the fundamentals of hypothesis formation and testing in research. It begins with defining what constitutes a hypothesis and progresses to the process of hypothesis testing. At the end, the chapter discusses the procedure for testing hypotheses, including the steps and techniques involved.

Chapter 10: Parametric Tests - This chapter explores various types of hypothesis testing methods and their applications. Then it covers parametric tests and their use in statistical analysis, including one-sample tests and the scenarios in which they are applicable. The chapter also discusses two-sample tests and provides an overview of Analysis of Variance (ANOVA).

Chapter 11: Non-Parametric Tests - This chapter begins with the concept of non-parametric tests. It covers the applications of non-parametric tests, including the sign test, rank correlation, rank sum test, and chi-square test. By the end of this chapter, students will be able to apply non-parametric tests to analyse data that does not meet parametric test assumptions, interpreting results accurately for diverse research scenarios.

Chapter 12: Report Writing - This chapter covers the essentials of writing a research proposal and report. It begins with an exploration of how to draft an effective research proposal, followed by guidelines for writing a comprehensive research report. At the end, the chapter explains the integral parts of a research report, including structure and content.

CHAPTER 1

Fundamentals of Research

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LEARNING OBJECTIVES

After studying this chapter, you will be able to:

- Elucidate the concept of research
- List the characteristics of good research
- Discuss various types of research
- Explain the role of ethics in research
- List the steps involved in the research process

1.1 INTRODUCTION

In simple words, the term 'Research' is associated with the act of seeking out the information and knowledge on a specific topic or subject. In other words, research refers to an art of systematic and careful investigation into an explicit field. The systematic investigation makes research as an art of scientific investigation. Research is of significant importance in various fields, such as business, economics and politics. Research is regarded as a powerful and essential tool, which leads human beings towards progress.

Research is conducted to serve a varied range of purposes, such as increasing the knowledge of the researcher, developing and revising theories based on observed facts, etc. For instance, organisations use research to take well-informed decisions about the products and services they deal into or to devise new strategies. Significant management decisions, such as pricing decisions, new product launch, undertaking new projects, etc., require a research to be conducted to find the probable state of the circumstances and the most feasible and appropriate strategies that can be designed and formulated in the given conditions.

A research study begins by first reviewing the available literature followed by defining the research problem. The research problem must be stated in a clear and concise way. Secondly, the authentic and accessible source of information is identified. Thirdly, the design of the research is decided, which gives direction to the research study. Further, the data (observations recorded in numeric, textual or any other form to be referenced easily) is collected and organised for easy analysis by researchers. Based on the analysis of the data, the research report is prepared, which comprises inferences on the given research problem and also contains the research findings.

This chapter will help you in understanding the concept of research. You will study the characteristics of a good research and types of research. Further, various research approaches and significance of research are also discussed. The latter section of this chapter will describe problems encountered by a researcher and ethics in research. Towards the end, you will learn about the research process.

1.2 CONCEPT OF RESEARCH

Research is 'search for knowledge'. It refers to an intellectual activity that comprises a systematic investigation about new findings or an activity that is aimed to gain

new knowledge of the already existing researched facts. The term 'research' has been defined by various authors in different ways. Few major definitions of research are as follows:

According to Clifford Woody, "Research comprises defining and redefining problems, formulating hypothesis or suggested solutions; collecting, organising and evaluating data; making deductions and reaching conclusions; and, at last, carefully testing the conclusions to determine whether they fit the formulating hypothesis."

In the words of Redman and Mory, "Research is a careful and systematised effort to gain new knowledge."

D. Slesinger and M. Stephenson define research as "Manipulation of things, concepts or symbols for the purpose of generalising to extend, correct or verify knowledge, whether that knowledge aids in the construction of theory or in the practice of art."

In the words of W.S. Monroes, "Research may be defined as a method of studying problems whose solutions are to be derived partly or wholly from facts."

Hence, in a broader perspective, the concept of research has different meanings. In simple terms, research is a process of collecting, analysing and interpreting the relevant information about any topic. The primary objective of performing a research is to explore answers to questions in a scientific manner. At a broader level, the objectives of research are to:

- **Achieve new insights:** Research is done with the objective to determine a phenomenon or explore something new. For instance, a study may be carried out to explore the eating habits and their effect on the growth of children aged 11 to 14.
- **Portray characteristics:** Research is done with the objective to describe the characteristics of a specific individual, situation or group. For instance, a study may be carried out to find the characteristics of a solar cell.
- **Determine frequency:** Research may also be done with the objective to determine the frequency with which an event occurs. For example, a study may be carried out to determine the frequency with which Huntington's disease occurs in humans.
- **Hypothesis test:** Research is also conducted with the objective to do hypothesis-based relationship test between variables considered for the study. For example, a research study may be carried out to test the relationship between polarity and stability.

The above-mentioned objectives of research are common objectives for all researches. Additionally, various research studies can have diverse objectives according to their own specific nature. For instance, the research conducted for marketing purpose will concentrate on the following objectives also:

- Product development
- Cost reduction
- Inventory control
- New product launching

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- Profitability improvement
- Productivity improvement

Similarly, a research in human resource development will have the objectives, such as developing new tools, concepts or theories, which may help in enhancing the skills and talent of human resource in an organisation.

1.2.1 CHARACTERISTICS OF A GOOD RESEARCH

There are various forms of research and some characteristics that are common to all types of research. Fundamentally, a research to be effective should have the following characteristics:

- **Directed:** Research should be directed towards arriving at some solution to a problem.
- **Systematic:** Research should be properly structured and should not be based upon intuition and guess.
- **Clear purpose:** Research should be carried out with certain clearly defined objectives.
- **Empirical:** Research should be based on the actual data that is derived from observation and experience. However, in case of research relating to abstract concepts, they can be measured by constructs.
- **Data-driven:** Research encompasses gathering new data from primary sources (first-hand data) or using the existing data (secondary sources) for doing research for a new purpose.
- **Logical:** Research ought to be guided by clear and logical reasoning.

Fundamentally, logical reasoning is of two types: induction and deduction. The process of moving from unambiguous to general is induction, whereas, the process of moving from general to unambiguous is deduction. The use of logical reasoning makes the research more significant.

- **Elaboration:** Research procedure should be explained and **detailed pro**perly. Elaboration is required to maintain continuity that would **help another** researcher taking the same topic for further advancement.
- **Efficient analysis:** The facts and figures accumulated in a research ought to be correctly investigated and analysed by utilising a suitable method.
- **Requires time:** Research ought to be a patient and unhurried activity. Proper time should be given to conduct any research so as to get a logical result.
- **Carefully designed:** Research must follow carefully designed procedures that apply diligent analysis. A sensibly designed research also requires data and information to be carefully collected and recorded.

1.2.2 TYPES OF RESEARCH

The classification of research can be based on various decisive factors, such as the technique, reason, accessibility of time and other assets, capacity, type of

investigation, and statistical substance. A wide categorisation of types of research is shown in Figure 1:

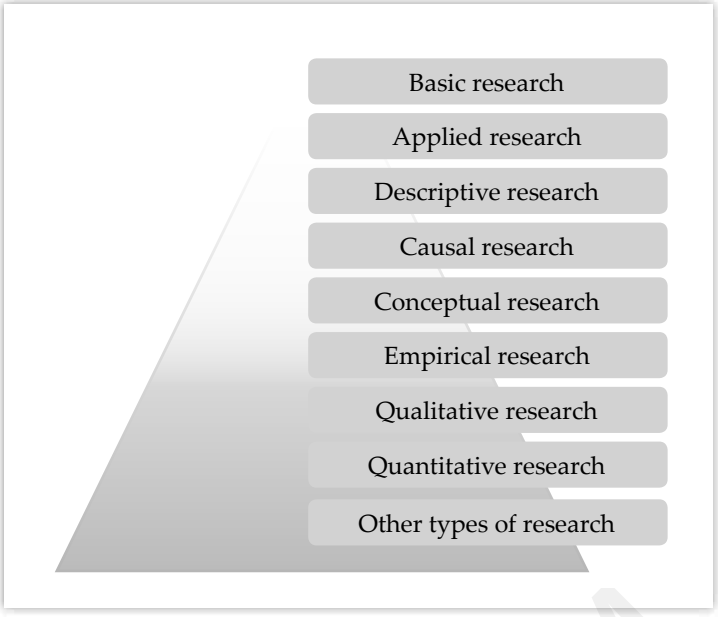

Figure 1: Types of Research

The types of research are explained as follows:

- **Basic research:** Basic research is done with the purpose to expand the knowledge of a subject. It is also known as pure, theoretical or fundamental research. As the basic research is inquisitive in nature, so, in most of the cases, the outcomes of basic research do not carry any immediate commercial value. It is aimed to gather knowledge for the sake of knowledge. Basic research is mainly concerned with generalisations and with the formulation of a theory. It can be conducted in any of the following two different ways:
  - **Discovery of a new theory:** Basic research may be entirely a new discovery, the knowledge of which has not existed so far.
  - **Development of the existing theory:** Existing theories are always based on assumptions, and provides the scope for changing or formulating new sets of assumptions and adding new dimensions to the existing theory by doing further research work.

  Basic research is useful in developing new scientific ideas and various ways of thinking. Some examples of basic research are as follows:
  - Research concerning natural phenomena, such as big bang theory and climate change
  - Investigation related to basic science
  - Research related to human behaviour
- **Applied research:** Applied research aims to solve practical problems of the world. It is also known as action research. The applied research aims to provide solutions (conclusions) of problems concerning society or business. It is conducted to test

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the basic assumptions or the empirical content or the very validity of theory under the given conditions. Applied research may explore ways to:

- Treat a disease
- Identify social, economic or political trends
- Improve agricultural productivity
- Curb or reduce carbon emissions
- Improve energy efficiency
- Reduce inflation

- **Descriptive research:** Descriptive research aims to describe the characteristics of a phenomenon. It includes a different kind of conducting surveys and fact-finding enquiries. In descriptive research, the researcher only describes the phenomenon. Descriptive research can answer what, where, when and how questions, but not why questions. Descriptive research may be conducted in the following situations:
  - To explain the inflation rate in India in the past 20 years
  - To know how India's housing market changed over the past 10 years
  - To know the most popular news channels among the middle-aged people
- **Causal research:** Causal research is also known as explanatory research. It is one step ahead of the descriptive research as it aims to investigate the cause-effect relationships. For instance, if, in a descriptive research, the inflation rates of the past 20 years in India is studied and explained without explaining its negative or positive impact on the Indian economy, a causal research would thoroughly investigate the causes of the same. In the cause-effect analysis, data can be analysed in different ways, such as by comparing inflation rates of different years, giving reasons of high/low inflation, etc.
- **Conceptual research:** Conceptual research aims to explore new concepts or ideas (theories) and upgrade or redefine existing concepts. It is more concerned with ideas and is commonly used by philosophers and thinkers. Conceptual research is conducted by analysing already present information on the concerned topic. No practical experiment is done in conceptual research.
- **Empirical research:** Empirical research aims to gain knowledge through experience or observation. The researcher heeds to investigate an established theory on the basis of a predefined hypothesis in this research. After theory investigation, the researcher arrives at some conclusions or predictions. After that, predictions are verified with a suitable experiment. Considering the results of the experiment, the theory on which the predictions are based is supported or revised.

  The concept of empirical research is explained with the help of an example. Assume that the topic of observation is 'Does the brain development of children learning to play musical instruments sometimes have a long-term effect?'

  Now suppose that the hypothesis for this topic is:

  'Brain development in children aged between 2 and 6 speeds up when children play musical instruments.'

On the basis of this hypothesis, a researcher draws some predictions, such as the brain development of children who play musical instruments is not affected. After that, the researcher would conduct a suitable experiment to test predictions. On the basis of the result of the experiment, the topic of observation would be supported or revised. For example, if the researcher finds that the brain development of children who play musical instruments is not affected by it, the topic of observation would be supported; otherwise, it would be revised.

- **Qualitative research:** Qualitative research is concerned with getting a deep understanding of qualitative phenomenon. The phenomenon in this research relates to quality or kind. For example, if the researcher wants to know the cause of the rising disrespect of the youth towards elders, he/she would have to deeply look at different aspects, such as changing lifestyle, increasing stress among the youth and the attitude of people towards the nuclear family. This research tries to find out why and how rather than what, when and where of a phenomenon. The aim of a qualitative research is to discover the fundamental ideas, desires and motives by using the method of in-depth interviews.
- **Quantitative research:** Quantitative research aims to study a phenomenon that is expressed in terms of quantity. Some examples of the quantitative research are as follows:
  - A research study that shows that the average rainfall in the month of June in Uttar Pradesh is more than that of July.
  - A research study that aims to show the percentage of all components of the earth's atmosphere.
- **Other types of research:** In addition to the types of research mentioned in the preceding section, there are some other types of research, which are explained as follows:
  - **One-time research:** This refers to the research that is carried only once.
  - **Longitudinal research:** This refers to the observational research that is performed for the same purpose repeatedly over a period of time on the same group of subjects.
  - **Laboratory research:** This refers to the research that is done in a laboratory. It is also known as simulation research. A research in the fields of natural sciences, such as Physics, Chemistry and Biology, are examples of the laboratory research. For example, reaction of one chemical with another chemical is an example of the laboratory research.
  - **Field-setting research:** This refers to the research that cannot be done in a laboratory. The research conducted on topics of economics, such as demand, supply, product and price are examples of a field research.
  - **Historical research:** This refers to the research in which the researcher either takes the help of historical sources to conduct fresh research or studies past events. For example, a research on the outcome of the Revolt of1857 may be considered as a historical research.

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1.2.3 RESEARCH APPROACH

A research approach refers to a plan or procedure that consists of assumptions to be considered and the detailed methods of data collection, analysis and interpretation to be used while performing research. Depending on the nature of the research problem being addressed, different organisations use different research approaches. Broadly, there are three types of research approaches, namely quantitative approach, qualitative approach and pragmatic approach (mixed methods). The types of research approach are shown in Figure 2:

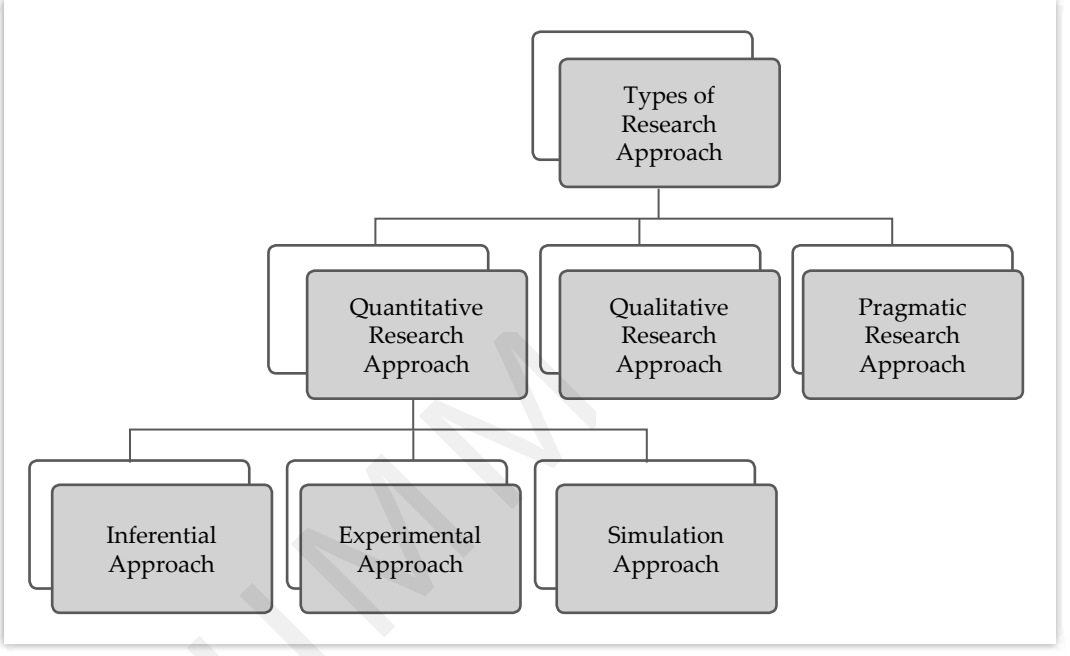

Figure 2: Types of Research Approach

A brief description of these approaches is as follows:

- **Quantitative research approach:** It refers to the generation of data in a quantitative form, which can be subjected to quantitative analysis. The quantitative analysis should be rigorous and done in a formal and rigid manner. The subtypes of quantitative approach are as follows:
  - **Inferential approach:** The approach that is used where a sample (a subset of the population on whom the experiments are conducted) of the population (the target group of people that are under investigation) is observed or studied. The primary aim of this approach is to infer some characteristics of the population under study by forming a proper database.
  - **Experimental approach:** The approach is useful for research in which some variables of a research study are manipulated to observe their effects on other variables.
  - **Simulation approach:** The approach is useful for conducting research in which an artificial environment is created to generate the relevant information and data. This approach is quite useful in the modern world. For example, training of pilots is conducted in a simulated environment.

- **Qualitative research approach:** The qualitative research approach deals with the subjective evaluation of attitudes, opinions and actions. This approach generates results in a non-quantitative form. This research is based out of researcher's insights and impressions. Usually, the techniques used in a qualitative research involve focus group interviews, projective techniques and depth interviews.
- **Pragmatic research approach:** This research approach is also known as mixed method. The research conducted in this approach involves collecting both quantitative and qualitative data to conduct inquiries, integrating the two forms of data, and using different designs that may involve philosophical assumptions and theoretical frameworks. The central postulation of this form of research is that by combining both qualitative and quantitative approaches, a more complete understanding of a research problem is achieved than either approach alone.

1.2.4 SIGNIFICANCE OF RESEARCH

Hudson Maxim has expressed that "All progress is born of inquiry. Doubt is often better than overconfidence, for it leads to inquiry, and inquiry leads to invention." The main motive of doing a research study is to find the hidden truth. Research leads to progress as research is done to solve problems, expand knowledge or explore a new phenomenon. In a society and in a business, there are various problems which researchers use to solve through different researches.

The role of research has greatly influenced the field of business and economy. Research is being used by organisations to solve operational problems and it is also useful to the government as it assists in framing economic and development policies. The growing competition and complexities in business have necessitated research in marketing. This need has given rise to a new field of research called marketing research. A marketing research is basically the methodical gathering, recording and analysing of facts about business problems.

Apart from the role of research in marketing, the significance of research in the field of business is noteworthy for an organisation because it helps:

- Identify and define opportunities
- Define, monitor and refine strategies
- Identify economic and business objectives
- Identify policy objectives
- Develop products
- Identify objectives of human resource development
- Identify promotional objectives
- Identify market objectives
- Identify customer satisfaction objectives

The significance of research for social scientists is reflected in studying social relationships and in seeking answers to various social problems. The main purpose of research in social sciences is related to two main motives, firstly with the knowledge

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for its own motives and, secondly, with the knowledge for what can be contributed to practical concerns of the society.

The significance of research can also be appreciated for the following purposes:

- For students, writing a master's or Ph.D. thesis may mean better career opportunities. It also aids them to attain a high position in the social structure.
- For professionals working with research methodology jobs, such as a survey research assistant, research associate, research faculty, etc., research may mean a source of livelihood.
- Philosophers and thinkers bring light to new ideas and insights after conducting research.
- Literary men and women may use research as a means for the development of new styles and creative work.
- Analysts and intellectuals use the concepts of research for the generalisations of new theories.

1.2.5 APPLYING RESEARCH IN DIFFERENT FIELDS OF MANAGEMENT

Application of research in different fields of management may be done in the following ways:

- Theory-building research is done with the aim to develop management theories. Such research is done for improving the understanding and knowledge related to the management process.
- Theory-testing research is done with the aim to test out theories of management. The testing is done by using the process of observations and measurements which guides in arriving at the decision as to whether accept or reject a theory.
- Problem-centered/practical research is primarily done with the aim of investigating a practical problem, question or issue in a specific organisation or management context with a view to resolving the problem and, subsequently, making recommendations for the procedure to be followed. The research is conducted to find and propose solutions related to real-life management problems.

Various functional areas in 'management' where research is used are as follows:

- **Application of Research in Marketing:** The application of research in the field of marketing is done for the following reasons:
  - For decision-making
  - For doing market research
  - For doing survey on demand
  - For conducting product research
  - For customer research
  - For sales research

- For promotional research
- For risk management on collaboration
- For research on market development
- For research on marketing and reach of competitors
- For research on the formation of marketing strategy
- For research to build up a competitive advantage

❍ **Application of Research in Finance:** The application of research in the field of finance is done for the following purposes:

- Portfolio management
- Risk perception
- Financial crisis management
- Research to assess the perception of mutual fund investors
- Investment analysis
- Break-even analysis
- Capital budgeting
- Ratio analysis
- Decision-making
- Financial planning for salaried employees
- Strategies for tax savings
- Research on investment pattern and preference of retail investors

❍ **Application of Research in HR:** The application of research in the field of HR is done for the following purposes:

- Recruitment and selection
- Training and development
- Manpower planning
- Labor welfare study
- Leadership style
- Administrative roles
- Performance appraisal system
- Research on MBO
- Comparative approach
- Problem identification
- Conflict management
- Research on statistical approach

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- **Application of Research in Production:** The application of research in the field of production is done for the following reasons:
  - Planning production
  - Supply chain management
  - Testing new products
  - Guaranteeing adequate distribution
  - Prototype development
  - In-house research is required for professional and self-development of the workers through training and mentoring
  - New technology approach
  - Undertaking research can help a company avoid future failure
  - Studying the competition and competitors
  - R&D for full utilisation of the machines
  - Strategic module for overall production and distribution
  - Operational module for production and sales synchronisation

1.2.6 PROBLEMS ENCOUNTERED BY A RESEARCHER

Conducting research requires several elements to be managed and arranged. Some elements are difficult to manage, while others are difficult to arrange. Research is carried by a single individual or a group/organisation/institution, but it requires the acceptance/approval of several others also, such as guides, supervisors, defense committee members, interviewees, focus group members, etc. The smooth flow of a research also depends upon the developing or developed nations. In the developing nations, research is in its initiation stage while the developed nations have sufficient facilities and resources to carry on research. Researchers particularly in a developing nation face the following problems:

- **Lack of scientific training:** The lack of a scientific training in the methodology of research is a great impediment for researchers in the developing nations. There is scarcity of capable and experienced researchers. Numerous researchers without any prior experience and without any certainty about research methods conduct the research. So, all researches done are necessarily not methodologically appropriate. Some researchers and their guides, due to lack of specific research training, take research as a scissor and paste job without doing actual analysis of the collected material. The outcome of such researches is that the results of research do not reflect the reality. Thus, irresponsible research necessitates the need of a systematic study of research methodology. A researcher must be properly equipped with all methodological aspects of research prior to starting any research project. As such, efforts should be made to provide short-duration intensive courses for meeting the requirement of a systematic research methodology.
- **Insufficient interaction:** The lack of interaction among various research and non-research organisations causes problems to researchers. There is inadequate communication between the sole researcher/university research departments on one side and business organisations/government departments/research

institutions on the other side. Due to the lack of interaction and proper contacts of researchers, a large amount of primary data remains unused.

In order to overcome this problem, efforts should be made to develop a satisfactory link among all concerned (institutions, organisations, researchers, etc.) for better and realistic researches. Certain systematic mechanisms, such as university-industry interaction programmes, must be developed so that researchers can get ideas and encouragement from the experienced practitioners.

- **Lack of secrecy:** The lack of confidentiality about the usage of information often creates problems for researchers. Business organisations in a developing country do not have much confidence that the information shared by them to researchers will not be misused. The concept of information secrecy is very important for any business organisation. This restricts business organisations to share information and proves a barrier to researchers. Consequently, the utmost requirement for the researchers is to generate the confidence among business organisations that the information/data obtained from a business organisation will not be misused.
- **Identification of research problems:** Researchers often face the problem of appropriate identification of research problems. The absence of adequate information often makes researchers choose such research problems and conduct research studies which may overlap with the previous researches. This results in duplication and wastes away resources. The solution to this problem is creating a proper list of subjects, with research problem topics, and the places where the research is done. Such lists need to be revised and updated at regular intervals and made available to all the prospective researchers for appropriate identification of the research problems.
- **Lack of assistance: Researchers often** face the problem of the absence of support in terms of time, funds and proper direction for research. It leads to unnecessary delays in the completion of the research studies. This difficulty can be lessened by providing sufficient and timely assistance to researchers.
- **Lack of resources:** Deficiency of resources leads to the wastage of energy and efforts of researchers. At many places, the functioning of library is not satisfactory and researchers have to spend a lot of their precious time in searching books, journals and reports. In many libraries, especially which are away from cities and state capitals, it is difficult to obtain copies of old acts/rules, reports and other government journals and publications. This creates a big obstacle in the research work.
- **Code of conduct:** There is a lack of pre-defined code of conduct for researchers. This, sometimes, results in inter-university and inter-departmental rivalries. Thus, it is required to develop a code of conduct for researchers which, if obeyed sincerely, can solve this problem.

1.2.7 ETHICS IN RESEARCH

Ethics refers to a branch of philosophy that distinguishes between right and wrong. Ethics helps in deciding whether an action is right or wrong. All people often develop a sense of right and wrong in their childhood. Ethical development is regarded as a long-term and continual process. Although some arguments say that ethics is merely

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a common sense, but it is also right to say that ethical norms vary according to individuals. Hence, different people may interpret ethical norms in different ways. For example, if an experimental research involves children as respondents, then the parents of the children must be informed about the same and prior permission should be taken. If parents are not informed and their consent is not gained, the research would be deemed as unethical.

The objectives which underline the necessity of adhering to ethics in a research are as follows:

- Ethics in research should be obeyed to protect the interests of participants involved in a research.
- Ethics in research should be followed to make sure that research is carried out in a manner that serves interests of individuals, groups and/or society as a whole.
- Ethics in research helps scrutinise specific research for its ethical soundness keeping in consideration issues, such as management of risk, protection of confidentiality and process of informed consent.

The primary ethical values related to research are shown in Figure 3:

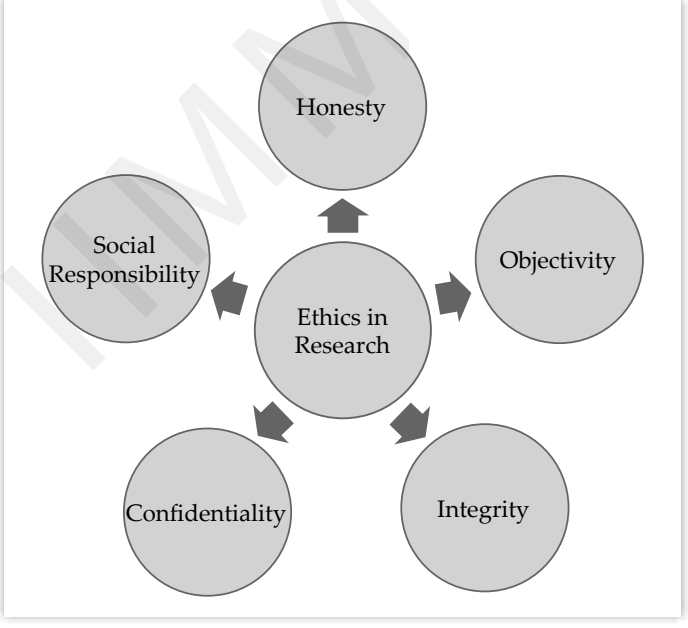

Figure 3: Ethics in Research

The ethical values related to research are described as follows:

- **Honesty:** It refers to truthfulness of the researcher in collecting and presenting data. A researcher should never fabricate the gathered data or misinterpret the data to arrive at the desired conclusion.
- **Objectivity:** It implies that a researcher should not be biased in research design, data collection, interpretation, analysis and other aspects of the research.
- **Integrity:** It implies that a researcher should be sincere in his/her action and should keep his/her promises.

- **Confidentiality:** It involves that the secret information, such as military secrets, papers, and personnel records which are used in the research, should be kept private.
- **Social responsibility:** It infers that a researcher should try to increase social welfare through his/her research study. In addition, the researcher should not harm society and environment in any way while conducting research. For example, if the research is related to animals, the researcher should give them proper care and respect.

A researcher should adhere to the following five major principles of research ethics:

1. Do good (Beneficence)
2. Do no harm (Non-malfeasance)
3. Obtain informed consent from research participants
4. Do not use deceptive practices
5. Research participants should have the right to withdraw from the research at any point of time

As ethical norms and standards are important for research, many universities and government organisations, such as National Institute of Health (NIH), National Science Foundation (NSF) and Food and Drug Administration (FDA), have adopted and implemented some rules and procedures related to research ethics.

1.2.8 MANAGERS AND RESEARCH

Managers equipped with the basic knowledge of research are at an advantage as compared to those managers who do not have any idea about it. Managers of an organisation often need to conduct research, so as to address various problems. For instance, stable demand for products and costs higher than the allotted budget are some of the business problems for managers. Growing competition and complexities in the business environment are the main reasons behind the occurrence of business problems. Managers with the help of thoughtful research methods can prevent the occurrence of unwanted situations before it gets out of control.

The management of an organisation should think of hiring professional researchers or consultants for problem-solving because managers of an organisation may handle only minor problems efficiently, whereas serious problems definitely need handling by professional researchers. The research conducted by professionals should be based upon an effective and fruitful interaction between managers and researchers if managers understand the fundamentals of the research. Managers' knowledge about research process, research design, data collection and data interpretation help them determine whether the solutions recommended by the professional researchers are feasible or not.

Additionally, managers require the knowledge of research because of various reasons, which are as follows:

- Differentiating good research from bad research
- Making important business decisions

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- Combining experience and scientific knowledge to take decisions
- Forecasting and planning about future uncertainties which are controllable

Self Assessment Questions

1. Research may also be done with the objective to determine the _____ with which an event occurs.
2. The research should be based on actual data that is derived from _____ and experience.
3. Basic research is not useful in developing new scientific ideas and various ways of thinking. (True/False)
4. The primary aim of _____ approach is to infer some characteristics of the population under study by forming a proper database.
5. A _____ research is basically the methodical gathering, recording and analysing of facts about the business problems.
6. The lack of confidentiality about the usage of information never creates problems for researchers. (True/False)
7. Ethics in research should be obeyed to protect the interests of participants involved in a research. (True/False)

1.3 RESEARCH PROCESS

A process refers to the act of doing something efficiently through an acknowledged set of actions. Research process implies the series of events needed to carry out research competently. Every research requires a pre-determined process to be followed because of the following reasons:

- A research process is required to achieve the desired results from the research. Most research studies are done with unambiguous goals that can be turned into specific outcomes only when a well-defined process is followed.
- A researcher is required to complete research study in a specific time. A research process is needed because in the absence of a well-defined process, researchers may not be able to complete their research timely.
- A research process is required to conduct research in a competent and successful manner. A pre-planned procedure guarantees competence in the research study.

Steps in a research process may vary as per the subject and need of research.

Figure 4 shows the fundamental steps of a research process:

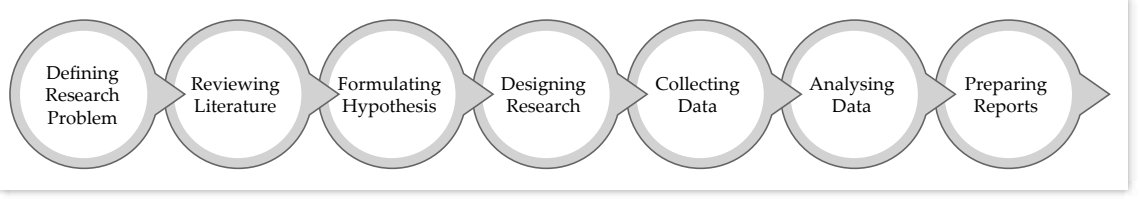

Figure 4: Fundamental Steps of a Research Process

The steps of a research process are closely correlated. It is not essential to follow the research steps in strict order. However, this order of steps provides a useful guideline to the researcher. These steps are discussed as follows:

- **Step 1: Defining Research Problem:** The first step refers to the identification of a problem whose solution can be attained by research. In simple terms, a research problem means the matter on which the investigator/researcher wants to investigate. At this stage, the researcher usually feels confused and doubtful. Research comes into existence through the efforts made by the researcher to solve doubts and confusions. Basically, two steps are involved in defining a research problem:
  - Knowing the problem correctly
  - Expressing the problem into meaningful terms
- **Step 2: Reviewing Literature:** The second step refers to a way of developing a proper understanding of the research problem. Usually, two types of literature may be reviewed by a researcher, i.e., conceptual literature, which comprises thoughts and presumptions and empirical literature, which comprises empirical studies done earlier on a same or similar topic. It is important for a researcher to review the literature properly to achieve the following:
  - Develop and refine research ideas
  - Improve subject information
  - Elucidate study questions
  - Focus research possibilities that have been disregarded or unseen
  - Shun easy monotonous work, which has been done previously
  - Find out and provide an insight into research advances, tactics and methods
- **Step 3: Formulating Hypothesis:** The third step relates to an uncertain hypothesis made by the researcher to consider the result of research. It provides the crucial point for the research and helps the researcher be on the right track.
- **Step 4: Designing Research:** The fourth step is deciding the type of research design that should be followed for conducting the research study. The research design selected is based upon the type of research problem and the scope of the research study undertaken. The preparation of the research design enables the researcher to yield maximal information from the research conducted.
- **Step 5: Collecting Data:** The fifth step relates to assembling information, which is crucial for any research study. There are essentially two types of data: primary data and secondary data. Primary data is collected by testing or investigations. In case of investigations, data can be composed through:
  - Observation
  - Interviews
  - Telephonic talk
  - Feedback form

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- Agenda
- Questionnaires

Secondary data relates to that information which has already been composed by some other researcher. Examples of such data are biographies, diary, records, and published material. In order to complete a research study successfully, exact and suitable information is compulsory.

- **Step 6: Analysing Data:** The sixth step of the research process is transforming and refining data to highlight useful information. There are various statistical methods to analyse the data, such as tabulation, bar diagrams and pie charts. Statistical theories, such as correlation, regression and time series are also used for data analysis. After the data analysis, the researcher is in a position to test the hypothesis formulated in step three. The researcher can check the rationality of the hypothesis by using several statistical tests, such as Chi square test, t-test and F-test.
- **Step 7: Preparing Reports:** The seventh step of the research process is the last stage in which a researcher shows the complete work done by him through a report prepared by him. Report writing should be done with great care by keeping in view the proper layout of report.

The main text of a report should include:

- Preface
- Summary of whatever researcher has found
- Main report
- Conclusion

At the end, proof tables, questionnaires, and other documents used in the research study should be given in the form of appendices. The research report also needs to contain a bibliography, i.e., a list of literary material consulted by the researcher. All the seven steps of a research process mentioned above are discussed in detail in further chapters.

Self Assessment Questions

8. _____ provides the crucial point for the research and helps the researcher be on the right track.
9. The preparation of a research design enables a researcher to yield minimal information from the research conducted. (True/False)
10. Report writing should be done with great care by keeping in view the proper _____ of report.

Activity

Make a list of 10 research companies running in India. Analyse their process of research and prepare a short report with the information collected.

1.4 SUMMARY

- Research is a process of collecting, analysing and interpreting the relevant information about any topic. The primary objective of performing a research is to explore answers to questions in a scientific manner.
- Research is done with the objective to determine a phenomenon or explore something new.
- Research is also conducted with the objective to do hypothesis-based relationship test between variables considered for study.
- A research to be effective should have the characteristics, such as directed, systematic, clear purpose, empirical, data-driven, logical, elaboration, efficient analysis, and carefully designed.
- The classification of research can be based on various decisive factors, such as the technique, reason, accessibility of time and other assets, capacity, type of investigation, and statistical substance. Various forms of research include basic research, applied research, descriptive research, causal research, conceptual research, empirical research, qualitative research, quantitative research and other types of research also.
- Depending on the nature of the research problem being addressed, different organisations use different research approaches. Broadly, there are three types of research approaches, namely quantitative approach qualitative approach and pragmatic approach (mixed methods).
- The main motive of doing a research study is to find the hidden truth. Research leads to progress as research is done to solve problems, expand knowledge or explore a new phenomenon.
- The significance of research for social scientists is reflected in studying social relationships and in seeking answers to various social problems.
- Problems encountered by a researcher include lack of scientific training, insufficient interaction, lack of secrecy, identification of research problems, lack of assistance, lack of resources, and code of conduct.
- The ethical values related to research are honesty, objectivity, integrity, confidentiality and social responsibility.
- Managers of an organisation often need to conduct research so as to address various problems.
- Research process implies the series of events needed to carry out research competently. The main steps to conduct a research include defining research problem, reviewing literature, formulating hypothesis, designing research, collecting data, analysing data and preparing reports.

1.5 KEY WORDS

- **Research:** It is an exploration for awareness.
- **Empirical literature:** It is an interdisciplinary field of research that is carried out in areas, such as psychology, sociology and philosophy.

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- **Objectivity:** It implies that the researcher ought not to be partial in research plan, collecting information, understanding, investigation, and other features of research.
- **Hypothesis:** It is a proposition made on the basis of limited evidence for further investigation.
- **Simulation:** It is a scientific modelling of natural systems with an aim to understand their functioning.
- **Honesty:** It implies to the truthfulness with which the researcher collects and presents data.

1.6 CASE STUDY: RESEARCH PROCESS FOLLOWED IN SURVEY LIMITED

Survey Limited, one of the top research companies, was started in Hyderabad, India in1990s. Since then, it has picked up research topics and conducted researches on major disturbing social issues, such as child marriage, dowry, and honor killing. Now, the company wants to conduct a research study on the increasing effect of alcohol on adolescents and youth. For the purpose, the company states its research problem as:

Alcohol beverages are causing negative effect on the health of adolescents and youth.

In order to clearly and deeply understand the topic, the company surveys and reviews already available research papers and thesis, which included conceptual as well as empirical literature.

It also takes the help from various books and journals. This in-depth review and survey of the available material enable Survey Limited to develop clearer understanding for formulating research hypothesis. Survey Limited formulates its research hypothesis as:

Westernisation and changing lifestyle are responsible for the increasing use of alcoholic beverages.

After formulating its research hypothesis clearly, SurveyLimited chalks out complete research design within which research would be carried out. It collects primary as well as secondary data from books, journals, and observation and personal interviews. The collected data is then analysed critically using various statistical tools, such as bars, pie charts, tables, and time series. Survey Limited presents a final report of its work that also includes strategies to reduce effects of alcohol.

QUESTIONS

1. What did Survey Limited do for a clear and deep understanding of the research topic?

   (**Hint:** The company surveyed and reviewed already available research papers and thesis)

2. How did in-depth review and survey of the available material help Survey Limited in conducting research?

   (**Hint:** To develop a clearer understanding for formulating research hypothesis.)

3. What tools were used to analyse the collected data?

   (**Hint:** Various statistical tools, such as bars, pie charts, tables, and time series.)

4. State the research process followed in Survey Limited.

   (**Hint:** Defining the topic of research, reviewing literature to gain more understanding about the topic, and so on)

5. What sources were used by Survey Limited for data collection?

   (**Hint:** Primary as well as secondary sources)

1.7 EXERCISE

1. Explain the characteristics of a good research.
2. What are the objectives of research?
3. Discuss the importance of research.
4. What ethical norms are required to be followed while conducting research?
5. What are the problems encountered by a researcher in the research process?
6. What are the applications of research in various fields of management?
7. Explain the research process in detail.
8. Explain various forms of research.

1.8 ANSWERS FOR SELF ASSESSMENT QUESTIONS

Topic	Q. No.	Answer
Concept of Research	1.	frequency
	2.	observation
	3.	False
	4.	inferential
	5.	marketing
	6.	False
	7.	True
Research Process	8.	Formulating hypothesis
	9.	True
	10.	layout

Notes

1.9 SUGGESTED BOOKS AND E-REFERENCES

SUGGESTED BOOKS

- Welman, J., Kruger, F., & Mitchell, B. (2005). *Research Methodology.* Cape Town: Oxford University Press.
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- Materials, U., Aptitude, R., & Notes, S. (2020). Steps Involved In Research Process | Research Aptitude Notes. Retrieved 7 March 2020, from https://ugcnetpaper1.com/research-process/

CHAPTER 2

Defining and Formulating a Research Problem

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LEARNING OBJECTIVES

After studying this chapter, you will be able to:

- Define the term 'management dilemma'
- Describe the importance and functions of a literature review
- Explain the ways of writing a literature review
- Discuss the types of sources for review
- Describe the concept of a research problem
- Discuss the conditions and components of a research problem

2.1 INTRODUCTION

In the previous chapter, you studied about the concept of research. The chapter discussed the characteristics and types of research. The latter section of the chapter described the problems encountered by a researcher. The chapter concluded with the explanation of the research process.

A management dilemma occurs when the decision-makers of an organisation, i.e., executives and managers, encounter a complex situation where they have to choose between two or more options. Their decision will have an influence on the profitability, competitiveness, stakeholder's wealth, etc. Here comes the need for dilemma management. The decisions of the management must be taken on the basis of the facts generated from the research. For conducting research, a researcher defines the area of study and formulates research problem. A research problem is an issue, a contradiction, or a gap that a researcher is willing to address. To find the answer to the problem, the researcher conducts literature review to gain the idea of previous researches on a similar topic or area of study. Literature review helps in developing the knowledge base, outlining the research questions and finding of the previous or existing research conducted by the other researchers on the same topic of study. It is important to find out the exact problem faced by the management for conducting research as it is correct to say that a problem rightly explained is half solved. If the researcher has recognised more than one problem, then the selection of problem must be done on the basis of priority, financial condition and time limit. Researchers must aware themselves about the selected problem by studying the available literature.

In this chapter, you will study the management dilemma. Next, you learn about the literature review, its functions and process. Further, the chapter will describe the concept of a research problem. Towards the end, the chapter will brief about formulating a research problem.

2.2 MANAGEMENT DILEMMA

A dilemma is referred to as a tough choice in a complicated situation where managers have to choose between more than one alternative. The word 'dilemma' is created by combining prefix 'di' and suffix 'lemma', where 'di' means 'double' and 'lemma'

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means 'proposition' or 'subject'. Let us assume that Priyamvadha went to the pacific mall. Now she has to choose between red dress and blue dress. Here, we cannot say that she is in a dilemma, but if a fire broke out at her floor of the residential building and her cat and dog are inside the room, and she can save only one of them, then this can be considered as an awful dilemma.

Therefore, we can say that the management dilemma is a complex situation faced by executives or managers when they have to achieve two or more goals at a particular time. It becomes difficult for them to prioritise one goal out of other goals. As an executive or a manager of an organisation, people are likely to face management dilemmas on a regular basis. For example, the marketing head of XYZ Organisation is in a dilemma because a few months ago, one competitor organisation announced that it will launch a new product very soon, which is now under the development stage. XYZ Organisation has also publicly announced to launch the same type of product. The launch of the new product is in 2 months, and the development team informs the marketing executive that the version of its product will not be up to the standard as that of its competitor. It needs at least more than a year for creating a product matching the competitor's standards, and it will be too late to start in a fresh manner. This type of a condition forces the marketing head to take a decision whether to launch the product or postpone it. The scope of business management is full of such problems called management dilemmas that need detailed business research and study.

A management dilemma is usually the symptom of a problem that requires a business decision, which can be related to:

- Increase in the overall costs
- Decline in the sales
- Increase in the number of defects in a product
- Rise in customer complaints post purchase of a product
- Conflicts among employees
- Low motivation levels
- Performance issues
- High absenteeism rate
- Resignation of key employees

It is necessary for an organisation to manage the dilemma to take the best business decisions. The dilemma management helps in resolving the complex issues in a systematic manner. Following points must be kept in mind while facing a dilemma:

- **Address the dilemma; do not try to avoid it:** In an organisation, dilemmas can arise because of the lack of foresightedness. A manager must understand that there is an issue and try to find a solution to it promptly. If the manager will try to avoid the issue, it will only escalate it. The manager can begin by evaluating what the underlying problem is and look for the appropriate solution. This will assist in preparing for future complexities.

- **Think productive**: In an organisation, it is necessary for managers and executives to think in a productive manner and analyse the situation from all angles. Managers must create willingness to work and help every employee in resolving issues. The goal is to pay more attention to the dilemma and find its best possible solutions. Management must avoid defensive and reactionary behaviours.
- **Review action:** After addressing the issue, it is good to review the actions. This helps in finding out whether the actions taken are successful or is there any other way to solve that problem. Managers must examine the work critically and find out the hidden mistakes.
- **Develop the environment for dilemma management:** An organisation must establish an environment within the workplace for dilemma management rather than its avoidance. Managers and executives must understand their mistakes, learn from them and take corrective actions.

Self Assessment Questions

1. A _____ is referred to as a tough choice in a complicated situation where managers have to choose between more than one alternative.
2. The dilemma management helps in resolving the complex issues in a systematic manner. (True/False)
3. Management must avoid the _____ and reactionary behaviours at the time of resolving the complex issues.

2.3 LITERATURE REVIEW

Literature is the assembly of scholarly writings on a certain topic. A literature review is a document that helps researchers examine the published information related to the particular subject area. A literature review covers a particular time period. It is not limited to the summarisation of the sources; rather, it combines both summarisation and synthesisation of sources. A summary is a recap or brief outline of previous important information of the source; whereas, a synthesis is the reshuffling or reorganisation of information. Literature review helps in providing an outline of current knowledge that allows the writer or researcher to recognise the relevant theories, methods, and gaps in the old and present researches. A literature review is conducted by collecting, evaluating and analysing books, journals, articles (publications) related to the research problem. For understanding the solution of the dilemma of management, researchers examine a wide variety of journals, books, and articles related to the business research problem. Researchers show a summary and critical evaluation of the literature reviews that fits their field of study to the interested parties. This process is known as the literature review.

A good literature review provides a clear picture of the current knowledge on the research subject. The objectives of a literature review are:

- To conduct a survey in the area or subject of study
- To synthesise the information into a summary

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- To perform a critical analysis of the collected information by recognising the gaps in the existing knowledge
- To show limitations of research theories and review controversial areas
- To present the literature in a proper manner

Let us understand the importance of a literature review.

2.3.1 IMPORTANCE OF A LITERATURE REVIEW

A researcher must not get confused between literature review and research papers. Both of them are different. A literature review does not give new ideas related to the topic of study or research problem. It just summarises and synthesises the ideas of others or existing literature. Research papers, however, develop new arguments and are based on the original research. Conducting literature review is just like doing homework and getting an idea about the topic in advance. It is important to conduct a literature review because:

- Literature review brings clarity regarding the subject of study and helps in understanding the subject.
- Literature review helps in familiarising the researcher with the research methodologies used by others for finding the answers to the related research problems.
- Literature review helps identify which methodologies in the previous researches have been most beneficial in analysing a topic.
- Literature review makes the researcher aware of the pitfalls and problems faced by others and helps in choosing the correct methodology to solve the problem.
- Literature review also helps broaden the knowledge base in the related research area in which researchers wants to study.
- Literature review helps in finding the researcher's present knowledge for conducting the study.
- Literature review helps identify the experts on a researcher's topic of study. For example, if any person has written 20 articles on a research topic related to your research subject, then he is likely to be knowledgeable about that topic. This person's written work could be a key resource for consultation in your research.
- Literature review helps in avoiding delicacy and plagiarism.
- Literature review helps make a comparison between the findings of the researcher and others.

Now, let us understand the functions of a literature review:

2.3.2 FUNCTIONS OF A LITERATURE REVIEW

Literature review helps the researcher create a link or bond with the readers and build trust. It also helps eliminate the chances of the repetition of the similar research publication. It saves the time, money and other resources invested by the researcher in conducting research. A literature review gives a theoretical background of the

research subject and establishes the relation between what a researcher is proposing to examine and what he/she has already studied.

The main functions of a literature review are shown in Figure 1:

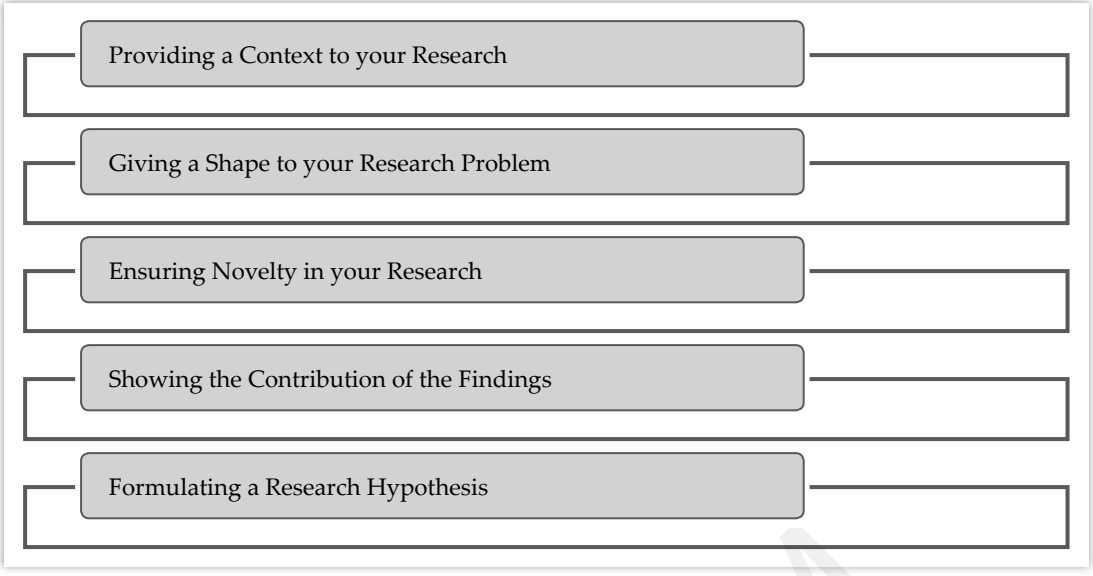

Figure 1: Functions of a Literature Review

Let us discuss the functions of a literature review:

- **Providing a context to your research:** A literature review helps place your research in the context of what is already known about the topic. It answers questions such as:
  - How does your research answer provide the solution to the management dilemma/question in comparison to the answers given by other researchers?
  - What contribution has your research work made?
  - What are the differences between your findings and the findings of other researchers?
- **Giving shape to your research problem:** By understanding the topic better, you will be able to conceptualise your research problem clearly and precisely. You will also be able to understand the relationship between your research problem and the work done in your research area.
- **Ensuring novelty in your research:** Finally, a literature review ensures that you do not 'reinvent the wheel'. In other words, you save effort in trying to rediscover something that is already known or published. This will ensure that you bring new and significant contributions to your field of research.
- **Showing the contribution of the findings:** It enables you to show how your findings have contributed to the existing body of knowledge in your profession.
- **Formulating a research hypothesis:** Researchers read and review the available literature related to the research topic. The review may include reading articles, books, cases or other research papers. After the literature review is completed, the researchers gain a sufficient amount of information regarding their study

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topic which helps them in narrowing down or limiting it and expressing it in the form of a research question. The research hypothesis is constructed using the research question. Therefore, a literature review helps in formulating the research hypothesis.

2.3.3 PROCESS OF A LITERATURE REVIEW

A literature review helps the researcher prepare well for conducting research. It shows the originality and relevance of the research problem and justifies the proposed research methodology. Research methodology involves the techniques that are used to recognise, select, process, and examine information about the research topic. Figure 2 shows the process of a literature review:

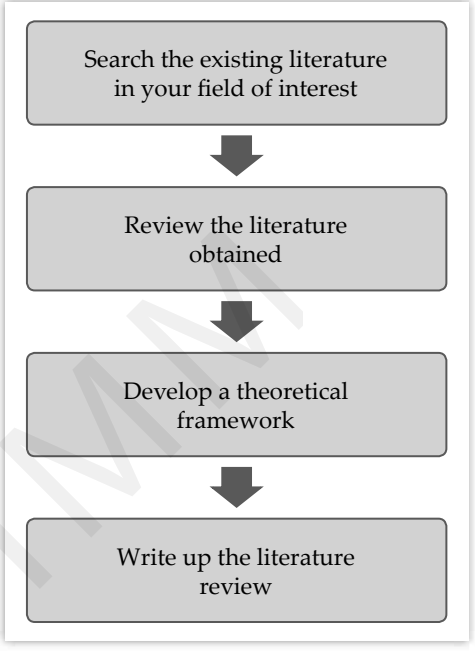

Figure 2: Process of a Literature Review

Let us understand the process of literature review in detail:

1. **Search the existing literature in your field of interest:** First, search what has already been done in the chosen topic of interest. To search the existing literature, compile a bibliography and/or a list of references, which is a list of books on the topic of interest. To save time, the researcher can go through the following sources:
   - Indices of journals on your research topic
   - Abstracts of articles on your research topic
   - Citation indices
   - Digital libraries
2. **Review the literature obtained:** After the researcher has identified the relevant journals and books, he/she must start reading them. Evaluate them critically to compile themes and issues that are associated with the research topic. The researcher must note down the main points to create a rough framework or theme of the research.

Do a critical evaluation of the literature to:

- Identify the proposed theories, critics and methodologies (sample size, data used, measurement methods)
- Assess whether the knowledge relevant to your theoretical framework has been confirmed beyond doubt
- Discover different perspectives among researchers and write down your opinions about their validity
- Find the gaps that are present in the existing body of knowledge

3. **Develop a theoretical framework:** A literature review can be a time-consuming task. Therefore, it is important to set the boundary and parameters for a research work. Sort out the information obtained from the literature sources according to theoretical framework. This will enable the researcher to focus in the literature search. In other words, the theoretical framework will provide foundation and guide to read further. It is quite possible as a researcher reads further. However, this is part of a research process.
4. **Write up the literature review:** The final step is to compile and write all the literature read and reviewed. To do so, the researcher must perform the following steps:
   a. Start review with a theme or points
   b. Organise and list all the themes to discuss and relate. This will give a structure to literature review
   c. Identify and describe various theories relevant to the field of research
   d. Describe the gaps that exist in the body of knowledge in the field
   e. Explain the recent advances and current trends in the field of research
   f. Compare and evaluate findings based on:
      i. Assumptions of research
      ii. Theories related to the topic of research
      iii. Hypotheses
      iv. Research designs applied
      v. Variables selected
      vi. Potential future work speculated by the researchers
   g. Acknowledge, cite and quote sources of research. Give credit to the works of other researchers. Quote their work to show how research contradicts or contributes to their work. This will make the literature review more comprehensive and precise.

2.3.4 HOW TO WRITE A LITERATURE REVIEW

After reviewing the existing body of knowledge on the topic of research, researcher has created a theoretical framework for the area of research. Researcher is now ready

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to write a literature review. How should researcher go about it? Some strategies of writing a literature review are shown in Figure 3:

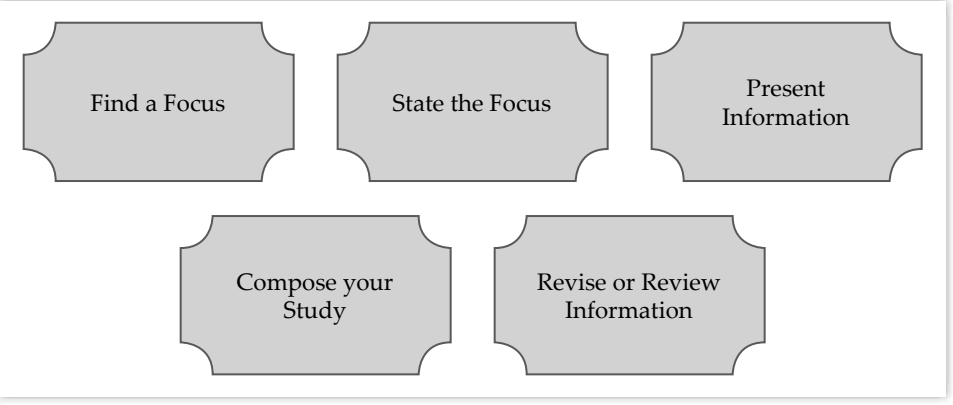

Figure 3: Strategies of Writing a Literature Review

The strategies of writing a literature review are as follows:

- **Find a focus:** A literature review is generally organised around ideas, and not just sources. As the researcher, read the existing body of knowledge in topic, consider and pick any of the following themes to focus and organise review:
  - Which themes connect the sources together?
  - Do they present single or multiple solutions?
  - Are there any gaps in the existing themes?
  - How effectively do they present the material?
  - Do they reveal a trend in the field?
- **State the focus:** The researcher writes a simple statement in the literature review that tells readers what to expect. Some examples are as follows:
  - The current trend in treatment for cancer combines surgery, medicine and natural healing.
  - Popular media is acquiring academic consideration.
- **Present information:** The researcher organises the information to present in the following way:
  - **Cover the basic categories:** A literature review contains the following three basic categories:
    - ✓ **Introduction:** It gives a quick idea of the topic of literature review, such as central theme.
    - ✓ **Body:** It contains discussion of sources. It can be organised chronologically, thematically or methodologically (discussed further).
    - ✓ **Conclusions/recommendations:** It provides the conclusion the researcher has drawn from reviewing literature.

- **Organise the body:** Once the researcher has the basic categories in place, consider how to organise the sources within the body of the review. Table 1 shows the ways to organise sources of a literature review:

Table 1: Ways to Organise Sources of a Literature Review

Organisation Methods	Description
Chronologically	Sources are organised according to when they were published.
By publication	Sources are organised by publication in a chronological manner if the order shows an important trend.
Thematic	Sources are organised around a research topic or a problem, rather than time progression. However, time progression may still be an essential factor in this case.
Methodologically	Sources are organised on the methods of the research or by author.

- **Consider additional sections:** Sometimes the researcher might need to add additional sections for the study, such as:
  - ✓ **Current situation:** This provides the necessary information for the readers to understand the topic or focus of the literature review.
  - ✓ **History:** This presents the chronological progression of the field.
  - ✓ **Methods and/or standards:** This presents the criteria used to select the sources in the literature review.

❍ **Compose your study:** After organising the basic categories, the researcher is ready to write the review. Some guidelines to follow during the writing are given below:

- Refer to several other sources when making a point. Back up your point with a suitable evidence.
- Selectively highlight only the most important points in each source. Your points must directly relate to the review's focus.
- Avoid using any direct quotes. This is because the survey nature of the literature review does not allow for in-depth discussion or detailed quotes from the text. However, if you do want to use quotes to emphasise a point, then use short quotes sparingly.
- Summarise and synthesise your sources within each paragraph and throughout the review.
- Maintain your own voice by starting and ending a paragraph with your own ideas and own words.
- When paraphrasing a source that is not your own, remember to represent the author's information/opinions accurately and in your own words.

❍ **Revise or review information:** Finally, the researcher must revise the review. Make sure that it follows the outline. Rewrite the language of review to present information in the most concise manner possible. Avoid unnecessary jargon or slang; use familiar terminology. The researcher must verify that sources are documented and format the review appropriately.

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2.3.5 TYPES OF SOURCES FOR REVIEW

The literature includes peer-reviewed articles, books, dissertations and conference papers. Literature review sources can be divided into two categories, such as primary and secondary sources for literature review. The primary sources are original and provide first-hand information. Some of the examples of primary sources are:

- Reports
- Thesis
- E-mails
- Conference proceedings
- Organisation reports
- Unpublished manuscript sources
- Some government publications

The secondary sources are non-original and provide second-hand information. Some of the examples of secondary sources are:

- Journals
- Books
- Newspapers
- Some (secondary) government publications

Self Assessment Questions

4. A literature review creates a rapport with the readers and builds trust. (True/False)
5. The secondary sources are non-original and provide _____.
6. Which among the following is not an example of primary sources?
   a. E-mails
   b. Organisation reports
   c. Reports
   d. Newspapers

2.4 CONCEPT OF A RESEARCH PROBLEM

A research problem is referred to as a statement which is about an area of concern, a condition that needs improvement, a difficulty to be eliminated, or a troublesome query that exists in scholarly literature, in theory, or in practice that requires meaningful understanding and deliberate investigation. In social science, the research problem is in the form of a question. A research problem does not explain the way to do something, offer a vague or broad proposition, or show a value question.

2.4.1 THE NEED FOR DEFINING A RESEARCH PROBLEM

It is important to formulate a research problem carefully to clearly indicate what you intend to achieve through research. It is said that a process well begun is half done. A well-formulated research problem makes the research process easier and more focussed. It helps the researcher:

- Separate the irrelevant data from the relevant data
- Keep the research work on track

- Ensure efficient and focussed literature review and other studies
- Keep the research centred around the problem

2.4.2 CONDITIONS AND COMPONENTS OF A RESEARCH PROBLEM

A research problem exists if the following four conditions are met:

- There must be a problem whose solution is presently not known.
- There must be an individual, group or organisation to which the problem can be attributed.
- There must be minimum two courses of action which a researcher can pursue.
- There must be at least two feasible outcomes of the course of action. Out of the two outcomes, one outcome should be more preferable to the other.

On the basis of these conditions, the components of a research problem are:

- **Individual, group or institution:** There must be somebody to whom the research problem can be attributed. It may be an individual, a group or an institution. The individual/group/organisation is the one that is facing the problem or difficulty. At times, these individuals or the group may themselves be researchers.
- **Research objectives:** There must be a purpose for which the research is conducted. Every research is carried out to meet some predefined objectives.
- **Environment:** It refers to the surrounding in which a problem exists. Environment is of three types: economic, social and political. A problem pertaining to the study of inflation would come under the economic environment and a problem pertaining to studying the effects of child marriage on the health of women would come under the social environment.

2.4.3 IDENTIFYING A RESEARCH PROBLEM

Identifying or selecting a research problem is a difficult and time-consuming task. While doing so, a researcher should consider the following factors:

- **Personal interest:** This is the chief motivation to select a research problem. Academic research is a time- and effort-consuming process. A researcher can consistently pursue it only if he/she is personally interested in resolving the problem. The interest of a researcher further depends on other factors, such as educational background, professional and personal experience and outlook.
- **Knowledge and competence:** The selection of a research problem depends on the researcher's knowledge in the field of interest and his/her capability to perform research successfully. The qualification of the researcher, and his/her training and experience must match the research problem.
- **Availability of resources:** An academic research usually involves large-scale data collection, wide travelling, a lot of time and finance. If sufficient resources, such as time and money are available to research a problem, then the problem is selected.
- **Relative importance:** If a problem is relatively important and urgent, then the research must be conducted to solve that problem first.

Notes

- **Usefulness and significance:** The practical usefulness of a problem is also a major motivation for a researcher to attend it.
- **Timelines of the problem:** Some problems take little time to be resolved, while others take a considerable time. So, the time taken to complete research work is also an important criterion to select a problem.
- **Data availability:** A researcher would select a problem, which has sufficient and relevant data available.
- **Novelty:** If a problem is around a current topic of interest, then it is more likely to be picked up for research. Any findings would invite immediate publicity and funding for the researcher.

2.4.4 FORMULATING A RESEARCH PROBLEM

The next step after identifying a research problem is to formulate it in a form agreeable for research. It means specifying the research problem in detail and narrowing it down to a workable size. In this step, all questions and sub-questions, which a researcher wants to answer by his/her research, are specified. In addition, the scope and boundaries of investigation are determined. While formulating a research problem, the researcher should clearly form the assumptions. Formulating a research problem is a three-step process. These steps are shown in Figure 4:

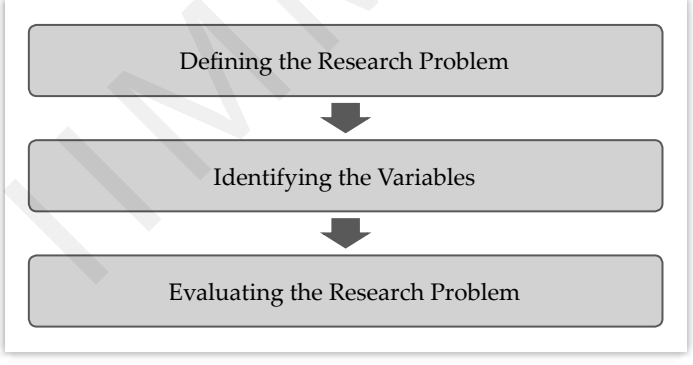

Figure 4: Steps to Formulate a Research Problem

Let us understand these steps in detail:

1. **Defining the research problem:** The first step of formulating a research problem is to mention the problem in the form of a question or statement to make it clearer and understandable. A good statement must clearly mention what exactly you want to solve or determine by the research study. You also need to describe the theoretical basis and background of the study. Major issues and elements of the research should be divided into sub-parts for better understanding. It is also important to state the problem in a manner that indicates the relationship between two or more variables.
2. **Identifying the variables:** As already discussed, it is very important to identify the variables involved in a research study because it helps in stating the problem in a more precise manner. In other words, all variables involved in a research problem should be defined in such a manner that they can be measured or expressed quantitatively or qualitatively.

3. **Evaluating the research problem:** The third step in formulating a research problem is to evaluate it in terms of originality, importance and feasibility. These factors are discussed as follows:

   - **Originality:** The research problem should be unique. Any topic on which a lot of research has already been done should be avoided because it would be difficult to highlight anything new in that topic. However, in some cases, you may decide to research a previously researched topic to verify its conclusions, explain and elaborate the conclusions in a more effective manner, and solve some of the inconsistencies of the previous research.
   - **Importance:** The research study should be significant enough to either become the basis of any new theory or pose some problems for further research. In addition, the research study should also have some practical applications.
   - **Feasibility:** This refers to the chances of conducting a successful research. You should take up a problem, which is feasible for you to conduct a research. A research problem may not be feasible because of the following reasons:
     - ✓ Lack of skills and competencies of the researcher
     - ✓ Lack of interest and enthusiasm of the researcher
     - ✓ High cost involved in the research study
     - ✓ Time constraint
     - ✓ Administrative constraints, such as lack of cooperation from administrative authorities

Self Assessment Questions

7. A well-formulated _____ makes the research process easier and more focussed.
8. The first step of formulating a research problem is to identify the variables. (True/False)
9. _____ is the chief motivation to select a research problem.
10. Formulating a research problem is a _____-step process. Choose the correct answer.

    a. three b. four

    c. five d. six

2.5 SUMMARY

- A dilemma is referred to as a tough choice in a complicated situation where managers have to choose between more than one alternative. The word 'dilemma' is created by combining prefix 'di' and suffix 'lemma', where 'di' means 'double' and 'lemma' means 'proposition' or 'subject'.
- A management dilemma is usually the symptom of a problem that requires a business decision, which can be related to an increase in the overall costs, decline in sales, conflicts among employees, etc.

Notes

- A literature review is a document that is prepared after conducting search and evaluation according to the subject or chosen topic area. It examines the published information related to the particular subject area about which the writer is writing.
- A good literature review provides a clear picture of the current knowledge on the research subject. Conducting literature review is just like doing homework and getting an idea about the topic in advance.
- Literature review also helps broaden the knowledge base in the related research area in which researchers want to study.
- A literature review gives the theoretical background of the research subject.
- The steps to conduct the literature review process include searching the existing literature in your field of interest, reviewing the literature obtained, developing a theoretical framework, and writing up the literature review.
- Literature review sources can be divided into two categories, such as primary and secondary sources for literature review.
- The primary sources are original and provide the first-hand information. The secondary sources are non-original and provide the second-hand information.
- A research problem is referred to as a statement which is about an area of concern, a condition that needs improvement, a difficulty to be eliminated, or a troublesome query that exists in scholarly literature, in theory, or in practice that requires meaningful understanding and deliberate investigation.
- It is important to formulate a research problem carefully to indicate what you intend to achieve through research.

2.6 KEY WORDS

- **Dilemma:** The tough choice in a complicated situation where managers have to choose between more than one alternative
- **Journals:** A scholarly publication that consists of articles written by the researchers, professors and other experts
- **Literature:** The assembly of scholarly writings on a certain topic
- **Primary sources:** Sources which are original and provide the first-hand information
- **Secondary sources:** Non-original sources which provide the second-hand information

2.7 CASE STUDY: MANAGEMENT DILEMMA OF WALMART INC.

Walmart Inc. was founded by Sam Walton. It was incorporated in 1969. Walmart is a multinational retail corporation that is based in America and operates discount department stores, grocery stores, and a chain of hypermarkets. Walmart is headquartered in Bentonville, Arkansas.

Walmart is considered as the largest retail organisation that operates different warehouses and departmental stores globally. The research was conducted for finding the solution of management dilemma of all Walmart stores in the US that

faced a reduction in sales during the harsh economic times with 2.6 percent reduction in store visits. Researchers used Management-Research Question Hierarchy (MRQH) for finding the management's dilemma. MRQH is a process of sequential question formulation that helps researchers find solutions to a specific situation or management dilemma.

It was found that during the initial 5 months, there was a drop of 82.8 million in customer visits when Walmart's competitors like the Dollar General Corp and the Kroger Co. have increased their sales. This was identified and defined as the existing problem which was required to be solved promptly. Walmart was required to make sure that its stores address all the existing demands of their customers for ensuring customer retention.

Various solutions suggested by the researches for Walmart stores were as follows:

- Management must recreate the organisation's leadership in terms of price and delivery as per the customer's needs.
- Management must focus on delivering high-quality products at reasonable or reduced prices in every season.
- Management must emphasise on offering a different range of products to the customer and offer more choices.

Source: *https://ivypanda.com/essays/wal-marts-management-dilemma/*

QUESTIONS

1. What dilemma was faced by the management of Walmart?

   (**Hint:** Sales reduction, increase in competitor's sales)

2. What is Management-Research Question Hierarchy (MRQH)?

   (**Hint:** Sequential question formulation, management's problem solution)

3. What is a dilemma?

   (**Hint:** Difficulty in making choice, complex situation)

4. Who were the competitors of Walmart?

   (**Hint:** Dollar General Corp, Kroger Co.)

5. What were the solutions recommended by the researchers to solve the management's dilemma?

   (**Hint:** Product quality, reduced price, more range of products)

2.8 EXERCISE

1. What do you understand by the term 'management dilemma'?
2. What is the importance of conducting a literature review in research?
3. Define research problem.
4. Explain the conditions and components of a research problem.

5. What are the steps to formulate a research problem?
6. What points must be kept in mind while managing a dilemma?
7. Describe the types of sources for review.
8. Explain the process of conducting a literature review.
9. List down the ways to organise the sources of a literature review.
10. What factors must be considered while identifying a research problem?

2.9 ANSWERS FOR SELF ASSESSMENT QUESTIONS

Topic	Q. No.	Answer
Management Dilemma	1.	dilemma
	2.	True
	3.	defensive
Literature Review	4.	True
	5.	second-hand information
	6.	d. Newspapers
Concept of a Research Problem	7.	research problem
	8.	False
	9.	Personal interest
	10.	a. three

2.10 SUGGESTED BOOKS AND E-REFERENCES

SUGGESTED BOOKS

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CHAPTER 3

Research Design

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Notes

LEARNING OBJECTIVES

After studying this chapter, you will be able to:

- Explain the concept of research design
- List the needs and features of a research design
- Discuss various types of research design
- Explain the components of a research design

3.1 INTRODUCTION

In the previous chapter, the use of research for handling management dilemma has been discussed. The chapter discussed the importance, functions and process of a literature review. The chapter next described how to write a literature review and the types of sources for review. Further, the need of defining a research problem, conditions and components of a research problem have been discussed. The chapter concluded with an explanation of formulating a research problem.

The preparation of the design of any research project, generally known as a research design, is one of the crucial stages for the success of a research project. A research design is a blueprint which is followed as a guide during the complete research study. A research design is needed to create the framework for a research study that acts as a guide for data collection and data analysis. A research design is the blueprint for collection measurement and analysis of data. The all-inclusive purpose of any research is to seek an answer to a research problem. The successful completion of any research project depends on how well its research design fits with its research problem.

A research design is, therefore, a comprehensive plan, framework and strategy for conducting a research. It formulates the basis of every research and offers vital information to the researcher, such as the research topic, data type, data sources and methods of data collection.

This chapter will help you in understanding the concept of research design. You will study the need and features of a research design. Further, various types of research design are also discussed. Towards the end, you will learn about the components of research design.

3.2 THE CONCEPT OF RESEARCH DESIGN

Once the research problem has been identified and the literature review has been done, the next step is to frame a research design. Any sort of research needs a design before beginning with data collection and analysis. A research design is framed with the purpose to ensure that the information collected from the research will enable the researcher to answer the research problem satisfactorily. Typically, in a research, it is needed to first consider what information is required to collect to answer the research problem. A research design is a systematic approach that a researcher uses to efficiently handle a research problem. It provides insights into 'how' to conduct

research using a particular methodology. It combines various components and data to arrive at a feasible outcome.

The decisions concerning what, where, when, how much, and by what means regarding an investigation or a research study constitute a research design. Some definitions of a research design by different experts are given as follows:

According to Claire Selltiz and others, "*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."*

According to David J. Luck and Ronald S. Rubin, "*A research design is the determination and statement of the general research approach or strategy adopted for the particular project. It is the heart of planning. If the design adheres to the research objective, it will ensure that the client's needs are served."*

According to Kerlinger, *"A research design is the plan, structure and strategy of investigation conceived so as to obtain answers to research questions and to control variance."*

According to Green and Tull, *"A research design is the specification of methods and procedures for acquiring the information needed. It is the overall operational pattern or framework of the project that stipulates what information is to be collected from which source by what procedures."*

In other words, a research design is a complete guide and provides answers to the following questions:

- What is the research all about?
- Why is the research required?
- Where will the research be conducted?
- What type of data is required?
- Where can the required data be found?
- What is the time-period of research?
- What will be the sample design?
- What techniques of data collection will be used?
- How will the data be analysed?
- What will be the style of report preparation?

SELF ASSESSMENT QUESTIONS

1. _____ provides insights into 'how' to conduct research using a particular methodology.
2. The decisions concerning what, where, when, how much, by what means regarding an investigation or a research study constitute a research design. (True/ False)

Notes

3.3 THE NEED AND FEATURES OF RESEARCH DESIGN

All researchers need a research design for conducting research. The need of a research design is depicted by the following points:

- **To facilitate smooth research operations:** A research design is needed because it enables the smooth functioning of various research operations. Thus, it makes research as efficient as possible in yielding maximal information with minimal expenditure of effort, time and money.
- **To plan data collection and analysis:** A research design is needed to make a plan in advance of data collection and analysis for conducting a research project.
- **To plan availability of research resources: A** research design should be prepared keeping in mind the objective and available resources of the research. A research design is needed to plan in advance the availability of staff, time and money. Groundwork of the research design should be done with great care as any error in it may trouble the entire research project.
- **To attain reliable results:** A research design creates a firm foundation of the entire structure of the research work and this has a great bearing on the trustworthiness of the results arrived at the end of the research work.
- **To conduct useful research:** Negligence in designing the research project may result into worthless research efforts. Such negligence may also give pointless research outcomes. Before starting research operations, it is vitally important to prepare an appropriate and efficient design.
- **To organise research ideas:** A research design is needed by the researcher to organise the ideas of research in a form, whereby it enables researchers to look for flaws and inadequacies in research problem. A research design can even be given to others for their comments and critical evaluation.

A research design is beneficial to researchers to plan research methods well in advance, select appropriate tools for data collection and run the research project smoothly.

Usually, a good research design minimises unfairness and maximises the trustworthiness of the data collected and analysed. The design that gives the least experimental error is reported to be the best design in scientific research. Similarly, a design is considered to be efficient and appropriate if it gives the maximum information and considers various aspects of a problem by yielding an opportunity. A good research design should possess the following characteristics:

- **Reliability:** A research design should be consistent throughout a series of measurements to provide consistency or reliability.
- **Objectivity:** A research design should allow the use of uniform measuring instruments. An impartial measuring instrument enables every observer or judge recording the performance to precisely record the data and give the uniform report. The objectivity also implies the use of the research methods which must be judged by the degree of agreement between the final scores assigned to different individuals by more than one autonomous observer. This guarantees the fairness

and transparency of the collected data which is further analysed and interpreted to get information.

- **Validity:** A research design should define the use of a measuring device or instrument and it only measures what it is expected to measure. For instance, an intelligence test conducted to measure the Intelligence Quotient (IQ) should measure only the intelligence and nothing else. The questionnaire for IQ test shall be framed accordingly.
- **Adequate information:** A research design should provide adequate information so that the research problem can be analysed on a wide perspective. A perfect research design should consider the following important factors:
  - The exact research problem to be studied
  - The main purpose of the research
  - The procedure of finding information
  - The accessibility of adequate and skilled manpower
  - The availability of enough financial resources for carrying research
- **Generalisability:** This implies how best the data collected from the samples can be utilised for drawing certain generalities, which will be relevant to a large group from which the sample is drawn. Therefore, a research design helps researchers generalise their findings provided that due care is taken in defining the population, selecting the sample, deriving appropriate statistical analysis, etc., while preparing the research design. A research problem to be generalised should have the following characteristics:
  - The problem should be clearly formulated.
  - The population should be clearly defined.
  - The most suitable techniques of sample selection should be used to form an appropriate sample.
  - Suitable statistical analysis should be carried out.
  - The findings of the research study should be capable of generalisations.
- **Other features:** A good research design should have other features too, such as flexibility, adaptability, efficiency, being economic, and so on. The maximum reliability with generalisation and minimum biasness should be depicted by a good research design.

Self Assessment Questions

3. _____ in designing the research project may result in the execution of the futile research exercise.
4. A research design cannot be given to others for their comments and critical evaluation. (True/False)

Notes

3.4 TYPES OF RESEARCH DESIGN

Research can be conducted in various ways and under diverse conditions. The type of research defines the type of research design needed. It is quite possible that a research design may be appropriate for one type of research, while it may not be suitable for another type of research. For instance, the marketing department of an organisation should conduct exploratory research to identify the potential areas of growth. In case the marketing department wants to see the impact of different packaging on the sales of a product, then experimental research should be conducted.

So, for an exploratory research, the research design should be flexible to accommodate continuous changes. On the other hand, if a research is diagnostic, then the flexible research design is not appropriate because this type of research demands precision, accuracy, minimum bias and reliability. Therefore, the research design must be rigid (not flexible) in this case.

Prior to deciding the research design of a particular type of research, the following questions must be asked:

- What is the nature of the problem of research to be conducted?
- Which technique of data collection and analysis would be used in conducting the research?
- Which situations are required to be applied to the selected method of data collection and analysis?

Depending on the type of research study to be conducted, the types of research design are shown in Figure 1:

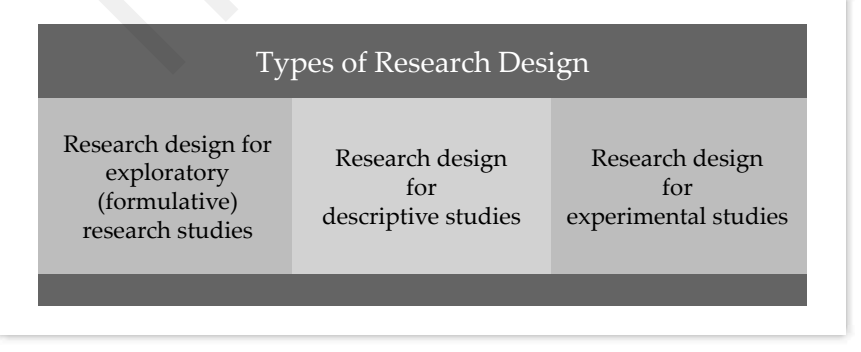

Figure 1: Types of Research Design

All types of research designs are discussed in further sub-heads.

3.4.1 RESEARCH DESIGN FOR EXPLORATORY (FORMULATIVE) RESEARCH STUDIES

The other name for exploratory studies is formulative studies. The prime objective of this type of research study is to formulate a problem for more precise investigation. Typically, these studies are undertaken in the absence of enough information regarding a problem or situation. An exploratory study exerts more emphasis on a problem or situation to gain familiarity with its different aspects. A researcher

conducts an exploratory study when some facts are known about a problem or situation and there is a need to know more about it. The key emphasis in such studies is on the discovery of ideas and insights.

For example, a restaurant chain might undertake an exploratory study to find out different ways that can be used to improve the quality of customer service in its restaurants chain without making any major investments. The researcher, in this case, initially will have only a little information regarding the current status of quality of customer service for which the researcher wants to conduct a research. Such information can be gained by exploratory study only. The researcher along with the research team formed for the purpose may interview the existing customers of the restaurant, review the available literature and consult experienced people in the field.

An exploratory study, by its very nature, considers different aspects of a situation or topic. Thus, the research design for an exploratory study must be flexible enough to consider all aspects of the research problem. Usually, the following methods are considered regarding the research design for exploratory studies:

- **Literature review:** The most important and fruitful method of formulating a problem with precision is the review of literature. If the problem has been formulated earlier, then the available literature can be reviewed to test it for its significance and usefulness. If the problem has not been formulated earlier, then the literature has to be reviewed for formulating it. Reviewing the available literature helps the researcher in applying the already developed theories and concepts to the subject of research.
- **Experience survey:** This implies doing survey of people who have real-world knowledge on the topic of the projected research or on the related topics. Experienced people can prove helpful in the research by providing significant and innovative ideas in the research. An experience survey can be conducted by scheduling interviews with the experienced people.

  For conducting interviews, one should prepare a set of methodical questions to be put to the experienced people. However, one should also give a sufficient chance to the respondents to raise questions and satisfy their concerns. An experience survey makes a research more practical, feasible and applicable. One may use either of the aforementioned methods for conducting an exploratory research. However, one should ensure that a research design is flexible enough to include different aspects of a problem.
- **Analysis of 'insight-stimulating' examples:** This is also considered as a fruitful and vital method for recommending research hypotheses. Predominantly, it is appropriate in areas where there is little experience to serve as a guide. This technique consists of the rigorous study of selected cases of the phenomenon in which one is interested. The existing records, if any, may be examined, the unstructured interviewing may take place, or some other approach may be adopted for the purpose of analysis of 'insight-stimulating'. The attitude of the researcher, the power of the study and the ability of the researcher to draw together diverse information into a unified interpretation are the main features that make this method an appropriate procedure for reminding insights.

Notes

3.4.2 RESEARCH DESIGN FOR DESCRIPTIVE STUDIES

Descriptive studies describe the facts and situations as they are. Such studies are concerned with describing the characteristics of a particular individual, or of a group. They are concerned with 'what' and not with 'how' and 'why' of a research problem. Research studies related to specific predictions, narration of facts and characteristics of human beings are examples of descriptive research. For instance, a research study that aims to describe or list the major features of the organisational culture that exists in Infosys office located at Hyderabad, India is a descriptive study.

As the aim of a descriptive study is to obtain accurate and complete information, so the researcher should be very careful about data and methods to be used. For descriptive studies, the research design should not be flexible as was the case with exploratory studies. It should be rigid and free from any bias. While finalising the research design for the descriptive and diagnostic studies, the researcher should focus on the following points:

- Objectives of the research study
- Clearly defining the hypothesis
- Techniques of data collection
- Sample selection
- Place and time-period of data collection
- Data processing
- Data analysis
- Report presentation

Therefore, in the descriptive and diagnostic studies, the primary requirement of the research design is the clarity of objectives. It means that the researcher should be clear about the type of study undertaken and the reasons behind the study. After that, the techniques of data collection should be selected.

There are various methods of data collection, such as interviews, observations and questionnaires. The researcher should select any of these methods according to the research study requirement, but the collected data should be free from any bias and ambiguity. However, it is good to ensure that the data collection method used would result in the least number of errors.

The time and place of data collection should also be taken carefully. For instance, if the researcher wants to survey the effects of recession, the data of only the recession period is to be considered. In the same manner, if the researcher wants to survey the effects of water scarcity on the lives of people, then the researcher should approach those areas that face acute water shortage. Thus, the time and place of data require discretion on the researcher's part.

The collected data must be properly analysed by using proper statistical and software tools. Finally, the report of the study is presented in detail. The report must be presented in a simple and planned manner to explain the findings to the people concerned in an effective way.

Generally, a descriptive research design combines the following:

- **Overall design:** It is framed with rigidity to protect against biasness and maximise reliability. So, it has a rigid design.
- **Sampling design:** It follows a probability sampling design.
- **Statistical design:** A pre-planned design for analysis is used.
- **Observational design:** Well-thought and structured data collection instruments are used.
- **Operational design:** In this, advanced decision about operational procedures is taken.

3.4.3 RESEARCH DESIGN FOR EXPERIMENTAL STUDIES

This research study is also known as the hypothesis-testing research study. In this form of research study, some variables of interest are manipulated to observe their effects on other variables. The simplest example of an experimental research is conducting a laboratory test. An experimental research is considered to be successful if the researcher confirms that a change in the dependent variable is only due to the change of the independent variable.

It is important for an experimental research to establish the cause and effect of a phenomenon. For example, a researcher conducts research to understand the effect of food on cholesterol and derive that most heart patients are non-vegetarians or have diabetes. These aspects are causes which can result in a heart attack (effect).

Professor R.A. Fisher prepared a research design for experimental studies when he was working with the Centre of Agriculture Research in England (Rothamsted Experimental Station). Initially, he conducted various agricultural researches by dividing an agricultural field into blocks. He carried out a separate research on every block. He found that the data collected in these experimental separate blocks was reliable. This encouraged him to develop experimental designs for scientific investigations also. An experimental research design is a blueprint within which an experimental study is conducted. The purpose of an experiment is to decide:

- Whether the observed differences among the treatments (or sets of experimental conditions) included in the experiment are due to chance only
- Whether the extent of these differences is of practical importance

To decide the above two points, following three principles of experimental design can be used:

- **Principle of replication:** It implies that an experiment should be repeated more than once and each treatment is used in more than one experimental unit. This will ultimately help in achieving statistical accuracy of the experiment.
- **Principle of randomisation:** It implies that the plan or design of an experiment should combine all extraneous factors under a general heading of 'chance'. A better estimate of the experimental error is achieved through application of the principle of randomisation.

Notes

- **Principle of local control:** It implies to reduce the experimental error by conducting the experiment more efficiently. As per this principle, the extraneous factor, a known source of variability, is made to vary purposely over as varied a range as needed. This is done to measure the inconsistency caused due to variation and eliminate the experimental error.

There are multiple ways to categorise experimental research designs. A basic way to categorise them is as follows:

- **Formal experimental research designs:** These designs use comparatively more refined and precise forms of data analysis.
- **Informal experimental research designs:** These designs use less sophisticated forms of data analysis.

Another common way in which they are categorised is:

- **Basic designs:** Basic designs refer to those designs that include only one independent variable. The main types of basic designs are shown in Figure 2:

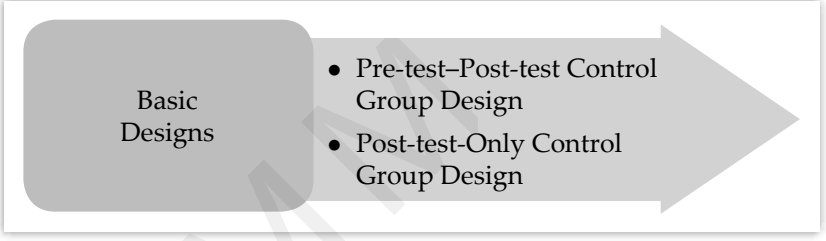

Figure 2: Types of Basic Designs

- **Pre-test-post-test control group design:** It is also called the randomised pre-test-post-test design or the classical controlled experimental design. In such experimental designs, the subjects are assigned to the experimental (treatment) and control (no treatment) groups using random numbers.

  The researcher or the experimenter controls the timing of administering treatment. Both groups are kept in the same environment except that the experimental group receives the treatment; whereas, the control group does not. The notions which are generally used in a basic design are:

  ✓ R: Random assignment

  ✓ T: Treatment

  ✓ O: Observation, outcome or effect

  Table 1 presents the symbolic representation of the pre-test-post-test control group design:

Table 1: Pre-Test, Post-Test Control Group Design

Group	Pre-test (First observation of the dependent variable)	Treatment (T)	Post-test (Second observation of the dependent variable)
Experimental Group (E)	O_1 (Average score of the experimental group on the dependent variable)	T	O_2 (Average score of the experimental group on the dependent variable)

Group	Pre-test (First observation of the dependent variable)	Treatment (T)	Post-test (Second observation of the dependent variable)
Control Group (C)	O_3 (Average score of the control group on the dependent variable)	No-T	O_4 (Average score of the control group on the dependent variable)

In such an experiment, the changes that are observed in the values of the dependent variable in the experimental group ($O_2 - O_1$) arise as a result of the treatment. Here, it might happen that there is a difference between the control group's score, i.e., ($O_4 - O_3$). The difference of O_3 and O_4 is the change in the value of the dependent variable that may occur even in the absence of any treatment.

- **Post-test-only control group design:** In a post-test-only control group design, the researcher randomly assigns subjects to the experimental and control groups. In such a design, the pre-test is not administered. The experimental group is exposed to a treatment, whereas no treatment is administered to the control group. Table 2 presents the symbolic representation of the post-test-only control group design:

Table 2: Post-Test-Only Control Group Design

Group	Treatment (T)	Post-test (First observation of the dependent variable)
Experimental Group (E)	T	O_1 (Average score of the experimental group on the dependent variable)
Control Group (C)	No-T	O_2 (Average score of the control group on the dependent variable)

The post-test-only control group design is used for research where it is not possible to assign subjects to groups randomly due to any (ethical/practical) reason. The main benefit of this design is that it is very simple to implement and has a low error propagation percentage. The main disadvantage of this design is that it is highly vulnerable to threats to internal validity.

- **Statistical designs:** Statistical designs refer to those experimental designs in which there are two or more independent variables. The main types of statistical designs are as follows:

  - **Completely randomised (C.R.) design:** The C.R. design refers to the design in which there is random assignment of subjects (experimental units) to treatments. Out of the three basic principles of experimental design, this design includes only two (the principle of randomisation and the principle of replication). In complete randomisation, every subject carries an equal probability to be assigned to any treatment. For example, if you wish to test eight subjects under two treatments (A and B), there is an equal opportunity of every subject to be assigned to any of the treatments. C.R. designs may be analysed using ANOVA, independent t-test, or non-parametric tests depending upon the number of treatments. A two-group randomised design is the simplest form of C.R. design. In this design, two randomisations (selecting the items randomly), namely random sampling and random assignment, take

place. Random sampling refers to selecting a sample from the population. Random assignment refers to assigning subjects selected from the sample to an experimental group and a control group. The diagrammatic representation of the two-group simple randomised design is shown in Figure 3:

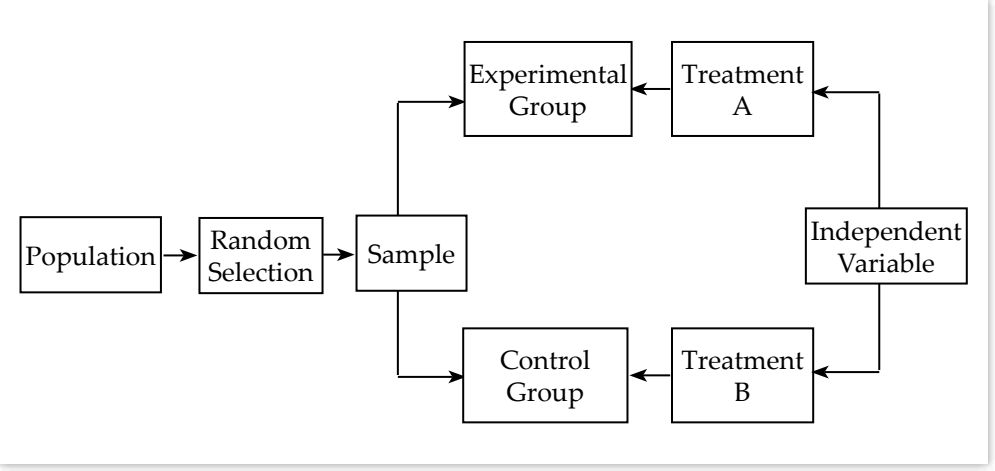

Figure 3: Two-Group Simple Randomised Design

The two-group simple randomised design is very simple to implement. The variations due to extraneous variables can be controlled using the control group.

Let us understand the concept of the two-group simple randomised design with the help of an example. Suppose you are conducting a study to compare two groups of students from a college. In this example, the college represents the complete population. On the basis of random sampling, students are selected out of the population and randomly assigned to two groups, that is, experimental group and control group. One group is given training, whereas, the other group is not. Here, it can be assumed that the group that has received the training (experimental group) is in a better position as compared to the other group (control group). This assumption/hypothesis can be tested using a two-group simple randomised design.

- **Randomised block design:** In this design, all three principles of experimental designs can be applied. The randomised block design refers to the design that is used when you want to eliminate uncontrolled variations. These variations are caused by a variable called blocking variable or nuisance variable. For example, a doctor wants to treat a patient with a specifically prepared medicine. In this case, the nuisance factor may be the time of giving medicine to the patient or room temperature. These factors affect the outcome but are not of prime interest to the doctor.

  Numerous nuisance variables exist in all experiments. One can eliminate their effect on the research study by a technique called blocking. For example, in the study of school students, one can expect homogeneity in the students of the same class as compared to the students of the entire school in terms of knowledge and skills. In this case, a class is a block that can help in reducing variation in the research.

Self Assessment Questions

5. The type of _____ defines the type of research design needed.
6. An experimental study exerts more emphasis on a problem or situation to gain familiarity with its different aspects. (True/False)
7. Research studies related to specific predictions, narration of facts and characteristics of human beings are examples of _____ research.
8. The simplest example of an experimental research is conducting a _____ test.

3.5 THE COMPONENTS OF RESEARCH DESIGN

Various components that constitute a research design are as follows:

- **Overall design:** This component of a research design concerns with a clear statement of the rigidity and flexibility of the research study to be followed.
- **Sampling design:** This component of a research design decides the population to be studied. This part of a research design also deals with the method of selecting samples for research.
- **Observational design:** This component of a research design relates to the conditions under which the observations related to the research problem are to be made.
- **Statistical design:** This vital component of a research design is related to getting the answer of the question of the number of items to be observed for research. This also clarifies about data collection, data gathering and its analysis to arrive at the relevant information.
- **Operational design:** This component of a research design deals with the techniques of carrying out the procedures related to sampling design, observational design and statistical design.

The important concepts related to a research design which are also useful in framing various components of the research design are explained through the following points:

- **Variable:** It refers to a parameter that keeps changing with time and space. The parameter or the variable can take on different quantitative values. Examples of the variables are income, expenditure and weight that keep on fluctuating from time to time. Various forms of variables are as follows:
  - **Dependent variable:** It refers to the variable that can be measured by the researcher. A dependent variable is affected by the changes in an independent variable. Researchers measure dependent variables.
  - **Independent variable:** It refers to the variable that causes a change in a dependent variable. Independent variables can be controlled. Researchers manipulate the independent variable to measure its impact on the dependent variable(s).

- **Extraneous variables:** These are referred to as independent variables or confounding variables which are not directly related to the research but they may affect dependent variables. For example, a researcher wants to study the relationship between the price of a commodity and the demand of that commodity. In this case, consider that 'demand' is a dependent variable and 'price' is an independent variable. When the price is low, the demand increases and when the price becomes higher, the demand decreases. However, the dependent variable demand may also be affected by other factors, such as income and taste of customers. These other factors constitute extraneous variables. These variables need to be controlled.
- **Control variables:** Control variables are those extraneous variables that can potentially affect the research experiment, but the researchers keep them same (or controlled) during experiments. This ensures that the experiments are conducted in a fair environment and are not affected by the extraneous variables.

❍ **Factors, outcomes, levels and treatments:** In an experiment, a factor refers to that variable that is manipulated or controlled by the researcher. The manipulation of a factor is done to study its impact on the research study.

The observation of the variable of interest yields outcome. Each factor can have two or more values called factor levels. These different factor levels are called treatments.

It must be remembered that factors may be qualitative or quantitative in nature. For instance, factors may include soil quality, type of seeds, type and amount of fertiliser. Here, the outcome is observed by observing the yield. In research studies, the researcher may use one or more factors. In a single factor study, treatments correspond to the factor levels. In a single-factor study, the number of treatments and the number of factor levels are equal. On the other hand, in n-factor studies, the treatments correspond to the combination of the factor levels. The number of treatments is calculated as the product of all the different factor levels. For instance, if there are two factors and one factor has 3 levels and the other has 4 levels, then the number of treatments would be 3 × 4, which equals to 12. Assume that a researcher is studying the impact of remuneration on job motivation. Then it is a single factor study wherein remuneration is the factor and different amounts of remuneration are factor levels. Similarly, if a researcher is studying the impact of gender and ethnicity on income, then it is a two-factor study wherein gender and ethnicity are factors. Here, gender can be male or female or trans-sexual (three levels) and ethnicity can be Dalits, Punjabis, Khasis, Bengalis, Jats, Rajputs, etc.

❍ **Experimental unit/group:** It denotes the unit/group to which a treatment is applied in a single trial of experiment. The experimental unit may be a plot of land, a patient in hospital, a group of operators or a set of machines. For example, one can compare a patient in a private ward with a patient in a general ward, in terms of the treatment they receive in the same hospital. In this case, the two patients are the experimental units.

❍ **Response:** It denotes the results of an experiment on the basis of a treatment. The response may be the yield of a process, the purity of a chemical, or any quantitative or qualitative expression.

Self Assessment Questions

9. _____ component of a research design decides about the population to be studied.
10. A dependent variable is not affected by the changes in an independent variable. (True/False)

Activity

Prepare a PowerPoint presentation on different types of research designs and their usage in real world.

3.6 SUMMARY

- A research design is framed with the purpose to ensure that the information collected from research will enable the researcher to answer the research problem satisfactorily.
- A research design is needed because it enables the smooth functioning of various research operations.
- A research design is needed to plan in advance the availability of staff, time and money.
- A research design should be consistent throughout a series of measurements so as to provide consistency or reliability.
- A research design should provide the use of measuring device or instrument which measures what it is expected to measure.
- Research can be conducted in various ways and under diverse conditions.
- An exploratory research should have flexible research design to accommodate continuous changes.
- A researcher conducts an exploratory study when some facts are known about a problem or situation and there is a need to know more about it.
- An exploratory study, by its very nature, considers different aspects of a situation or topic.
- The aim of descriptive studies is to describe the facts and situations as they are.
- For descriptive studies, research design should not be flexible as was the case with exploratory studies. It should be rigid and free from any bias.
- An experimental research is considered to be successful if the researcher confirms that a change in the dependent variable is only due to the change of the independent variable.
- Various components which constitute a research design are overall design, sampling design, observational design, statistical design and operational design.

Notes

3.7 KEY WORDS

- **Factor:** It is a quantitative or qualitative independent variable.
- **Causal relationship:** It is the cause-and-effect relationship between two variables.
- **Experimental unit:** It is an object from which data are taken for an experiment.
- **Experiment:** It is the test done to check a statement or assumption made by the researcher.
- **Nuisance variable:** It is a measurable quantity that cannot be controlled and affects a dependent variable.
- **Random assignment:** It is a method by which subjects are assigned to experimental and control groups without any bias.

3.8 CASE STUDY: RANDOMISED DESIGN FOR BUS FARE REDUCTION

A bus transport organisation's senior manager wants to know the effect of reduction in fare by ₹ 5, 10 and 15 on an increase in the number of passengers. The senior manager designs a completely randomised design which is as follows:

To conduct the study of reduction in price, the senior manager takes 24 routes and randomly assigns 8 routes to treatment A (reduction of ₹ 5), 8 routes to treatment B (reduction of ₹ 10) and 8 routes to treatment C (reduction of ₹ 15). The tabular representation of design is as follows:

Table A: Completely Randomised Design Table

Routes	Number of Travellers Earlier	Treatment	Number of Travellers After
Group 1 (8 routes)	X1	A	X2
Group 2 (8 routes)	X3	B	X4
Group 3 (8 routes)	X5	C	X6

The preceding table shows the observations made by the researcher before the treatment, which are termed as X1, X3 and X5 for different fare reductions. It is also showing the observations made by the researcher after the treatment, which are termed as X2, X4 and X6.

Thus, by comparing X2 and X1, X4 and X3, X6 and X5, the effect of fare reduction will be clear to the mamnager.

QUESTIONS

1. How many bus routes were considered by bus transport organisation's senior manager for conducting bus fare reduction study?

   (**Hint:** 24 routes)

2. Which of the designs should be considered better: randomised block design or completely randomised design? Give reasons.

(**Hint:** Completely randomised design because there is an equal opportunity of every subject to be assigned to any of the treatments)

3. How have the 24 routes been assigned to three groups?

   (**Hint:** Randomly assigned 8 routes to treatment)

4. How has the effect of fare reduction been analysed by the manager?

   (**Hint:** By comparing X2 and X1, X4 and X3, X6 and X5)

5. How was the comparison of travellers made by the manager?

   (**Hint:** By comparing the number of travellers prior to treatment and number of travellers after the treatment)

3.9 EXERCISE

1. What is a research design? List the questions asked to structure a complete research design.
2. Explain the needs of a research design.
3. What are the features of a research design? Explain.
4. Explain the components of a research design.
5. Discuss the significant concepts used in framing various components of a research design.
6. What do you mean by research design for exploratory research studies?
7. Explain the research design for descriptive studies.
8. Describe the research design for experimental studies.

3.10 ANSWERS FOR SELF ASSESSMENT QUESTIONS

Topic	Q. No.	Answer
The Concept of Research Design	1.	Research Design
	2.	True
The Need and Features of Research Design	3.	Negligence
	4.	False
Types of Research Design	5.	research
	6.	False
	7.	descriptive
	8.	laboratory
The Components of Research Design	9.	Sampling design
	10.	False

Notes

3.11 SUGGESTED BOOKS AND E-REFERENCES

SUGGESTED BOOKS

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CHAPTER 4

Sampling

Table of Contents

LEARNING OBJECTIVES

After studying this chapter, you will be able to:

- Explain the concept of sampling
- Describe the characteristics of a good sample design
- Discuss the errors in measurement and sampling errors
- Explain the concept of non-sampling errors
- Describe the probability and non-probability sampling methods

4.1 INTRODUCTION

In the previous chapter, you studied the concept of research design. The chapter discussed the features and types of research design. The chapter concluded with the components of research design.

Sampling is the process of choosing a subset of subject matter or units from the whole population related to the area of study for the purpose of conducting research. Researchers use the sampling method when it is not feasible to study every single element of the target population. Population refers to the collection of elements, individuals, items and objects about which the researcher desires to collect the information. Population can be finite or infinite. The population is finite when it has a fixed number of items or elements; for example, the number of people working in an organisation or the number of students in a school. The population is infinite when it has no fixed number of items or elements and the researcher has no clue or idea regarding the number of items or elements, for example, the total number of stars in the sky.

The researcher must make a methodological plan for obtaining a sample from the target population. This plan is called sample design and the number or items or elements in the sample are known as the sample size of the population. The researcher can use the census method or sample survey method for collecting information, but sample method may result in inaccuracy or error, which is called sampling error.

In this chapter, you will study the concept of sampling and how to determine a sample size. The chapter will also describe the errors in measurement and sampling errors. Towards the end, the chapter briefs about the methods of sampling.

4.2 CONCEPT OF SAMPLING

A sample can be a group of people, items/elements or objects selected out of the population for conducting research. The sample must be taken in a way that it should represent the population characteristics for confirming that research findings can be generalised to the entire population. Researchers use sampling when the size of the population is large as it helps in decreasing the time taken to collect information, reduce expenses, efforts, etc.

Figure 1 shows how samples are taken from the population:

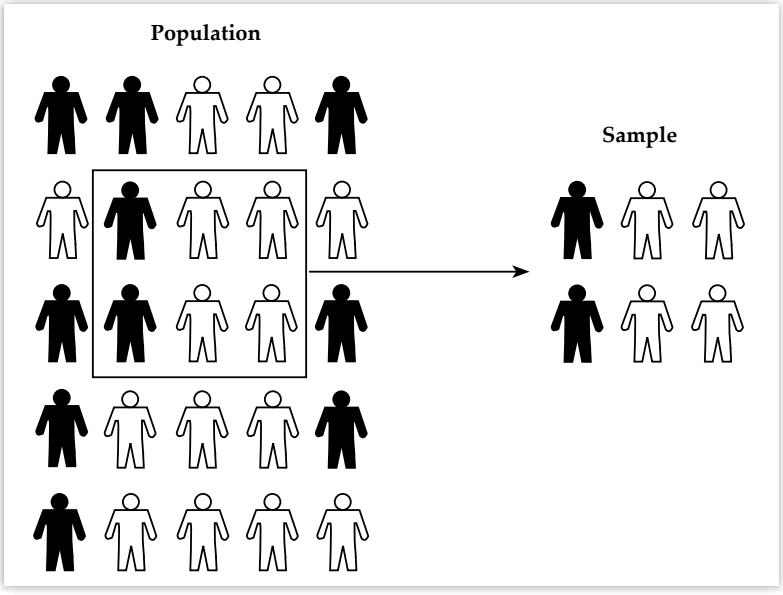

Figure 1: Population and Sample

According to **P.V. Young,** *"A statistical sample is a miniature picture of cross selection of the entire group or aggregate from which the sample is taken."*

According to **Goode and Hatt,** *"A sample, as the name applies, is a smaller representative of a larger whole."*

Let us understand the population and sample with the help of some examples:

1. Manyata is a professor of psychology in the University of Delhi. She is interested in studying the level of stress that B. Tech. students encounter during finals. Manyata is planning to conduct a sample survey and send it around the finals time to some students for ranking their level of stress during finals on a scale of 1 to 5. Manyata needs to select students for conducting her survey.

   Once the students are selected for the survey, the final number of students is called the survey sample.

2. Dr. Suyash, the chancellor of a university, wants to collect the feedback of students on a grading system. It is not practically possible to take the feedback from each and every student. A sample shall be chosen and based on it, the general feedback would be considered. A representative sample is the outcome of improved exactness and accuracy of results.

Researchers may use two primary methods of data collection, i.e., the census method and sampling method. Let us understand these methods in detail.

4.2.1 CENSUS VERSUS SAMPLE SURVEY

Census method of data collection is the method in which researchers study all the elements or items of the population. The Government of India (GOI) conducts the Census of India in every 10 years. Census is also called 'Complete Enumeration'. It gives thorough information covering many aspects of the problems, but it is a time-consuming and expensive method of data collection. Now, instead of studying all the elements of the population, some representatives, i.e., elements are selected from

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the target population which is called sample. For selecting a sample, researchers must determine the population. Once a researcher recognises the target population, a sample must be selected. Table 1 shows the difference between census and sample survey:

Table 1: Difference between Census and Sample Survey

Census	Sample Survey
In this method, a researcher studies every unit or element of a target population.	In this method, few elements of the target population are studied, and not all.
This method involves complete calculation.	This method involves partial calculation.
This method of data collection is very time-consuming.	This method is quicker than the census method.
This method incurs more cost.	This method incurs less cost.
The results derived from the census method are accurate as each member is surveyed. So, there is a chance of minimal sampling error.	The results are subject to inaccuracy as only a few items are surveyed from a large population as a sample. So, there are chances of sampling errors.
This method is good for heterogeneous (high variability types) data.	This method is good for homogeneous (similar type) data.
This method is highly reliable.	This method is not reliable.

4.2.2 SAMPLING DESIGN PROCESS

A sampling design is considered as a road map that provides the foundation or basis for the selection of a sample survey. Figure 2 shows the steps involved in the sampling design process:

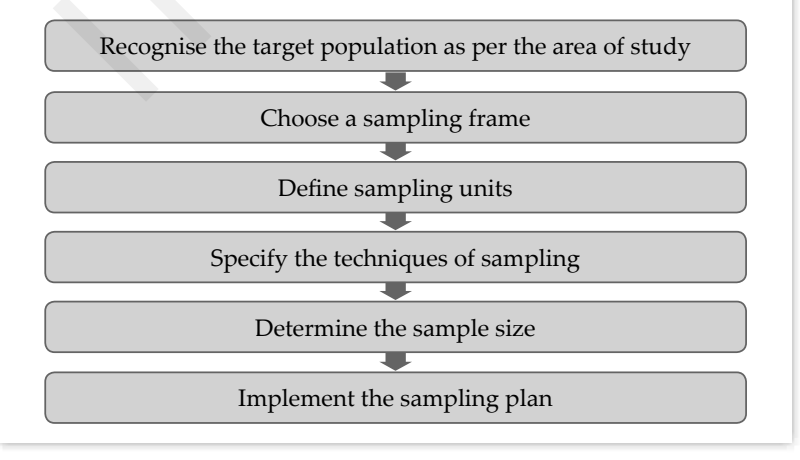

Figure 2: Steps in the Sampling Design Process

Let us understand these steps in detail:

1. **Recognise the target population as per the area of study:** The first step is to identify the target population in which the researcher is interested in generalising the findings. The group of individuals or items from which the sample can be drawn as a sample is called the target population.
2. **Choose a sampling frame:** The next step is to select a sampling frame**.** Sampling frame is a list of all those elements or items within a target population which can

be sampled. For example, Geeta takes 4 schools near to her house in her sampling frame for conducting her study.

3. **Define sampling units:** The next step is to define the sampling units. It is splitting up the population in parts, for example, if a researcher wants to survey the entire nation, the sampling unit will be states, districts, blocks and villages.
4. **Specify the techniques of sampling:** The next step is to choose the technique of sampling. There are two types of sampling techniques, i.e., probability and non-probability techniques. When the sampling frame is the same as the target population (approximately), the researcher must use a random sampling technique for choosing the sample. But when the sampling frame is not representing the target population, the researcher must select a non-random sampling technique.
5. **Determine the sample size:** The number of elements/items that a sample has is called the sample size. A researcher should decide the sample size carefully. It should be neither too large nor too small. Before selecting a sample size, the following points should be considered:
   - **Flexibility:** The sample size should have the ability to adapt to changes to some extent when required.
   - **Representativeness:** The sample should represent the whole population.
   - **Precision:** The sample should involve the desired accuracy.
   - **Reliability:** The sample should be free from errors.
   - **Population variance:** The deviation in the items of the population is called population variance.

   Choose a sample size wisely to control the population variance. For an extremely diverse population, choose a large sample and vice versa if there is little diversity in population.
6. **Implement the sampling plan:** The last step is to implement the sampling plan after identifying the target population, choosing sampling frame, specifying sampling technique and determining the sample size.

4.2.3 CHARACTERISTICS OF A GOOD SAMPLE DESIGN

Researchers must know the characteristics of good sampling design for better and accurate results. A good sample design satisfies the following conditions:

- Sampling design must produce a representative sample.
- Sampling design must result in less sampling errors.
- Sampling design must be feasible in the context of available funds.
- Sampling design results should be applicable to the whole population.
- Sampling design should be able to prevent systematic bias in a better way.

4.2.4 DETERMINING SAMPLE SIZE

Researchers must take care of the following points while determining the sample size:

- **Homogeneity (similarity) or heterogeneity (dissimilarity) of the population:** Researchers while determining the sample size must consider the nature of the universe/population. When the nature of the universe or population is

homogeneous, a small sample can be taken for representing the behaviour of the entire universe or population. When the universe or population is heterogeneous (dissimilar) in nature, samples must be selected as from each heterogeneous unit.

- **Class intervals:** If there is a large number of class intervals to be created, then the sample size should be more as it has to showcase the whole population. In case of small samples, there are chances that few samples are not being included.
- **Research study nature:** The sample size depends on the researcher's study. For an intensive study conducted for a long duration, large samples are selected. But for technical study, the selection of a large number of respondents may result in increasing complexity while collecting information.

Self Assessment Questions

1. Researchers use _____ when the size of the population is large as it helps in decreasing the time taken to collect information, reduce expenses, efforts, etc.
2. A sample size is considered as a road map which provides the foundation or basis for the selection of a sample survey. (True/False)
3. _____ method is quicker than the census method.

4.3 ERRORS IN MEASUREMENT AND SAMPLING ERRORS

An error is a fault or the disparity between the evaluated value and the correct or exact value. Following are the types of errors in measurement:

- **Systematic errors:** These errors are also known as systematic bias. Systematic errors are consistent and happen again and again because of defective equipment or inappropriate experiment design.
- **Gross errors:** These errors are physical errors in the analysis, calculation and recording. Gross errors occur due to human errors that lead to inconsistencies in the research data. When the researcher studies or records incorrect or different values from the data, these errors occur. These errors are predictable in nature and can be corrected by reviewing and revisiting the research report.
- **Random errors:** This error is random and unpredictable in nature. Random errors occur due to a large number of variables that are beyond the researcher's control and affect the outcome of the study. Random errors are of two types: sampling errors and non-sampling errors.

The researcher must be able to recognise the sources of errors in the measurement and should minimise them. Some important reasons that may cause errors are:

- **Errors due to the interviewer's attitude:** These errors occur because of the biased attitude of the interviewer. The interviewer can encourage or discourage certain viewpoints of respondents by rephrasing questions.
- **Errors due to respondent's reluctance:** These errors occur due to the reluctance of respondents to respond to questions. The respondents may feel reluctant to answer questions correctly because of fatigue, hunger or ill-health. The respondents may also commit errors because of the lack of knowledge.
- **Errors due to ineffectiveness of the instrument:** These errors occur because of the ineffective measuring instrument, such as a questionnaire. If the questionnaire

contains a lack of choices, complex language, poor printing, non-essential questions, then it cannot get the desired outcomes from the respondents.

- **Errors due to the situational factors:** These errors occur because of the situational factors. Any condition that puts a strain on the interviewer can cause an adverse impact on the rapport between the interviewer and the respondent.

Some important methods that result in less sampling errors are discussed as follows:

- **Increasing sample size:** Increasing the sample size will reduce sampling errors. If the sample size is equal to the complete population, the scope of sampling error is zero.
- **Stratification:** This refers to dividing the given population into homogeneous and non-overlapping units or sub-groups (known as stratum) to make the sample more representative. Grouping is done on the basis of one or more common attributes.

Sampling error is the error or mistake that occurs in the data collection process as an outcome of taking a sample from the target population rather than using the entire population.

It is a statistical error that occurs when a researcher does not select a sample that represents the entire population of data and the results from the sample are not applicable to the entire population. These statistics may have a value close to or exactly the same as that of the entire population. For example, if a researcher wants to analyse the average production of wheat in a village during a specific year, then the researcher needs to find out the target population. In this case, the population will be the farmers. There are 8,000 farmers in the village who produce wheat. Out of these 8,000 farmers, the researcher selects 800 farmers and calculates the average production of wheat based on the data (figures) given by 800 farmers. There is a surety that the output average that has been extracted will have a slightly different value as compared to the original average. This particular phenomenon is commonly known as sampling error. Hence, these errors may arise because only a small section of the population as a sample had been selected. Hence, it is commonly known that a small sample of population won't give the exact criteria to anything, or won't show the real trend of the outcome, but still these errors can be brought down with a better sampling design.

Self Assessment Questions

4. _____ error occurs due to a large number of variables that are beyond a researcher's control and affect the outcome of the study.
5. The researcher must be able to recognise the sources of errors in the measurement and should minimise them. (True/False)
6. Which among the following is also known as a systematic bias?
   a. Systematic
   b. Random
   c. Gross
   d. None of these

4.4 NON-SAMPLING ERRORS

These errors do not occur because of wrong sampling. Some examples of non-sampling errors are population mis-specification error, data-processing error,

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respondent error, and non-response error. Non-sampling errors may occur even if all the elements of a given population are considered for a study. In other words, non-sampling errors arise as a result of factors other than sample selection. Non-sampling errors may also be caused because of selection bias, ambiguous population specification, sampling frame error, processing error, respondent errors, non-response errors, physical environment, inadequacy of enumerators, etc. For example, a population contains 1,000 elements. The researcher intends to find the average income of the population. Even if the researcher considers all 1,000 elements to find the average income, he/she may get inaccurate results because of non-sampling errors.

A few of the main reasons are given as follows:

- **Improper division of sampling units of a population:** The following example explains why improper division of sampling units causes non-sampling errors. Suppose an organisation wants to conduct a skill development program for its employees who do not have the required skills to perform job duties. For this, the organisation needs to find out the number of employees who need to attend the program. To do so, employee population of an organisation is divided as skilled population and unskilled population. However, this division may not be a precise division of the employee population. The reason is that some people are involved in non-technical jobs, some are involved in technical jobs and some people work on multiple projects simultaneously. In addition, some people may be more qualified, but they perform unskilled jobs. Thus, this division of the employee population as skilled and unskilled workers is not clear cut, which may lead to non-sampling errors.
- **Poor response of respondents:** This makes it difficult for the researcher to derive accurate results. Usually, respondents show reluctance in supplying accurate information about their income, age and current level of education and skills. The incorrect information provided by respondents leads to erratic results, even if each element of the population is considered.

Self Assessment Questions

7. _____ errors do not occur because of taking a sample for data collection.
8. The poor response of respondents makes it easy for the researcher to derive accurate results. (True/False)
9. Non-sampling errors may also be caused because of:
   a. Selection bias
   b. Ambiguous population specification
   c. Sampling frame error
   d. All of these

4.5 METHODS OF SAMPLING

There are two methods of sampling, i.e., probability and non-probability sampling methods. These sampling methods are shown in Figure 3:

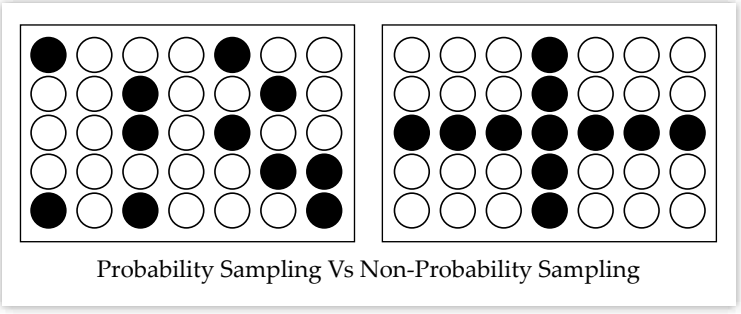

FIGURE 3: Probability and Non-Probability Sampling

Source: *https://towardsdatascience.com/sampling-techniques-a4e34111d808*

The researchers select the sampling methods based on the requirement of their chosen topic of the research study. Sampling methods must give:

- Precision and accuracy
- Extra information about the target population
- Expenditure recognition

Let us understand the concept of probability and non-probability sampling.

4.5.1 PROBABILITY SAMPLING METHODS

Probability sampling is the method of sampling in which the probability of selecting each item from the target population as a sample is equal. The probability sampling method is alternatively known as random sampling. Examples of this sampling are tossing the coin and selecting a chit out of five chits. Figure 4 shows the types of probability sampling:

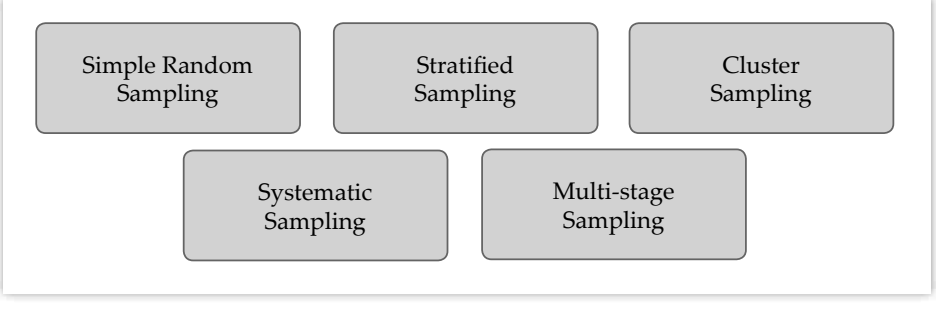

FIGURE 4: Types of Probability Sampling

Let us understand the types of probability sampling in detail:

- **Simple random sampling:** In simple random sampling, each element or item has the same or equal chance of getting selected. This method is used when the researchers do not have any type of prior information regarding the target population; for example, random selection of 20 employees from the manufacturing organisation of 50 employees. Each employee has the same chance of getting selected as a part

of sample. Here, the probability of selection is 1/50. Figure 5 shows simple random sampling:

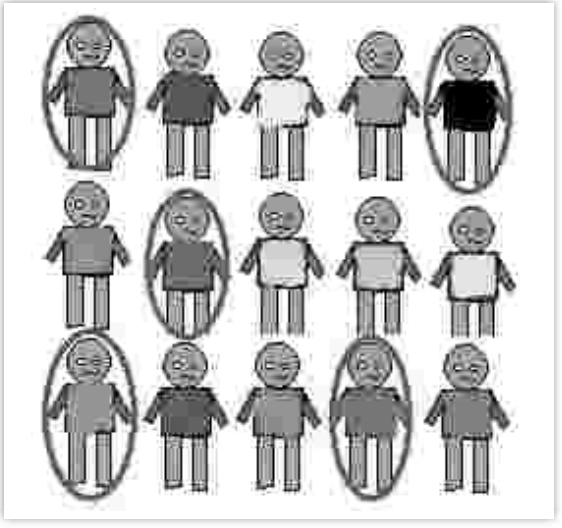

Figure 5: Simple Random Sampling

Source: *https://towardsdatascience.com/sampling-techniques-a4e34111d808*

- **Stratified sampling:** In the stratified sampling method, there is a division of the elements or items of the target population into little sub-groups which is called strata. These groups are made on the basis of the similar characteristics between the elements or items within the sub-groups. After making sub-groups, the researcher selects the elements randomly from each of these strata. Figure 6 shows stratified sampling:

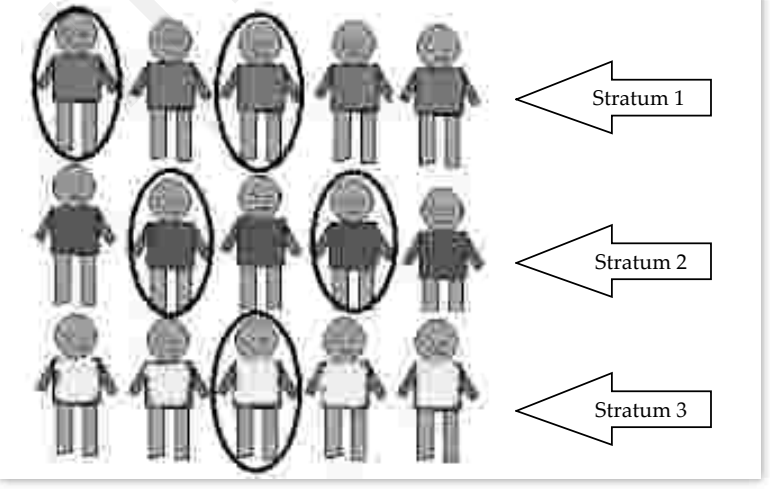

Figure 6: Stratified Sampling

Source: *https://towardsdatascience.com/sampling-techniques-a4e34111d808*

- **Cluster sampling**: In cluster sampling, the entire population is divided into groups or clusters. After that, these clusters are selected on the basis of random sampling. All elements of the selected clusters should be included in the sample leaving out all the elements of the non-selected clusters. For example, a population has been divided into 10 clusters named a, b, c, d, e, f, g, h, i and j. The researcher requires only 3 clusters for his/her sample out of 10 clusters. Suppose 3 clusters, namely a,

i, and d, are selected randomly. In the sample, all elements from these 3 clusters would be included. Cluster sampling looks similar to stratified, but in stratified sampling, elements or items are selected from all sub-groups. However, in cluster sampling, clusters themselves are selected and all elements or items are from the selected clusters that are included in the sample.

- **Systematic sampling**: In systematic sampling, a sample is selected from the sampling frame at regular intervals. In this type of sampling, the elements in the sampling frame are numbered consecutively. After this, a random number is chosen. Thereafter, the sampling fraction is calculated as the ratio of the actual sample size and the total population. Starting with the randomly selected number, samples are drawn using a frequency (inverse of the sampling fraction). For example, if we need to select 100 units out of available 1,000, the sampling fraction is 1/10 and the frequency would be 10. It means that if a researcher starts with a randomly selected element at number 3 (in sampling frame), then he would choose 13th and 23rd elements. Systematic sampling is used in cases when the researcher has a complete list of all the members of the population.
- **Multi-stage sampling**: In multi-stage sampling, population is partitioned into various clusters and multiple clusters are again divided and grouped into different strata on the basis of similarity. Clusters (one or more) can be randomly selected by the researcher from each stratum. The researcher performs this process continuously until the cluster cannot be further divided anymore. For instance, the world can be divided into countries and countries into different states, states into cities, cities into urban and rural areas, and these areas having similar features can be merged for forming strata. Figure 7 shows multi-stage sampling:

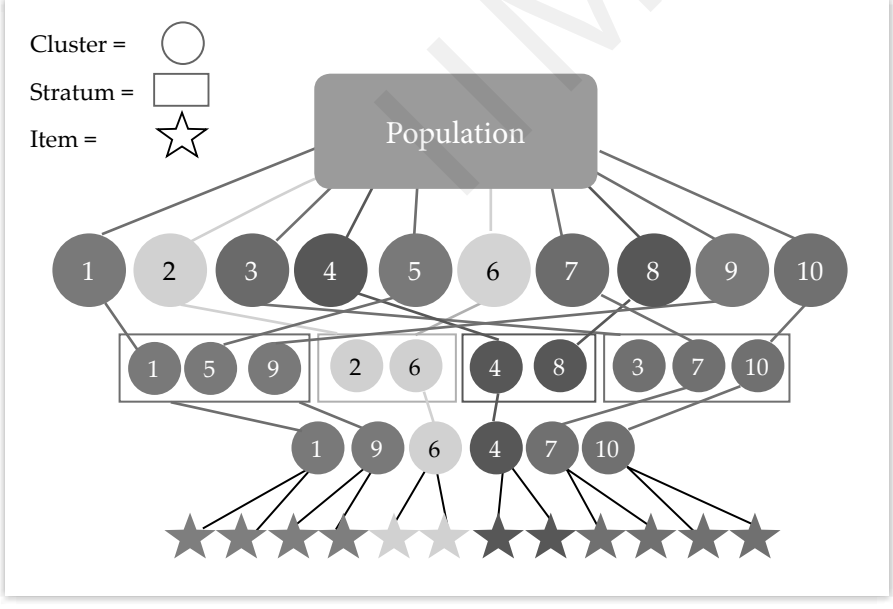

FIGURE 7: Multi-Stage Sampling

4.5.2 NON-PROBABILITY SAMPLING METHODS

Non-probability sampling is also known as non-random sampling. In this sampling method, samples are collected in a manner that all individuals or elements in the population do not get equal chances of being selected. The major advantage of this sampling is that it is inexpensive. However, the results obtained from non-probability sampling cannot be generalised confidently for the entire population

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because an unknown proportion of the entire population was not sampled. However, the results obtained from the non-probability sampling cannot be generalised with much confidence. Figure 8 shows the types of non-probability sampling methods:

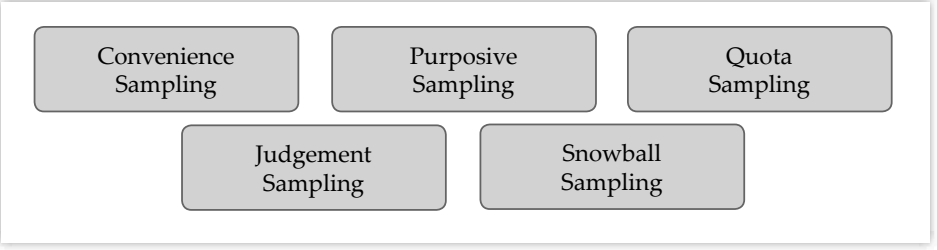

Figure 8: Types of Non-Probability Sampling Methods

Let us understand the types of non-probability sampling:

- **Convenience sampling:** In this type of non-probability sampling, the researcher selects those elements or subjects from the target population that are easily accessible to him/her. For example, in a college, volunteers are required to organise a tree plantation camp. The strength of the college is 2,000 and the number of volunteers required is 50. In this case, the easiest way to select volunteers is their accessibility. The researcher can select those students as volunteers who are easily accessible to him/her. Convenience sampling helps in conducting pilot studies by facilitating the researcher to obtain the basic data. However, convenience sampling has a sampling bias as the researcher selects the sample according to his/her own convenience. Since the sample is not truly representative of the population, the results of the study cannot be generalised for the whole population.
- **Purposive sampling:** Purposive sampling is a non-probability sampling method wherein the sample is chosen purposively on the basis of certain characteristics of a population and the objective of the study. For example, a researcher wants to gather opinion of working mothers about the conditions at their workplaces. In this case, the researcher would contact only those women who are mothers and working. The females not falling in this category would not be surveyed. There are two sub-types of purposive sampling, namely quota sampling and judgement sampling.
- **Quota sampling:** In this sampling method, the given population is first divided into mutually non-overlapping sub-groups, such as male/female/children or Indian/American/Asian/European or salary from ₹ 20,000 to 30,000 p.m./salary from ₹ 30,001 to 40,000 p.m. The sub-groups are divided in a manner such that they are a replication of the population. Thereafter, a sample is formed by selecting members from each sub-group according to the proportion of each sub-group in the total population. This is called proportionate quota sampling. In case the members from each sub-group are selected based on a criteria other than proportion, it is called non-proportionate. In quota sampling, the researcher ensures equal representation of all elements from the population in the sample.
- **Judgement sampling**: In judgement sampling, the elements or units from the population are selected on the recommendation of experts in the field of research work that is being carried out. The experts are asked to select the units that should be included in the sample so that the sample is truly representative of the population. Usually, the expert selects such elements in the sample that can provide the best information on the research subject. In judgement sampling, the reliability

of sample directly depends on the expert's judgement. Quota sampling can also be considered as a type of judgement sampling because the elements that are chosen for each quota depend upon the judgement of the interviewer/researcher.

- **Snowball sampling:** Snowball sampling is also known as chain sampling or referral sampling. This type of sampling is used in research where it is difficult to identify or locate the units or elements to be included in the sample. In the snowball technique, the researcher first picks up one or more subjects (to be included in sample) and then he/she asks them to recommend or refer to subjects that conform to the criteria for being included in the sample. This process of referral is repeated with the new subjects till the required number of subjects in the sample is fulfilled. This method of sampling is called snowball sampling because the process is akin to the process of rolling a snowball downhill. The initial snowball size (sample subjects) keeps on increasing in size till the snowball reaches a flat surface (the desired sample size is achieved). Snowball sampling is used in those cases where there is no list of population of interest or when the subjects refrain from identifying themselves socially or due to the secretiveness or illegality of the organisation for which they work.

Self Assessment Questions

10. In _____ sampling, population is partitioned into various clusters and multiple clusters are again divided and grouped into different strata on the basis of similarity.
11. Which of the following is also known as chain sampling or referral sampling?
    a. Judgement sampling
    b. Snowball sampling
    c. Quota sampling
    d. Purposive sampling
12. Convenience sampling helps in conducting pilot studies by facilitating the researcher to obtain the basic data. (True/False)

Activity

Find out the advantages and disadvantages of probability and non-probability sampling method.

4.6 SUMMARY

- A sample can be a group of people, items/elements or objects selected out of the population for conducting research.
- Sampling is the process of choosing a subset of subject matter or units from the whole population for the purpose of conducting a research.
- Researchers may use two primary methods of data collection, i.e., the Census method and Sampling method.
- Census method of data collection is the method in which researchers study all elements or items of the population. In the sample survey method, a few elements of the target population are studied, and not all.
- A sample design is considered as a road map which provides the foundation or basis for the selection of a sample survey.

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- A good sample design must be error-free and must produce the representative sample.
- An error is a fault or the disparity between the evaluated value and the correct or exact value. An error may occur due to biased attitude of the interviewer, respondent's reluctance, ineffectiveness of instrument, etc.
- Sampling error is the error or mistake that occurs in a data collection process as an outcome of taking a sample from target population rather than using the entire population.
- Non-sampling errors may also be caused because of selection bias, ambiguous population specification, sampling frame error, processing error, respondent errors, non-response error, physical environment, inadequacy of enumerators, etc.
- There are two types of sampling methods, i.e., probability and non- probability sampling methods.
- Probability sampling is the method of sampling in which the probability of selecting each item from the target population as a sample is equal. In the non-probability sampling method, samples are collected in such a manner that all individuals or elements in the population do not get equal chances of being selected.

4.7 KEY WORDS

- **Sampling:** The process of obtaining elements from the entire population
- **Sample design:** The methodological plan to obtain a sample from population
- **Probability sampling:** A sampling technique wherein the samples are gathered in a process that gives all the individuals in the population an equal chance of being selected
- **Census:** The method in which the researcher studies all elements or items of the population
- **Sampling errors:** The statistical error that occurs when a researcher does not select a sample that represents the entire population of data

4.8 CASE STUDY: IRS-RANDOM SAMPLING ERROR

This is the case of a random sampling issue between Internal Revenue Service (IRS) and the owner of the tax preparation service in a federal court where the IRS was the plaintiff and the owner was the defendant. Simple random sampling is a method of sampling where all the elements of the population have equal chances of being selected as a sample. The key highlight of the case is that the IRS in their statistical evaluation or analysis inappropriately used their sample for creating inferences regarding the population as a whole. The defendant was responsible for filing 24,399 federal income tax returns' applications for the tax year 2003. According to IRS, *it reviewed 345 tax returns out of 24,399 and 313 resulted in needing additional tax assessment which means 91% of the original sample had returns that owed additional tax to the IRS, and the additional tax was owed for a variety of reasons. The IRS calculated from these 345 returns that the actual tax loss directly due to these returns being improperly prepared by the defendant(s) was in excess of $1.1 million (United States v. Brier, et. al., pg. 3). The IRS further stated that if this rate loss were applied to all 24,399 returns, then the estimated loss to the United States government would be in excess of $85 million for the years 2003*

through 2007 (United States v. Brier, et. al., pg. 5). Thus, the IRS was looking for damages close to 85 million dollars.

There were two major sampling selection errors made by the IRS analyst:

- The 345 tax returns were chosen from returns that had a Schedule C attached.
- The statistical inference and finding were made by evaluating these 345 samples only.

Therefore, any inferences from the study could not be generalised for the whole population. The IRS made the basic mistake in sample selection and did wrong calculation and, ultimately, provided inaccurate conclusions. This affected the credibility of the IRS. This proves that any person having the basic knowledge of statistics and research methodology can catch and highlight errors that are being stated in the inferences made from inaccurate mathematical analysis and poor sampling selection techniques.

QUESTIONS

1. Who is/are the plaintiff and defendant in the above case study?

   (**Hint:** IRS and owner of a tax preparation service)
2. What type of errors were found in the inferences made by IRS?

   (**Hint:** Mathematical, sampling errors)
3. According to you, what are the sampling selection errors?

   (**Hint:** Small sample out of large population)
4. What are the reasons behind the occurrence of errors in sampling?

   (**Hint:** Interviewer's attitude, knowledge, sample selection techniques, respondent's skills)
5. Describe some ways that can help in reducing errors in sampling.

   (**Hint:** Careful assessment of population, sample selection, sample size)

4.9 EXERCISE

1. What is sampling design?
2. Explain the steps involved in sampling design.
3. Describe the types of errors in measurement. How can these errors be minimised?
4. What is the difference between census and sample survey?
5. Explain the sampling errors in detail.
6. Describe the methods of sampling.
7. Write a short note on:
   a. Stratified sampling
   b. Cluster sampling
   c. Snowball sampling
8. Why does non-sampling error occur?

4.10 ANSWERS FOR SELF ASSESSMENT QUESTIONS

Topics	S. No.	Answer
Concept of Sampling	1.	sampling
	2.	False
	3.	Sample survey
Errors in Measurement and Sampling Errors	4.	Random
	5.	True
	6.	a. Systematic
Non-Sampling Errors	7.	Non-sampling
	8.	False
	9.	d. All of these
Methods of Sampling	10.	multi-stage
	11.	b. Snowball sampling
	12.	True

4.11 SUGGESTED BOOKS AND E-REFERENCES

SUGGESTED BOOKS

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- Sampling in Statistics: Different Sampling Methods, Types & Error - Statistics How To. (2020). Retrieved 18 March 2020, from https://www.statisticshowto.datasciencecentral.com/probability-and-statistics/sampling-in-statistics/
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CHAPTER 5

Measurement and Scaling

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LEARNING OBJECTIVES

After studying this chapter, you will be able to:

- Explain the concept of measurement
- Discuss the process of developing measurement tools
- List the basic criteria of a good measurement tool
- Explain the types of scaling techniques
- Describe the bases of scale classification

5.1 INTRODUCTION

In the previous chapter, the concept of sampling has been explained. The chapter discussed census versus sample survey, developing sample design/sampling process and characteristics of a good sample design. The chapter also described errors in measurement and sampling processes as well as non-sampling errors. The chapter concluded with an explanation of methods of sampling.

Measurement and scaling both play an important role in the daily lives of all human beings. Measurement is important for measuring physical objects that can be measured and expressed in some measuring units. The absence of measurement in human lives would even make their daily activities very tough. For instance, construction of a house or an office cannot be imagined without measuring its length, width or height. Even purchase of rice, flour, milk or any groceries is not possible in the absence of a measurement unit, such as kilograms, grams and litres. Dimensions are required even for buying clothes.

Scaling is the procedure of making a continuous sequence of values upon which the objects to measure are placed or rated on the base of certain rules.

Apart from physical objects measurement, measuring abstract concepts, such as happiness, motivation, and success is difficult using a standardised measure. This is because these are subjective concepts and everybody holds different views about them. Hence, scaling is used, which helps measure abstract concepts. Scaling is used for measuring the non-physical entities that are not measurable.

Both measurement and scaling are essential parts of a research study. In any research, data collection is not possible without measurement and scaling. The reliability and authenticity of a research result are related to accurate and specific data collection. It is said that 'a research is as good as the data that is used for research' and quality data requires a well-defined measurement and scaling.

This chapter will help you in understanding the concept of measurement. You will study the measurement scales, the development of measurement tools and the basic criteria of a good measurement tool. Further, the concept of scaling techniques is also discussed. The latter sections of the chapter will discuss the types of scaling techniques and bases of scale classification. Towards the end, you will learn about the techniques of scale construction.

5.2 CONCEPT OF MEASUREMENT

Measurement is referred to as the process through which numbers are assigned to observations or objects. Measurement is done through numbers assigned on the basis of pre-determined rules. Technically, measurement can also be defined as a process of mapping specific domain aspects against other aspects of a range conferring to some rule of correspondence. It is quite easy to assign numbers to objects on the basis of their characteristics, but it is quite tough in case of other objects. For example, physical weight, biological age or a person's financial assets can be easily measured, whereas measuring things, like social conformity, intelligence, or marital adjustment is very difficult and needs closer attention. In other words, the quantitative features, like weight, height, etc., can be easily measured directly with some pre-defined standard unit of measurement, but it is not that easy to measure properties, like motivation to succeed, ability to stand stress, etc.

Overall, measurement is considered as a function of using a yardstick to determine the characteristics of a physical object. Measurement standards are important for measuring both qualitative and quantitative aspects. Earlier, measurement of qualitative aspects was not easy, but, today, there exist standardised tools to measure abstract concepts, such as intelligence, unity, honesty, bravery, success and stress. High accuracy and confidence can be expected while measuring the quantitative characteristics of an object.

5.2.1 MEASUREMENT SCALES

The famous psychologist, Stanley Smith Stevens mentioned 'measurement scales' in his article named 'On the Theory of Scales of Measurement' in the year 1946. The term measurement scale refers to a classification used to describe the nature of the information within the numerals assigned to variables. Scale characteristics determine the level of measurement. Prior to the selection of 'measuring scale', a researcher must make efforts to understand the level of measurement. Stevens also mentioned that all scientific measurement is done using the four types of scales. These types of measurement scales are shown in Figure 1:

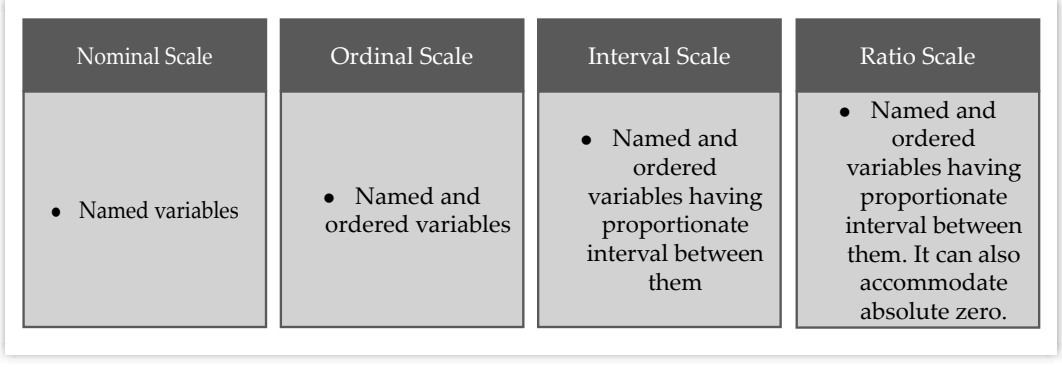

Figure 1: Types of Measurement Scales

For the purpose of measurement in the research study, researchers require to formulate some form of scale in a defined range and then, accordingly, map the characteristics of objects from the domain onto the formulated scale. The scales of

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measurement are considered in terms of their mathematical properties. Various forms of measurement scales are discussed as follows:

- **Nominal scale:** It is the basic form of measurement scale used to classify, identify or label individuals, companies, products, brands or other entities into categories. The scale is also known as a categorical scale. Nominal scales are not numerically significant as the numbers used in nominal scales do not have arithmetical value and these are also not mutually exclusive. Different numbers, such as (1, 2, 3, ...) assigned to cricket players in a team, books in a library, computers in the Internet cafe or computers in an office, are based on a nominal scale. These numbers of nominal scales do not help perform any mathematical operations related to the research study. Consider a cricket team in which 11 players of the team are assigned numbers from 1 to 11. In this situation, finding the average of 1 to 11 does not signify any meaning as numbers assigned to all team members are simply labels and do not have any arithmetical value. The nominal scale signifies the lowest level of measurement. Some of the characteristics of a nominal scale are as follows:
  - A nominal scale does not have any arithmetic origin.
  - A nominal scale does not show any order or distance relationship.
  - A nominal scale distinguishes things by putting them into various groups.
  - A nominal scale is generally used to conduct surveys and ex-post-facto research (a type of research that is used by researchers to predict the possible causes behind an effect that has already occurred).

  The nominal scale also has certain limitations, which are as follows:
  - There is no rank order.
  - There is no possibility of mathematical calculation and analysis.
  - There is a limitation of statistical implication as there is a possibility to express the mode, but the calculation of the standard deviation and the mean is not possible.
- **Ordinal scale:** This scale is also known as ranking scale. An ordinal scale only specifies a greater than or less than value, but does not answer how much greater or how much less. It allows the respondents to rank some alternatives based on some common characteristics. It simply places events or objects in order by assigning ranks. This scale is used as a measure to compare two or more entities. Let us understand the ordinal scale with the help of an example. A company assigns ranks to its objectives as shown in the following table:

Company Objectives	Ranks Assigned
Increase in sales	2
Increase in revenue	1
Increase in customers	3
Decrease in cost	4

In the above table, different ranks have been assigned to the company's objectives. It is clear that the company has preferred to increase sales as compared to the number of customers. However, it cannot be said that the company's preference

for the increase in sales is two times higher than the company's preference for a decrease in cost. Therefore, it can be inferred that an ordinal scale is an improvement over the nominal scale. The main characteristics of the ordinal scale are as follows:

- The scale is not expressed in absolute terms.
- The scale ranks the things from the highest to the lowest.
- The adjacent ranks do not have equal variance always.
- Central tendency is measured with the use of a median.
- Dispersion is measured by using percentile or quartile.

Despite the above-mentioned characteristics of the ordinal scale, the limitation of the ordinal scale is that arithmetic operations, such as addition, subtraction, division, etc., cannot be performed with the assigned ranks.

- **Interval scale:** The interval scale is also known as the cardinal scale. It is based on the principle of 'equality of interval', i.e., the intervals are assumed equal and are used as the basis for making the units equal. In other words, in the interval scale, the interval between successive positions is equal. The positions are separated by equally spaced intervals or bases. For example, a researcher wants to measure the level of happiness among youths along a scale rated from 1 to 10. With the use of an interval scale, following conclusions can be made:
  - The most happy is represented by number 10 and the least happy is represented by number 1.
  - Number 7 represents a higher level of happiness than number 6.
  - The difference in the level of happiness between 4 and 3 is the same as the difference in the level of happiness between 7 and 8.

  The characteristics of the interval scale include the following:
  - Interval scales are set arbitrarily and have no absolute zero.
  - The central tendency can be measured by using mean.
  - Dispersion can be measured by using standard deviation.
  - The test of significance is measured by using t-test (a type of hypothesis test that allows comparison of means) and f-test (a test used to know if the variances of two populations are equal).

  The interval scale contains features of nominal scale and ordinal scale. Though, the key limitation with the interval scale is that the ratio of two observations cannot be taken. It cannot be stated that number 4 represents the double happiness level as compared to number 2. The other limitation of the interval scale is that it lacks an absolute or true zero of measurement.

- **Ratio scale:** It is a scale that contains an absolute zero. The ratio scale implies that at point zero, the scale does not infer any feature of an object. It signifies the actual amounts of variables. The physical dimension measures, such as weight, height and distance, fall under this category. Generally, all statistical techniques are pertinent to ratio scales and all mathematical operations that have real numbers can also be assigned with ratio scale values. For instance, the point zero of centimetre scale or

metre scale does not imply any measurement, such as length, breadth or height. Arithmetical operations, such as multiplication and division can be easily carried out with ratio scale.

Ratio scale is the most substantial measurement scale as almost all statistical operations are possible by its measurements, which cannot be performed by other scales. For example, it can be measured that the weight or height of Ram is twice that of Shyam with the help of ratio scale, but this measurement is not possible with the help of all other scales. Some of the important characteristics of the ratio scale are as follows:

- The ratio scale has an absolute zero measurement.
- The central tendency can be measured by using geometric and harmonic means.

5.2.2 DEVELOPING MEASUREMENT TOOLS

Measurement tools are also known as assessment tools and are used for the purpose of measuring or collecting data. Some examples of measurement tools are scales, questionnaires, interviews, surveys and indexes. The procedure to develop measurement tools comprises four stages. The stages are shown in Figure 2:

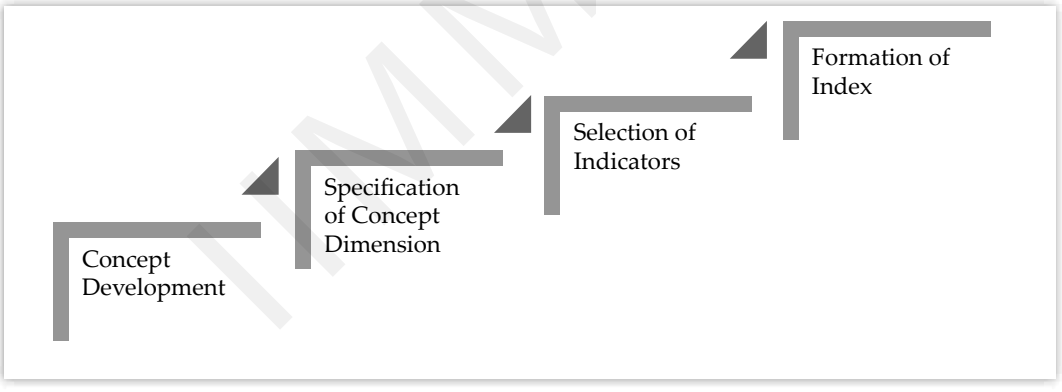

Figure 2: Measurement Tools Development

The stages of developing measurement tools are discussed as follows:

- **Stage 1 – Concept development**: This stage requires that researchers should develop a good understanding of the topic that they want to research. This stage of concept development is more evident in theoretical studies than in the more pragmatic form of researches, which are evolved on pre-established fundamental concepts.
- **Stage 2 – Specification of concept dimension**: As the concept gets developed properly in the first stage, the researcher needs to identify the dimensions of the concepts. The task of specification of the concept of dimension can be accomplished either by using deduction, which means the use of more or less intuitive approach, or by use of empirical correlation. The correlation should be of the individual dimensions with the total concept and/or the other concepts. For example, on the launch of a new product in the market, several dimensions, such as customers, price, social responsibility, reputation of the organisation, and geographical areas should be considered.

- **Stage 3 – Selection of indicators**: It is the third stage in the process of developing measurement tools. Indicators are devices to measure knowledge, opinion, choices, expectations, and feelings of respondents. Examples of indicators are scales and questionnaires. As there is rarely a perfect measure of a concept, the researcher should consider more than one indicator to have the stable scores and improved validity.
- **Stage 4 – Formation of index**: The last stage of the process of developing measurement tools is based on the other three stages. A researcher takes into account multiple dimensions of a particular concept and collects suitable indicators for proper measurement. After that, these indicators are combined into a single index for proper measurement. Consequently, an overall index is prepared. For example, an overall Body Mass Index (BMI) is prepared by National Institute of Health (NIH) by using individual indicators, such as weight and height, to measure body fat.

5.2.3 BASIC CRITERIA OF A GOOD MEASUREMENT TOOL

A measurement tool should clearly and accurately indicate what the researcher intends to measure. Additionally, it should be easy and efficient to use. There are three basic criteria of good measurement, as shown in Figure 3:

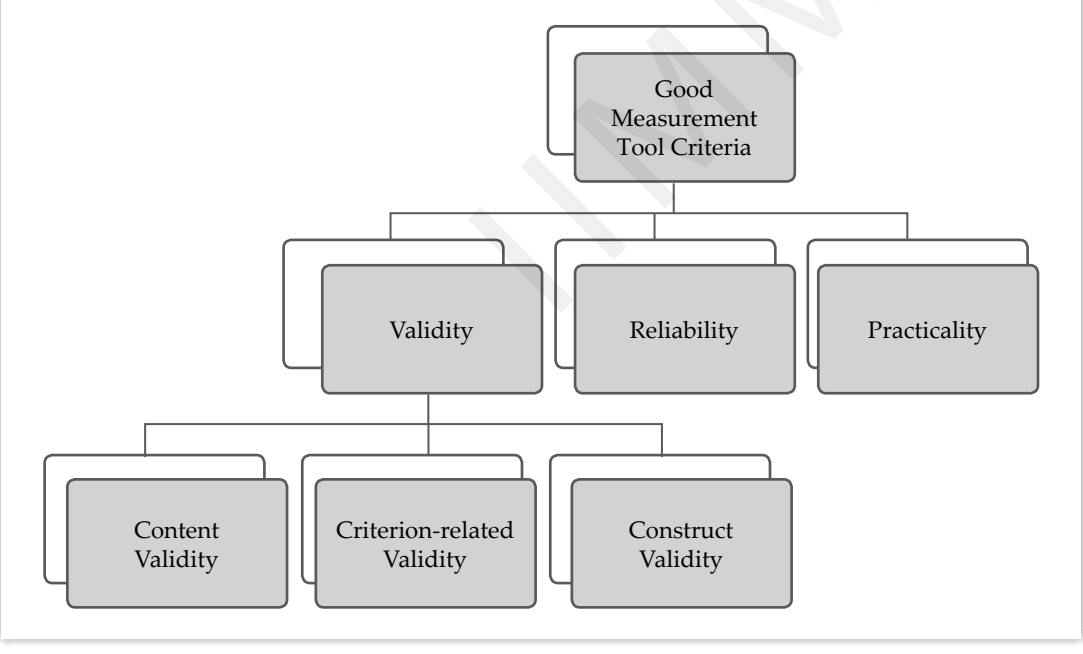

Figure 3: Criteria of Good Measurement

The fundamental criteria of good measurement are explained as follows:

- **Validity:** It denotes the ability of an instrument to measure the sample under study with logic and reasonability. This is needed to achieve the expected outcome from a good measurement. Ascertaining the validity of a measuring instrument is not an easy or quick task. Researchers have put efforts to assess the validity in diverse ways. However, to assess the validity of a measuring instrument, there are three widely approved criteria. These are discussed as follows:

- **Content validity:** It is the scope to which the measuring instrument content provides appropriate coverage of the topic. In case the measuring instrument contains a representative sample of the universe, the content validity is considered good. The determination of the instrument is principally judgemental and instinctual. A panel of persons can also determine the validity by judging how well the measuring instrument meets the standards, but it cannot be expressed numerically.
- **Criterion-related validity:** It is the situation in which some criterion is used to judge the validity of the measuring instrument. In other words, it is as the ability to predict some outcome or estimate the existence of some current condition. Generally, it is done by making a comparison of the instrument with other instruments of the same type in which the researcher has more confidence; for example, comparing the results of two IQ tests on a group of four students.

  The success of measures used for some empirical estimating purposes is reflected by such validity. A criterion-related validity in a broad term is subdivided into the following:

  - ✓ **Predictive validity:** It refers to the usefulness of a test in predicting some future performance.
  - ✓ **Concurrent validity:** It refers to the usefulness of a new test as compared to a well-established test.
- **Construct validity:** It is one of the complex and abstract validity measurement criteria. It implies that there should be compatibility between a theoretical concept and a measuring instrument. Technically, a measure signifying a degree confirming to predicted correlations with other theoretical propositions is said to possess construct validity. For defining construct validity, a set of other propositions is associated with the results received from using the researcher's measurement instrument. If the measurements arrived at the researcher's devised scale correlate in a predicted way with the other propositions, it can be concluded that there is a presence of some construct validity.

❍ **Reliability:** This is another important criterion of good measurement. The reliability of a measuring instrument is defined if it gives a consistent outcome. A valid instrument is considered to be reliable, but a reliable instrument is not necessarily a valid instrument. For example, suppose a scale is used to measure the weight of objects. The scale consistently shows all objects to be overweight by 2 kilos. In that case, a scale is said to be reliable but not valid at all. The two important aspects of reliability are stability and equivalence. Stability prevails when an object or a person, being measured by the same instrument, and consistent results over a period of time, are exhibited. The equivalence aspect observes the diverse errors which can occur under different conditions. One should not get confused about the two aspects of reliability, stability, and equivalence as stability is more concerned with situational variations, whereas, equivalence is concerned with variations due to investigators and sample of items.

❍ **Practicality:** This feature of instruments of measurement implies that a good measurement should be economic, interpretable and convenient. The economy

aspect is related to the cost consideration of measurement. If a measurement is out of reach because of the high cost, it is of no use for the researcher. The interpretability aspect is specifically important when persons other than those who designed the test will interpret the results. The measuring instrument, to be interpretable, must be accompanied by (a) comprehensive instructions for administering the test, (b) scoring keys, (c) suggestion about the reliability, and (d) guides for using the test and for interpreting results. Convenience refers to the ease with which a measuring instrument can be administered. For example, a questionnaire with sufficient coverage of topic and easy language can be administered with more ease.

Self Assessment Questions

1. The term 'measurement scale' refers to a classification that describes the nature of information within the numerals assigned to _____.
2. _____ allows the respondents to rank some alternatives based on some common characteristics.
3. In the interval scale, the interval between successive positions is unequal. (True/False)
4. _____ operation can be easily carried out with ratio scale.
5. Predictive validity refers to the usefulness of a test in predicting some future performance. (True/False)

5.3 CONCEPT OF SCALING TECHNIQUES

Researchers often face difficulties of valid measurement at the time of measuring attitudes, opinions, physical concepts and institutional concepts. Certain specific procedures are required, which may enable researchers to measure abstract concepts more precisely. A scale denotes a continuum consisting of the highest point and lowest point along with numerous intermediate points between the extreme points. The relation of scale-point positions is that when the first point appears to be the highest point, the second point indicates a higher degree in terms of the given characteristics as compared to the third point, and so on. Scaling defines the measures that are to be used for assigning numbers to various degrees of opinion, attitudes and other concepts. It may be described as a 'procedure for the assignment of numbers to a property of objects to impart some of the characteristics of numbers to the properties in question'.

Following are the ways of doing scaling:

- Judging about some characteristics of an individual and then judging the individual directly on the basis of a scale, which has been defined in terms of that characteristic.
- Framing questionnaires in such a way that the score of individual's responses can be assigned on the scale easily.

In practical usage, the normally used attitude measurement scales are ordinal. These scales are basically self-report inventories, with a list of favourable and unfavourable statements towards the subject under study.

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5.3.1 TYPES OF SCALING TECHNIQUES

A tool or mechanism that is used to differentiate individuals from one another on the variables of interest of research is known as a scale. Various researchers use different scales depending on the needs of their study. The different types of scales are shown in Figure 4:

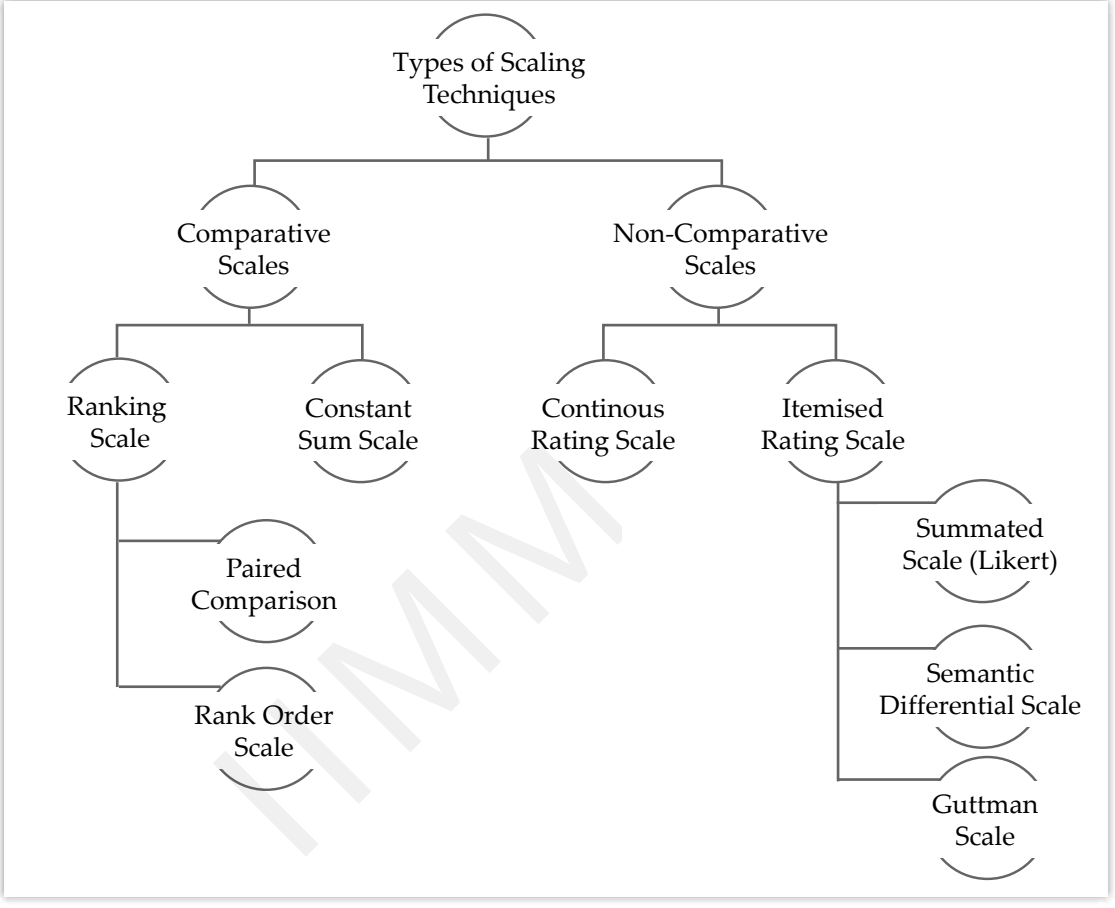

Figure 4: Types of Scaling Techniques

The types of scales mentioned in Figure 4 are discussed as follows:

- **Comparative scales:** Comparative scales comprise the direct measurement of stimulus objects and data having rank-orders or ordinal properties only. It consists of scales wherein the researchers ask the respondents for their relative preference between two or more objects. For instance, "Do you prefer Nescafe or Bru?" Comparative scales comprise paired comparison, rank order, and constant sum scale.
  - **Ranking scale:** Ranking scales are defined as scales that are used for making relative judgements. Ranking scales are further divided into two approaches, which are discussed as follows:
    - ✓ **Paired comparison:** The paired comparison approach of ranking scale offers a way to make comparisons among objects. In the pair comparison method, the respondents are asked to express their attitude by making a choice between two objects, say between Real Juice and Tropicana,

according to some criterion. Fundamentally, if there are 'n' stimuli to judge, the number of judgements required in a paired comparison is N = n(n–1)/2. For example, if there are 8 products, then the respondents need to make (8(8–1/2)) = 28 comparisons. If the number of comparisons becomes quite large, then there is a risk because the respondents may show reluctance to take part in the research. In such a case, comparisons can be reduced by applying the law of transitivity. This law says that if A is preferred to B and B is preferred to C, then A would automatically be preferred to C. The limitations of paired comparison include:

- This technique is useful when the number of brands is limited.
- This technique may give biased results as it is dependent upon the order in which the objects are presented.
- This technique does not replicate a true market situation, which involves selection from multiple alternatives.

✓ **Rank order scale:** In this approach of ranking scale, respondents are asked to give rank to their choices as per their preferences. The rank order scale is commonly used to measure preferences for brands as well as attributes. Following is an example of the rank order method:

Items	Choices/Preferences
A	6
B	3
C	2
D	5
E	1
F	4

In the given example, 6 items are shown. The respondent was asked to rank the items as per his/her preferences. Item E is the most preferred and item A is the least preferred by the respondent.

- **Constant sum scale:** Constant sum scale is viewed as an ordinal scale because of its comparative nature. In this form of scaling, the respondents are asked to rate the different characteristics of an object and assign some number of units to each characteristic. The respondents have to rate each characteristic in such a manner that the total number of units or points equals the total number of units assigned by the researcher or the experimenter. Respondents assign the number of units to each characteristic based on the importance of the characteristics to them. If the characteristic holds no importance for an object, the respondent can assign zero units to it. For example, an HR professional may create a constant sum scale that equals to 100 marks, to know the relative importance of different infrastructural features in an organisation, such as drinking water, clean washroom, gymnasium, sports room, canteen, etc. The respondents under study were instructed to assign the numbers to infrastructural features in such a way that the sum of all the marks allocated to infrastructural features of the organisation must be equal to 100. After the response of all respondents has been noted, the numbers of points earned by

each attribute are counted. The values arrived through constant sum scale method can be used to conclude results or help in research.

- **Non-comparative scales:** These are those scales wherein each object is measured independently of the other objects under the same research study. Absolute results are obtained for each object. Examples of non-comparative scales include continuous rating scales, Likert scale, etc. They are generally divided into two categories: continuous rating scale and itemised rating scale.
  - **Continuous rating scale:** In a continuous rating scale, the respondents are asked to rate different objects on a continuum according to a certain criterion. A continuum is a line running from one extreme value to the other extreme value of the criterion. The rating is given by respondents by marking a point on the continuum.
  - **Itemised rating scale:** In itemised rating scale, items are shown in the form of ordered statements and the respondents are required to select the category that best describes the concerned item. The respondents are asked to make a choice according to their preferences or opinions. A brief description of each category is associated with the itemised rating scales. The most common itemised rating scales used by researchers include Likert scale (summated scale), semantic differential scale, Thurstone and Guttman scale.
    - ✓ **Summated scale (Likert):** Summated scales are constructed by using the item analysis approach. Such scales consist of a number of statements that express either positive or adverse feelings towards any topic or idea. The summated scale is most frequently used in studying social attitudes. It follows the pattern developed by Likert; thus, the summated scale is also termed as the Likert scale. Most commonly, a Likert scale contains five degrees of a statement. Let us know more about the Likert scale with the help of the following example (statement and options).

      Statement: The Internet is creating a positive impact on children.

      Re**sponse options:**

      (a) Strongly Agree (1)

      (b) Agree (2)

      (c) Neutral (3)

      (d) Disagree (4)

      ✓ (e) Strongly Disagree (5)

      In the preceding example, there are five degrees of responses for the given statement. The right extreme of the scale shows the strongest approval of the statement, whereas the left extreme indicates the strongest disapproval of the statement. The middle points are between these two extremes. Each point on the scale has a numerical value. This example constitutes only one statement, but more than one statement can be used in Likert scale. In the Likert scaling method, each statement is assigned a numerical value. The total score for each respondent is calculated by considering his/her response to each statement.

- ✓ **Semantic differential scale:** Factor scales are developed using the factor analysis approach. The semantic differential scale is an example of factor scale and was developed by Charles E. Osgood, G.J. Suchi and P.H. Tannenbaum. It measures the connotative meaning of objects, events and concepts. The semantic differential scale comprises bipolar adjectives, such as valuable-worthless and good-bad. The respondent is asked to select his/her position between these two adjectives. Let us understand the concept of the semantic differential scale with the help of the following example. A semantic differential scale analysing candidates for a managerial position is shown in Table 1. Here, two adjectives (successful and unsuccessful) are shown on two extremes. In between these two extremes, scores (3, 2, 1, 0, –1, –2, and –3) are mentioned to rate the candidates according to the level of traits possessed by them. Successful-unsuccessful, progressive-regressive, and true-false represent the evaluative attitude. The potency attitude is represented by the severe-lenient and strong-weak pairs. The rest of the adjectives shown in Table 1 represent the activity factor. The semantic differential scale has a wide usage in measurement of the attitude of different people. Table 1 shows the semantic differential scale for rating candidates for a managerial position on the basis of the given traits and scores:

Table 1: Semantic Differential Scale for Analysing Candidates for a Managerial Position

Successful						Unsuccessful
Progressive						Regressive
Active						Passive
Fast						Slow
Strong						Weak
Severe						Lenient
True						False
3	2	1	0	–1	–2	–3

- ✓ **Guttman scale:** The Guttman scale, also known as cumulative scale, consists of a series of statements to which respondents express their agreement or disagreement. It is important to note that in the cumulative scale, statements appear in the form of a cumulative series. It means that if there are seven statements and the respondents agree with statement 4, then they would also agree with statements 1, 2 and 3.

  Let us understand the concept of cumulative scale with the help of the following example:

  - ♦ I can do the counting.
  - ♦ I can do addition.
  - ♦ I can do subtraction.
  - ♦ I can do multiplication.
  - ♦ I can do division.

Notes

5.3.2 BASES OF SCALE CLASSIFICATION

You have come to know that some numbers are assigned to measure abstract concepts. These numbers are not assigned arbitrarily but on the basis of certain factors.

These are shown in Figure 5:

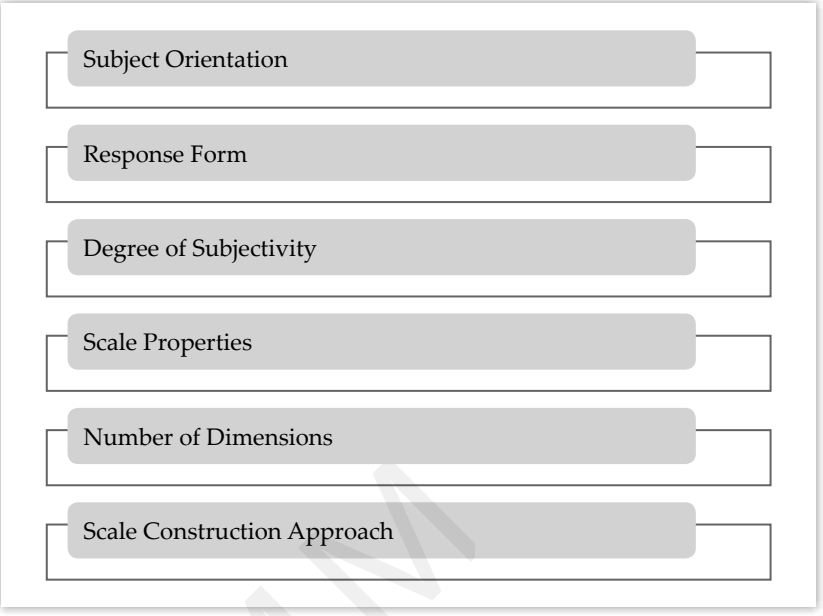

Figure 5: Bases of Scale Classification

A brief description of the bases of scale classification is as follows:

- **Subject orientation:** In this base of scaling, variations in the responses given by differentpeople are analysed and examined.
- **Response form:** It is the basis of scale classification in which variations across both stimulus and subject are assessed. Based on responses, two types of scales are available, such as categorical and comparative. Categorical scales are also called rating scales. For example, suppose there is a statement,

  I cannot live without my mobile phone.

  Response options are as follows:

  - Strongly disagree
  - Disagree
  - Agree
  - Strongly agree

  On the other hand, comparative scales are known as ranking scales. For example:

  Please rank the following options in the order of your preferences.

  - Watching TV
  - Listening to songs
  - Going out for a movie
  - Morning walk

  Use alphabetical letters to show your preference.

- **Degree of subjectivity:** It is the basis which classifies the scale either by measuring personal preferences or non-preference judgements. In the first case, respondents may be asked to exhibit their personal opinion. For example:

  Which of the following organisations do you favour the most?

  - Organisation A
  - Organisation B
  - Organisation C
  - Organisation D

  In the second case, the respondent may be simply asked to decide the most profitable organisation. It is clear that in the second case, the scope of personal opinion is not there.

- **Scale properties:** This is the base of scale classification according to which scales can be classified as nominal, ordinal, interval, and ratio scales. These are already discussed in the previous sections.

- **Number of dimensions:** It indicates the dimensions on the basis of which scales are classified. Two types of scales are used: one-dimensional and multi-dimensional.

- **Scale construction approach:** It indicates scale-classification on the basis of different approaches used.

5.3.3 TECHNIQUES OF SCALE CONSTRUCTION

Scales are used in almost all fields of research. However, it is used extensively in studies related to psychology and social sciences. While measuring attitudes of the individuals, a researcher normally follows the technique of marking the attitude scale in such a way that the score of the individual responses assigns a place on a scale. Under this approach, respondents express their agreement or disagreement with a number of statements relevant to the issue. While developing such statements, following points should be taken care of:

- The statements must elicit responses, which are psychologically related to the attitude being measured.
- The statements need to be such that they discriminate not only between extremes of attitude, but also among individuals who differ slightly.

A brief description of scale construction approaches is as follows:

- **Arbitrary approach:** According to this approach, a scale is developed on an ad-hoc basis, that is, for a specific purpose; therefore, it cannot be generalised. Arbitrary scales are easy to develop and provide a specific information about a particular topic.
- **Consensus approach:** According to this approach, items to be included in the scale are decided on the basis of consensus in a panel of judges. The items are evaluated in terms of their relevance to topic and certainty in implication.
- **Item analysis approach:** According to this approach, items are developed in the form of a test and given to respondents. After completing the test, the total scores are calculated for each respondent and the items are evaluated to determine which questions discriminate between high and low raters.

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- **Factor analysis approach:** According to this approach, the correlation between different items is established on the basis of a common factor.
- **Cumulative scale approach:** According to this approach, the approval of an item representing an extreme position should also result in the approval of all items indicating a lesser than the extreme position.

Self Assessment Questions

6. _____ defines the measures of assigning numbers to various degrees of opinions, attitudes and other concepts.
7. The paired comparison approach of ranking scale restricts to make comparisons among objects. (True/False)
8. In itemised rating scale, items are shown in the form of ordered statements in and the _____ are required to select the category that best describes the concerned item.
9. The summated scale is most frequently used in studying social attitudes. (True/False)
10. The degree of subjectivity is the basis which develops the scale either by measuring _____ preferences or non-preference judgements.

Activity

Search on the Internet a research paper related to 'measurement scales and its use in presenting statistical data' and prepare a report of 1,000 words.

5.4 SUMMARY

- Measurement is considered as a function of using a yardstick to determine the characteristics of a physical object.
- For the purpose of measurement in research study, researchers require to formulate some form of scale in a defined range and then, accordingly, map the characteristics of objects from the domain onto the formulated scale.
- Nominal scale is the basic form of measurement scale used to classify, identify or label individuals, companies, products, brands or other entities into categories.
- Ordinal scale is also known as ranking scale. An ordinal scale only specifies a greater than or less than value, but does not answer how much greater or how much less.
- The interval scale is also known as cardinal scale. It is based on the principle of 'equality of interval', i.e., the intervals are assumed equal and are used as the basis for making the units equal.
- Ratio scale contains an absolute zero. The ratio scale implies that at point zero, the scale does not infer any feature of an object.
- Measurement tools are also termed as assessment tools and these are used for the purpose of measuring or collecting data.

- The stages of developing measurement tools are concept development, specification of concept dimension, selection of indicators and formation of index.
- A measurement tool should clearly and accurately indicate what the researcher intends to measure.
- Validity denotes the ability of an instrument to measure the sample under study with logic and reasonability.
- Reliability is another important criterion of good measurement. The reliability of a measuring instrument implies the consistent outcomes received through measurement.
- The practicality feature of instruments of measurement implies that a good measurement should be economic, interpretable and convenient.
- A scale denotes a continuum consisting of the highest point and lowest point along with numerous intermediate points between the extreme points.
- A tool or mechanism that is used to differentiate individuals from one another on the variables of interest of research is known as a scale.
- The types of scales include comparative scales and non-comparative scales. Comparative scales include ranking scale and constant sum scale. Ranking scale is divided into paired comparison and rank order scale. Non-comparative scales include continuous rating scale and itemised rating scale. Itemised rating scale includes summated scale (Likert), semantic differential scale and Guttman scale.
- Arbitrary scales are easy to develop and provide specific information about a particular topic.
- The consensus approach implies that the items to be included in the scale are decided on the basis of consensus by a panel of judges.

5.5 KEY WORDS

- **Ad hoc:** It implies a solution that is designed for a specific problem.
- **Measurement:** It implies a yardstick to determine the characteristic of any physical object.
- **Connotative:** It implies the figurative meaning of a word.
- **Non-preference judgement:** It implies **t**he style of judgement in which there is no scope of personal bias.
- **Scaling:** It implies a branch of measurement that tries to measure abstract concepts.

5.6 CASE STUDY: CBA RANK ORDER SCALING TO KNOW CUSTOMER PREFERENCES

In Sri Lanka, a toothpaste company named CBA Ltd. is proposing the launch of a new brand of toothpaste in its product chain. Prior to launching the new product, the management of the organisation thinks that it is imperative to gather material information about customer preferences and the most leading brands in the

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toothpaste industry. The study of the existence of competitors in the market, desired expectations of consumers and the preferences of customers will enable the company to design its new product as per the market requirements.

For this purpose, CBA Ltd. conducted small research on a sample of 300 respondents, using a questionnaire containing questions based on rank order scale. The respondents were presented with 10 toothpaste brands simultaneously and were asked to rank or order them according to their own presumed criteria. Following form along with instructions was given to the respondents:

Form for Preference for Toothpaste Brands		
S. No.	**Brand**	**Rank Order**
1	Crest	
2	Formula Action	
3	Sensodyne	
4	Pepsodent	
5	Plus White	
6	Oral B	
7	Close Up	
8	Antiplaqu	
9	Ultra Brite	
10	Colgate	

Instruction to rank preferences:

- Rank the several brands of toothpaste in the order of your preference.
- Pick the brand that you prefer the most and assign it a number 1.
- Assign a number 2 to the second most liked brand.
- Continue with this process until all the brands have been ranked in order of your preference.
- The least preferred brand of toothpaste should be rated 10.
- Also, no two brands should be ranked in the same number.
- The criteria of preference entirely dependent on respondent. There is nothing like right or wrong answer.

By compiling and analysing the information received from the survey, the company could make an assessment that the product characteristics present in Brand 5 (Close Up) were most valued by customers, followed by Brand 3 (Ultra Bite) and Brand 9 (Pepsodent). The price, durability, quality, functionality, packaging and other features of the topmost brands gave the required market information to the company for deciding the desired specifications in the new product to be developed.

The value of competition prevailing in the toothpaste market could also be assessed by the company. Although the survey gave details on the most favoured and unfavoured brands, but could not reveal the distances between research objects or the reasons for customers' choices between different brands. It was felt that the survey provided limited information for knowing about the criteria based on which consumers accept or reject a product. It could not reveal why a product was important or unimportant to the respondents.

QUESTIONS

1 What other forms of scaling methods could be used by CBA Ltd.?

(**Hint:** No other scaling method can be used.)

2. What are the limitations of the measurement scale used by CBA Ltd.?

(**Hint:** Rank order scale yields ordinal data. It gives better results only when a direct comparison is required between research objects.)

3. What had management thought to do before launching the new product?

(**Hint:** Gather material information such as customer choices and preferences)

4. What did CBA Ltd. management do to collect information from customers?

(**Hint:** Conducted a survey of 300 samples)

5. How did CBA Ltd. collect the desired specifications for the new product to be developed?

(**Hint:** Price, durability, quality, functionality, packaging and other features of the topmost brands gave the required market information)

5.7 EXERCISE

1. Discuss the concept of measurement.
2. Explain the types of scales.
3. Explain comparative scales.
4. Describe various non-comparative scales.
5. What are the different bases of scale classification?
6. Explain the stages of developing measurement tools.
7. Enlist the basic criteria of a good measurement tool.

5.8 ANSWERS FOR SELF ASSESSMENT QUESTIONS

Topic	Q. No.	Answer
Concept of Measurement	1.	variables
	2.	Ordinal scale
	3.	False
	4.	Arithmetical
	5.	True
Concept of Scaling Techniques	6.	Scaling
	7.	False
	8.	respondents
	9.	True
	10.	personal

Notes

5.9 SUGGESTED BOOKS AND E-REFERENCES

SUGGESTED BOOKS

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CHAPTER 6

Data Collection Techniques

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LEARNING OBJECTIVES

After studying this chapter, you will be able to:

- Outline the importance of data collection
- Differentiate between primary data and secondary data
- Explain the different methods of data collection
- Discuss the factors affecting the selection of data collection methods

6.1 INTRODUCTION

In the previous chapter, you studied about the construction of measurement scales and different types of scaling techniques used for measurement of objects in research. After completing this part of the research design, the next step is to collect data from the respondents. This chapter focusses on methods of collection of data. Data can be collected from two types of sources, i.e., primary or secondary.

Every researcher requires several data-gathering tools and techniques. Data collection methods form an integral part of the research design. There are various data collection methods and each has its merits and demerits. These tools vary in design, complexity, interpretation and administration. Each data collection tool is suitable for gathering a certain type of information. The problems that are researched with the usage of an appropriate data collection method largely enhance the value of research study. Different tools available for data collection are interviews, questionnaires, schedules, observation techniques, etc. The researcher should select a tool from the available ones which will best provide the data that is sought for testing the research hypothesis. If the existing research tool does not suit the purpose of research, then the researcher must modify the tool accordingly or construct some other tool. Reliability and accuracy must be maintained in the process of data collection.

This chapter begins by defining primary data and secondary data. The primary data refers to the information gathered firsthand by the researcher on the interest variables for the specific purpose of the research study. On the other hand, the secondary data refers to information gathered from the already existing sources like records of companies, government publications, etc. In the latter part of the chapter, various methods of primary data collection and secondary data collection are discussed in detail. Factors affecting the selection of data collection methods are described at the end of the chapter.

6.2 DATA COLLECTION

A research can be done on any subject related to any stream, including management, computers, medical engineering, etc. However, every type of research requires data to be collected from various sources. The process of gathering data for the research is known as data collection. Data collection can be defined as a process of collecting

information from all the relevant sources for finding answers to the research problem, for testing the hypothesis, and for evaluating the results.

No research can be carried out without sufficient, useful and relevant data. To obtain accurate data, it is important for a researcher to approach the right resource. For instance, if the researcher wants to conduct research on the most prevailing disease, then he/she would approach doctors to collect data for a number of patients suffering from different types of diseases. After collecting data, the researcher processes and analyses the data to obtain meaningful information.

6.2.1 TYPES OF DATA

Data is basically a collection of facts and figures retrieved from observations or surveys. It is collected by a researcher keeping in view the objectives of the research study.

There are mainly two types of data which are explained below:

- **Primary data:** Primary data are the data that are collected fresh and for the first time. The researcher may himself collect this data directly from the respondents or through his team. Since this data has not been published yet anywhere, it proves to be more objective and authentic for research objectives. The relevance of this data is higher than other data because it has not been altered. The primary data can be collected through field observations, surveys, questionnaires or through experiments. It can include a wide geographical coverage and a large population. The degree of accuracy of primary data is very high because they are specific to the researcher's needs and relevant to the topic of the research study. Moreover, since the primary data is current, it can provide a realistic view of the topic under consideration to the researcher.

  For example, census reports and records collected by Central Statistical Organisation (CSO) are examples of secondary data.

- **Secondary data:** It refers to the data that was collected in the past, but can be utilised in the present scenario/research work. The collection of secondary data requires less time in comparison to collecting primary data.

  For example, census reports and records collected by Central Statistical Organisation (CSO) are examples of secondary data.

Self Assessment Questions

1. _____ refers to the data that does not have any prior existence and is collected directly from the respondents.
2. _____ refers to the data that has already been collected by other sources and is readily available.

6.3 METHODS OF DATA COLLECTION

Selecting the right method for data collection is important to get reliable data. The different methods of primary and secondary data collection are described in the upcoming section.

Notes

6.3.1 METHODS OF PRIMARY DATA COLLECTION

There are various methods of primary data collection, as shown in Figure 1:

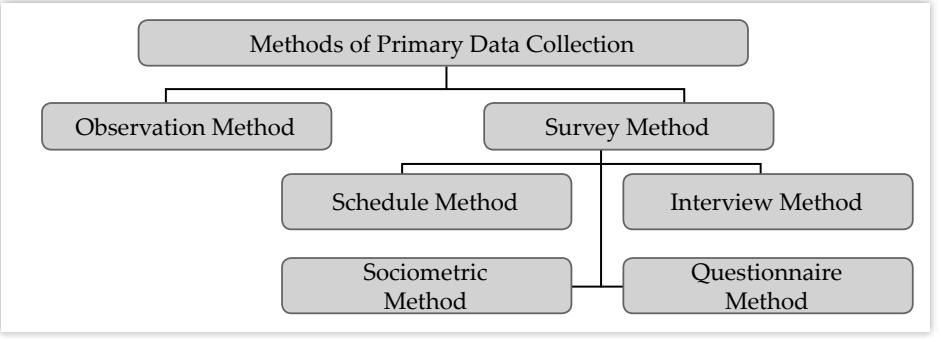

Figure 1: Methods of Primary Data Collection

Let us discuss these methods in detail.

- **Observation method:** In this method, the population of interest is observed to find out the relevant facts and figures. Observation method is a technique under which data is collected by the observer from the field, through the process of recording behavioural patterns of people, objects and occurrences without communicating or questioning. It may be defined as the process of systematic viewing coupled with a recording of the observed phenomenon. It is used for studying the dynamics of a given situation, for making frequency counts of target behaviours, or for reviewing any other behaviours as indicated by the evaluation needs.

  For example, site visits may be made to an after-school programme for documenting the interactions between youth and staff present within the programme. This method is generally suitable when the researcher wants to gather currently prevailing real-life information for his research.

  It offers the following advantages:

  - This technique can be stopped or begun at any time
  - It provides access to large sections of people

  It suffers from the following disadvantages:

  - It is a time-consuming activity
  - The result is dependent upon the performance of the observer

  Observation is done using the following methods:

  - **Natural method:** In this method, the researcher observes the behaviour of people without any intervention.

    For example, the researcher observes bikes passing on the road to study the most popular brand in the city. In addition, the researcher can observe the activities, movements, gestures and facial expressions of people. It takes place when the people being observed have no idea that they are being observed.

    It offers the following advantages:

    ✓ It is the simplest method.

    ✓ It does not require the willingness of the people to report.

It suffers from the following disadvantages:

- ✓ Not all occurrences may be open to observational studies.
- ✓ When the researchers are collecting natural observations, they usually do not acquire the informed consent of the people being observed which makes it somewhat unethical.

- **Contrived method:** Under contrived method, a research setting is created by the observer in order to carry out the research. All the respondents are observed in this simulated environment. The researcher can control all the major aspects of the research environment. Therefore, data can be collected easily and quickly. It takes place when people are aware of their participation in the study, but do not have an idea about what aspects are being observed.

  For example, when a group of people's reaction towards a particular situation, such as the impact of different types of bacteria and resistance level of people is being observed in a laboratory set-up.

  It offers the following advantages:

  - ✓ It is easier than the natural method
  - ✓ The researcher has full control over the method

  It suffers from the following disadvantages:

  - ✓ The artificial environment may increase the frequency of certain behavioural patterns to be observed
  - ✓ Contrived method is less natural than other forms of observation.

- **Direct method:** In this method, the researcher waits for a particular experiment or behaviour to occur. This process takes a longer time to get a single response.

  For example, the researcher is observing the sale of new products in an automobile showroom. In this case, the researcher has to wait till the time a customer comes in the showroom and asks for the new product. When the customer comes and sees the new product, he/she may or may not purchase it on the same day. In such a situation, the researcher has to wait till that customer comes back to buy the product. This method is used when other data collection procedures like survey/questionnaire are not effective or when the objective is to analyse an ongoing behaviour process.

  It offers the following advantages:

  - ✓ The physical outcomes can be readily counted
  - ✓ The method is easy to execute and complete

  It suffers from the following disadvantages:

  - ✓ It is a time-taking procedure
  - ✓ It requires high diligence on the part of the observer

  In the direct method, the researcher directly observes and records the actions of the people under study. On the contrary, in the indirect observation, the researcher reports the event through documents or correspondence diaries, or organisational files. The researcher usually observes the effects of the behaviour which is recorded using mechanical or electronic devices.

For example, the calls between customer care executives and customers are recorded in various call centres for training and quality purposes.

- **Structured method:** In this method, the researcher knows what is to be observed.

  For example, if the researcher has to know about a particular brand of a car, he/she would observe only that brand of car and would not pay any attention to other car brands. The structured method consumes less time and makes it easier for the researcher to analyse the data. It is used when the researcher specifies in detail what has to be observed and how measurements have to be recorded.

  It offers the following advantages:

  ✓ It simplifies and systematises the data-recording process.

  ✓ It is likely to produce quantitative data beneficial for analysing and comparing information.

  It suffers from the following disadvantages:

  ✓ Results are not detailed and in-depth.

  ✓ It is useful for studying small-scale interactions only.

- **Unstructured method:** In this method, the researcher does not know what exactly he/she has to observe. The unstructured method is used in exploratory research. In this method, the researcher wants to search for all the aspects that can affect a particular problem.

  For example, the researcher observes the buying behaviour of people for different brands of the same product. He/she would study all factors that can affect the buying decision of people. After that, he/she would analyse the buying decision for a particular brand. Under this method, the researcher enters the research field with some idea of what might be important, but not of what exactly will be observed.

  It offers the following advantages:

  ✓ The observer has the freedom to decide and observe everything that is relevant.

  ✓ It is more explorative than the structured method.

  It suffers from the following disadvantages:

  ✓ It is an unfocussed approach with the investigator documenting as much as possible.

  ✓ It is more time-taking than the structured approach.

- **Mechanical method:** In this method, the researcher uses some devices to observe people's responses. Examples of these devices are video cameras and audiometres. This method has application in real-time scenarios, such as voice pitch metres for measuring emotional reactions, analysing traffic flows in the urban square, monitoring website traffic, etc.

  It offers the following advantages:

  ✓ It does not require the direct participation of the respondents.

- ✓ It is subject to a low level of observation bias.
- ✓ The method is more accurate as compared to natural method and its recordings can also be reviewed later for further detailed study.

This method suffers from the limitation of bearing the expenses of advanced technology.

In a nutshell, the observation method helps in getting non-biased responses from the respondents; and, therefore, provides accurate data for the research. However, this method does not allow the researcher to evaluate the past data. This method is used to study only the present scenarios.

- **Survey method:** The essence of the survey method is explained as questioning individuals on a certain topic and describing their responses accordingly. It is used to test concepts, reflect the attitude of people, establish customer satisfaction level, conduct market segmentation research, and so on. Surveys can be conducted in a faster and cheaper manner as compared to other methods of data collection such as observation method. However, they are subject to the human bias of the respondents and their unwillingness to provide information. The survey method is further categorised into four types, i.e., interview method, questionnaire method, sociometric method and schedule method.

  - **Interview method:** The interview method is basically used to do an in-depth study of the research problem. In this method, the researcher asks the respondents to react or speak on a particular topic or situation. In this method, the researcher is in a better position to study the attitudes, motivation level and opinions of the respondents. However, the researcher should keep certain things in mind while conducting the interviews. Sometimes, it is very difficult for the researcher to ask direct or personal questions because the respondents are not willing to answer such questions. Therefore, the researcher should make the interview environment comfortable to get the answers to personal questions from the respondents. An interview offers the researchers an opportunity to uncover information that is otherwise not accessible using techniques, such as questionnaires and observations. However, this method has the potential of being affected by subconscious bias because interviewees will only reveal information which they are prepared to give about their perceptions of opinions and events.

    For example, in a job interview, the recruiters usually try to get information regarding the work attitude of the prospective employees. For instance, if an organisation has a work culture of continuous and perpetual crisis situation, then the employer must question the candidate whether he/ she will be able to perform under conditions of stress and, if yes, how?

    The interview method is further divided into some sub-methods which are as follows:

    - ✓ **Structured interviews:** In these interviews, the researcher prepares questions and decides their sequence before the interview. This method is used for validating results when the number of participants is quite large. Structured interviews are conducted using a set of previously decided questions and the same set of questions is administered to all the participants. Structured interviews should be used in case of research related to areas where literature is highly developed or after using observational or some other less structured approach.

For example, a structured interview can include questions such as:

1. How (as an HR) will you handle a situation of understaffing.
2. What were your major achievements in the previous job?
3. Which manager in your previous jobs was best according to you and why?
4. Which organisations do you dream of working in at some point in time and why?

It offers the following advantages:

- They are easy to replicate because a fixed set of questions are used.
- They are fairly quick to conduct and the results obtained are representative of a large population.

It suffers from the following disadvantages:

- This method is not flexible because a fixed interview schedule has to be followed.
- The answers lack detail and closed questions only generate the quantitative data.

✓ **Unstructured interviews:** In these interviews, questions are not predefined. The researcher asks questions according to the situation and environment of the interview. This method is used for probing more details of a participant so as to assess and judge his responses. Unstructured interviews are carried out when the researcher wants to explore detailed information about the thoughts or behaviour of interviewees.

It offers the following advantages:

- This method is more flexible as questions can be adapted and changed based upon the respondents' answers.
- It generates qualitative data with the use of open questions.

It suffers from the following disadvantages:

- It may be time-consuming.
- It is cost-intensive as it includes the costs of employing and training the interviewers.
- The participants are interviewed one at a time.

✓ **Individual in-depth interviews:** In these interviews, the researcher takes the interview of one respondent at a time. These interviews prove useful in getting in-depth knowledge of the topic under study from each respondent. However, individual in-depth interviews are time-consuming.

It offers the following advantages:

- More complete answers can be obtained if there are certain doubts in the mind of the interviewer.
- The researcher can analyse the body language of the interviewees.

It suffers from the following disadvantages:

- ♦ It is time-consuming and capital-intensive
- ♦ The respondents may be self-conscious and may not answer trustfully.

✓ **Focus group interviews:** In these interviews, the researcher takes the interview of a group of respondents at a time. The groups of respondents can be further classified into consumer panels. In one consumer panel, there are 8 to 12 members and they are provided with a topic for discussion. They are informed about the motive for conducting the interview, various aspects that would be covered during the discussion, and the guidelines of the interview. Consumer panels are used to collect in-depth data from a group of people about their experiences and perceptions related to a specific matter. Group interviews are more structured and are, thus, easy to evaluate. In consumer panels, people are selected randomly and introduced to a new product, flavour or advertisement. Thereafter, they are asked to discuss their experiences with each other. This helps the researcher in assessing interviewees' responses with respect to the product.

For example, a group of 10 members of a sales team are interviewed and asked about their opinions related to a particular sales strategy.

It offers the following advantages:

- ♦ It helps in collecting the inputs of multiple persons in one session.
- ♦ Group interaction can provide in-depth discussion and greater insight.

It suffers from the following disadvantages:

- ♦ This method requires a skilled facilitator to conduct the interview.
- ♦ Only a limited number of questions can be asked in group interviews.

✓ **Telephonic interviews:** The researcher takes these interviews with the help of a telephone. The researcher searches the telephone numbers of people and contacts them to get information. Telephonic interviews are convenient for the researcher, as they save travelling cost and time.

For example, many organisations today prefer to conduct a telephonic interview before calling candidates for the interview. The usual questions included in a telephonic interview include:

1. Breifly describe about yourself.
2. Why do you want to change your job?
3. How did you come to know about this job?
4. What particular attributes of this position do you find interesting?

It offers the following advantages:

- ♦ It is cheaper and faster than the personal interview method.
- ♦ Since there is no face-to-face contact, the respondents may be willing to give information which they might reluctantly provide in a personal interview.

It suffers from the following disadvantages:

- ♦ Surveys have to be restricted to the respondents who have telephonic facilities.
- ♦ Designing effective telephonic surveys is a tedious and challenging task.

✓ **Computer-assisted interviews:** As is clear from the name, the researcher takes interviews with the help of computers. There are two types of computer-assisted interviews, namely Computer-Assisted Telephonic Interviews (CATI) and Computer-Assisted Personal Interviews (CAPI). In the CATI, a computer system is connected with the telephone of the interviewer. The questions appear on the screen of the computer and the interviewer asks those questions through the telephone. The interviewer feeds the responses of the interviewees in the computer system. In the CAPI, interviewees can administer their interviews themselves with the help of software installed in their systems. They can directly feed their responses in computer systems. This method is used for conducting business-to-business research at various trade shows or conventions.

It offers the following advantages:

- ♦ It makes implementation of surveys possible in a shorter period of time and with lesser costs.
- ♦ Data collection is not limited by geographical or time constraints of interviewees.

It suffers from the following disadvantages:

- ♦ It requires expert knowledge of computer-aided tools and technology.
- ♦ Respondents or interviewers must have access to a computer system.

Interviews provide an in-depth knowledge of the topic and help in getting responses from a large population. Moreover, less cost and effort are involved in telephonic interview and CAPI technique. However, interviews do not rule out the influence of interviewer on the respondent.

- **Questionnaire method:** A questionnaire represents the written form of an interview; however, there is one difference between a questionnaire and an interview. It is easy to code a questionnaire than an interview because the questions in a questionnaire are mostly in quantitative form while the questions in an interview are mostly in qualitative or exploratory form. A questionnaire is known as a research instrument comprised of a series of questions, used for the purpose of gathering information from the respondents. It is generally used to collect useful information from a large population in a short period of time.

  It offers the following advantages:

  ✓ Questionnaires are cheaper and do not require much effort on the part of the questioner as compared to other verbal or telephonic surveys.

  ✓ Data can be collected from a large number of people.

  ✓ Quantifiable answers provided by a standard questionnaire are easy to compile and analyse.

It suffers from the following disadvantages:

- ✓ Questionnaires are limited by the fact that the respondents must be able to correctly understand and respond to questions.
- ✓ Designing a good questionnaire requires a lot of effort and skill.

A detailed explanation of the questionnaire method is given in Chapter 7 of this book.

- **Sociometric method:** The sociometric method/test enables the researcher to analyse a social group or workgroup by studying attractions and repulsions among group members. In this method, a social group is taken and its members are asked to perform some activities in a particular situation. This method is used to understand the interaction, communication, and choices of individuals in a group. The researcher uses the sociometric test to find out the relationship pattern within a group. On the basis of the choices of individuals, a sociogram or sociomatrix is built to study these patterns. The process of the sociometric method involves three steps which are as follows:
  - ✓ **Introduction:** The researcher informs the respondents how to perform activities.
  - ✓ **Gathering information:** The researcher asks questions from the respondents.
  - ✓ **Drawing conclusion:** The researcher starts interpreting the responses of the team members and drawing conclusions from the data collected.

  This method presents an insight of flow of information within a social group. However, at the same time, it increases the necessity to have a skilled researcher. This method is generally used to describe and evaluate social status, social structure, or social development by measuring the extent of acceptance or rejection among individuals in the group. In short, it is a graphical representation to study social relationships and social problems.
- **Schedule method:** The schedule method is same as the questionnaire method as both the methods contain a set of questions in the written form. The main difference between the two is that in the schedule method, enumerators are appointed to conduct the research. These enumerators meet the respondents personally and fill the questionnaires themselves. Sometimes the responses can also be filled by the respondents, but in the presence of enumerator, who can guide them if they face any problem. The schedule method is the most used method by government agencies, research institutes, or big organisations to make extensive enquiries on a certain issue. This method increases the chances of getting accurate responses and the number of responses as compared to the questionnaire method. However, this method consumes more time and involves more cost as enumerators have to be appointed.

  It offers the following advantages:

  - ✓ It reduces the non-response level of the respondents to a negligible level as opposed to the higher level of non-response in the questionnaire method.

- ✓ Information can also be collected from the illiterate respondents.
- ✓ The identity of persons is known to ensure that expected respondents have filled the answers.

It suffers from the following disadvantages:

- ✓ It is costly than questionnaire method as it requires field workers.
- ✓ This method is difficult to use if the researcher wants to cover a wide area.

6.3.2 METHODS OF SECONDARY DATA COLLECTION

As secondary data has been collected in the past, it can be retrieved from various sources by the researcher. Following are the sources for collecting secondary data:

- ❍ **Company records:** They provide information in the form of balance sheets and sales records. This information is used to perform trend analysis of the data and forecasts the overall growth of a company in the future. It also helps in deciding whether the company is moving on the right track to achieve its vision or not. Company records are maintained every year by the company itself.
- ❍ **The Internet:** It gives information regarding previous researches done on the same topic. The Internet also provides lots of data related to research from different sources.
- ❍ **Print media:** It offers information that is publicised. Print media includes newspapers, magazines, books, research papers and journals. The data collected from print media is used to get an overview of the present market situation and experts' opinions on different topics.
- ❍ **Census and other government records:** They include large data of each and every individual of the state. This data contains personal information of respondents. It is used mostly used by government and big organisations. This type of data helps in conducting research on a big scale.
- ❍ **Indirect method:** In this method, the researcher observes the behaviours that have occurred in the past using recordings, journals, magazines, industry publications, etc. This method consumes less time and is less expensive as compared to the other methods. Suppose a researcher needs to know the sale of a particular brand in a store. In this case, data can be collected from registers showing the sale of different products in the store.

Self Assessment Questions

3. The sociometric method/test enables the researcher to analyse a social group or workgroup by studying attractions and repulsions among the group members. (True/False)
4. The schedule method is same as the sociometric method as both the methods contain a set of questions in the written form. (True/False)
5. Which of the following provide(s) information in the form of balance sheets and sales records?

   a. Company records
   b. The Internet
   c. Print media
   d. Census

6.4 FACTORS AFFECTING THE SELECTION OF DATA COLLECTION METHODS

The selection of an appropriate method of data collection depends on a number of factors which are as follows:

- **The objective of research:** It plays an important role in determining the method of data collection. It defines the motive of conducting research, which, in turn, helps in knowing the type of data (quantitative or qualitative) that needs to be collected.
- **The time frame for research:** This is the duration within which research needs to be completed. If the time frame to complete the research is less, the researcher would use data collection methods that are less time-consuming. However, if the time to complete the research is more, then the researcher can use data collection methods that take more time, but provide relatively authentic data such as an in-depth interview used for exploratory study.
- **Availability of resources/funds:** If the researcher has sufficient funds to conduct the research, he/she can use expensive methods of data collection, otherwise, he/she has to look for economical methods.
- **Precision:** It refers to the measure of how close a result comes to its true value. If the data collection is not done with precision, the findings of the research would not be valid.
- **Skills of the researcher:** This makes or destroys the whole effort of data collection. Selection of a skilled researcher is necessary because if the researcher is unskilled, he/she may not be able to select the right method of data collection.
- **Size of sample:** Different types of data collection methods are suitable for different sample sizes. Therefore, the researcher must select the type of data collection method based on the sample size. For example, it would be highly inconvenient to administer a questionnaire to the participants of a census survey.

Self Assessment Questions

6. Selection of a skilled researcher is necessary because if the researcher is unskilled, he/she may not be able to select the right method of data collection. (True/False)
7. A researcher having sufficient funds to conduct the research can use expensive methods of data collection; otherwise, they should look for economical methods. (True/False)
8. If the time period to complete the research is_____, the researcher would use data collection methods that are less time-consuming.

Activity

Suppose you are given the responsibility by your organisation for conducting research on the popularity of baby food brands among consumers. Which data collection method would you prefer to select for conducting the research?

Notes

6.5 SUMMARY

- The process of collecting data for research purposes is known as data collection.
- Primary data is the data that does not have any prior existence and is collected directly from the respondents.
- The data that is collected in the past but can be utilised in the present scenario/ research work is known as secondary data.
- Observation method is a technique under which data is collected by the observer from the field, and through the process of recording behavioural patterns of people, objects and occurrences without communicating or questioning.
- A questionnaire is known as a research instrument comprised of a series of questions, used for the purpose of gathering information from the respondents.
- The selection of an appropriate method of data collection depends on a number of factors, such as objectives of research, resource availability, etc.

6.6 KEY WORDS

- **Observation:** It is the process or action of closely monitoring something or someone.
- **Survey:** A general investigation of the experiences or opinions of a group of persons so as to record the facts or features.
- **Enumerator:** A person employed in executing a specific task, for example, in taking a census of the population.
- **Respondent:** It refers to an individual who replies to something, especially one who gives information for a questionnaire or responds to an advertisement.
- **Census:** A process of systematic acquiring and recording of information related to members of a population.

6.7 CASE STUDY: BUYERSYNTHESIS'S PRIMARY DATA COLLECTION FOR ABC (A NON-PROFIT ORGANISATION)

BuyerSynthesis is a consultancy organisation that provides primary data collection services. It provides consumer insights to its various clients which include consumer-facing companies, creative agencies and non-profit organisations. This organisation was established in 2002 and is located in Denver, USA. The organisation helps its clients by creating more effective marketing strategies and plans by better understanding their buyers.

BuyerSynthesis believes that the consumers are the most important factor in any business. Therefore, the organisations must become consumer-oriented. BuyerSynthesis helps in taking the voice of an organisation's consumers to the concerned organisations which can then plan their marketing strategies accordingly

BuyerSynthesis team carries out primary research projects along with their client's in-house teams to carry out their research.

BuyerSynthesis worked with an organisation ABC (a non-profit organisation). The management of ABC wanted to research ways in which it can refresh its image so as to attract new-generation people without losing its loyal customers. The organisation also wanted to bridge the gaps with its core audiences.

In order to carry out data collection for this, BuyerSynthesis started with an internal audit of the marketing department of ABC so that they may assess the challenges and the resources of ABC. This was essential in order to find out what aspects of marketing required refurbishing and whether the recommendations of BuyerSynthesis would be feasible for them or not.

To begin with their research, BuyerSynthesis roped in numerous participants from ABC's audience to carry out its focus group research. The focus groups were segmented using three categories, viz., generation, visitation frequency and when their last visit to ABC was.

The focus groups were moderated and they discussed the following aspects:

- What did ABC mean to them?
- What changes in the organisation would they like to see?
- What could be the effect of innovations on them?

All the participants narrated their experiences with respect to the recent and memorable experience.

Focus group research helped BuyerSynthesis in gaining information regarding who ABC's audience was and what attributes were important for them. BuyerSynthesis also recognised that the organisational members felt a high degree of personal attachment with ABC and they deeply appreciated it.

On the basis of research, BuyerSynthesis made certain recommendations which helped ABC in enhancing the relationship between the organisation and its clients and, at the same time, keep the costs under control. This research led ABC to develop innovative audience engagement and delivery plans. In addition, the process of planning infrastructure improvement was also expedited.

QUESTIONS

1. Describe the nature of BuyerSynthesis as an organisation.

   (**Hint:** BuyerSynthesis is a marketing research organisation and it helps its clients by creating more effective marketing strategies and plans by better understanding their buyers.)

2. What were the major topics that were discussed within the focus groups created by BuyerSynthesis for ABC?

   (**Hint:** The major topics that were discussed within the focus groups included: What ABC meant to them?; What changes in the organisation would they like to see, etc.)

3. What was the first step adopted by BuyerSynthesis for collecting data for ABC?

   (**Hint:** Data collection with an internal audit of the marketing team of ABC.)

4. How did focus group research help BuyerSynthesis in gaining information about ABC?

   (**Hint:** To gain information about ABC's audience and what attributes were important for them.)

5. How did the recommendations made by BuyerSynthesis help ABC?

   (**Hint:** Enhancing the relationship between the organisation and its clients and, at the same time, keep the costs under control.)

6.8 EXERCISE

1. Define data collection and describe the different types of data collection in detail.
2. Explain the different methods of primary data collection.
3. How is data collected using the schedule method?
4. Explain the different methods of secondary data collection.
5. Which factors are to be considered while selecting the methods of data collection?

6.9 ANSWERS FOR SELF ASSESSMENT QUESTIONS

Topic	Q. No.	Answer
Data Collection	1.	Primary data
	2.	Secondary data
Methods of Data Collection	3.	True
	4.	False
	5.	a. Company records
Factors Affecting the Selection of Data Collection Methods	6.	True
	7.	True
	8.	less

6.10 SUGGESTED BOOKS AND E-REFERENCES

SUGGESTED BOOKS

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CHAPTER 7

Introduction to Questionnaire Designing

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LEARNING OBJECTIVES

After studying this chapter, you will be able to:

- Describe the concept of designing a questionnaire
- Identify the different types of questions used in questionnaire designing
- List the steps used in questionnaire designing
- Discuss how to design an effective questionnaire

7.1 INTRODUCTION

In the previous chapter, you studied the concept of data collection. The chapter discussed the types of data. The latter section of the chapter described the methods of data collection. The chapter concluded with the explanation of the factors affecting the selection of data collection methods.

Businesses operate on facts and data. Without data, an organisation would have no idea on where it stands and where it needs to go. One of the simplest, cheapest and quickest ways to gather data is to create questionnaires. The design of a questionnaire determines the success of data collection.

Creating a questionnaire is an art as well as a science. If it is well-designed, then it will have better chances of inviting responses than a badly crafted questionnaire. While creating a questionnaire, you must consider various factors, such as how many questions to ask, whether to ask close-ended questions or open-ended ones, how to keep the wording of questions simple and effective, how to create questions that invite correct responses from respondents, how to place questions in the questionnaire and when and where to distribute questionnaires.

In this chapter, you will study the concept of questionnaire designing. Next, you learn about the types of questions in questionnaire designing. Further, the chapter will describe the steps of questionnaire designing. Towards the end, the chapter will brief about designing an effective questionnaire.

7.2 CONCEPT OF QUESTIONNAIRE DESIGNING

Questionnaires are often designed for collecting standardised information about behaviour, opinion, experience or preference of a group of respondents. As compared to other forms of surveys, questionnaires are cheap and require less effort. Some advantages of the questionnaire are:

- **Economical:** The cost of creating and implementing questionnaires is very low.
- **Wide coverage:** They are best to cover a large number of people. They make it possible to contact many people who could not otherwise be reached.
- **Rapidity:** They provide speedy results.
- **Easy to implement:** They are easy to plan, create and administer.
- **Less pressure on respondents:** Respondents can take their time to answer questions.

- **Uniformity:** They do not allow much variation in recording responses.
- **Greater validity:** Responses are interpreted without any bias or prejudice by the recorder.
- **Anonymity:** They ensure anonymity of the respondents.

The questionnaires also have their set of disadvantages as follows:

- **Limited response:** These are only applicable to an educated class; they cannot be applied to illiterate or semi-literate class. There is also a high possibility of the respondents skipping questions.
- **Lack of personal contact:** Even the best designed questionnaire may fail to elicit a suitable response due to lack of proper personal contact, which may result in failure to interpret questions or plain indifference.
- **Poor response:** The questionnaires sent on email generally have very poor response rate.
- **Incomplete entries:** Often respondents may leave out some crucial fields, making it difficult for the recorder to interpret their responses.

Thus, it is important to design a proper questionnaire to gather complete, relevant and meaningful data.

As an example, consider the two questionnaires: Which one is well-designed?

Figure 1 shows a sample of a well-designed questionnaire:

Thank you for taking the time to fill in this questionnaire, you will remain anonymous. I just need a sample of an audience (in this case media students) to use as an example for a research project.

Are you Male Female	When was the last time you saw a film, what was it?
Are you old are you? Years Months Who do you live with at home (be specific please)	How many hours a day would you spend watching reading or listening to: TV Radio Internet Print (magazines/newspapers)
Do you have a part-time job? YES NO PAID VOLUNTARY If so, please describe what you do	Please list your top 3 TV programmes. 1. 2. 3.
Do you get pocket money/allowance? Yes No If Yes, how much do you get per week? What do you spend it on, generally	List in order of preference (I being your most preferred, 5 being the least preferred) which genres (types of programmes)you watch: Sports Soap Sitcom Documentaries Film
Please list your top 3 favourite foods 1. 2. 3.	You are going to help organise some kind of music event for your age group: what types of music/ bands would you want to play?

Figure 1: A Well-Designed Questionnaire

(**Source:** *cs3240 Team 13*)

Notes

Figure 2 shows a sample of a bad questionnaire:

1. Which is your sex? ___ Male ___ Female
2. What is your class standing in the University?

   Fresh ___ Soph ___ Jr ___ Sr ___ Special
3. How old were you at your last birthday? _____ Years
4. What is your major(s)?

   (If unknown at this time write "Unknown" in space provided)
5. What is your current GPA for all college courses?

_____ 3.8 to 4.00	_____ 2.8 to 2.99	_____ 1.8 to 1.99
_____ 3.6 to 3.79	_____ 2.6 to 2.79	_____ 1.6 to 1.79
_____ 3.4 to 3.59	_____ 2.4 to 2.59	_____ 1.4 to 1.59
_____ 3.2 to 3.39	_____ 2.2 to 2.39	_____ 1.2 to 1.39
_____ 3.0 to 3.19	_____ 2.0 to 2.19	_____ Below 1.20

   If you do not have any idea of what your GPA is check here
6. What is your current marital status? _____ Never Married, single
   _____ Divorced/Widowed/Separated
   _____ Married
7. Do you have any children [adopted or natural or spouses?] ____ Yes ____ No
8. What is your birth order? ____ I was an "only child"

____ Raised in Institution	____ Oldest of siblings
____ Youngest of Siblings	____ In Middle (some siblings older & younger)

Figure 2: A Bad Questionnaire

(**Source:** *cs3240 Team 13*)

Figure 1 shows a well-designed questionnaire, whereas Figure 2 shows a bad questionnaire. Figure 1 depicts the characteristics of a good questionnaire because of the following:

- It deals with a specific topic and target audience (i.e., media students).
- The structure is more clear as compared to Figure 2.
- It consists of complete and clear directions, and important terms are clarified.
- Its significance is clearly stated on the covering paragraph/questionnaire itself.
- Less number of private questions as compared to Figure 2 will make the respondents more comfortable in answering.
- It is properly arranged and visually appealing.

Figure 2 depicts a bad questionnaire because the structure of this questionnaire is not clear and it contains questions that people may not be comfortable in answering.

7.2.1 FEATURES OF A WELL-DESIGNED QUESTIONNAIRE

The development of a questionnaire is a complex and laborious process and requires verification of its usefulness prior to its implementation. A well-designed questionnaire must attain the following characteristics in order to achieve the predefined objectives of research:

- Interest
- Precision

Let us discuss each feature.

- **Interest:** Respondents are more likely to complete a questionnaire, which is interesting to them. Here are some tips to create an interesting questionnaire:
  - **Visually appealing:** Present questionnaire in an appealing and engaging format. Try adding in colour and images to convey your organisation's brand and personality. Make your questionnaire usable and intuitive with no possibility of doubt or confusion.
  - **Intriguing and engaging options:** Instead of boring choices like very satisfied, satisfied, etc., try using more interesting languages, such as I love you guys, We're still friends, I'm a little upset, and so on.
  - **Make it brief:** Ask only relevant questions. Value the time of the respondents. They will thank you for it.
- **Precision:** The questions included in a questionnaire must be to the point. Questions are considered precise when the researcher receives correct answers for the given to-the-point questions. Table 1 indicates some dos and don'ts of a questionnaire design:

Table 1: Dos and Don'ts of a Questionnaire Design

Dos	Don'ts
1. Clearly define target respondents, their age, education level, etc.	1. Avoid leading questions, which subtly prompt the respondents to answer in a particular way. Such questions result in false or slanted information. Examples: **Leading question:** You are satisfied with our customer service, aren't you? **Non-leading question:** How satisfied are you with our customer service? **Leading question:** Do you always consume fast food? **Non-leading question:** How frequently do you consume fast food?
2. Decide if your questionnaire should be anonymous or not.	2. Avoid technical terms or jargons. **Jargon question:** Which feature would you like baked into our new product? **Non-jargon question:** Which feature would you suggest to be included into our new product?

Notes

Dos	Don'ts
3. Carefully research and draft questions so that they meet the purpose of the questionnaire and get the desired data.	3. Avoid using terms that the respondents may not be familiar with: **Bad question:** Do you have a history of carcinomic cancer in your family? Yes/No **Good question:** Do you have a history of lung/prostate cancer in your family? Yes/No
4. Start your questionnaire with the most relevant questions and then follow naturally.	4. Avoid making the questionnaire too lengthy.
5. Create engaging questions throughout the questionnaire.	5. Avoid repetitive questions.
6. Word questions so that they are clear and easy to understand.	6. Avoid double-barrelled questions — asking two questions in one line. For example, do not ask: Did this project teach you to discipline your child and manage your home finances?
7. Give space for respondents to write their comments on topics not covered in the questionnaire.	
8. Pilot test the questionnaire before launch.	
9. Use multiple formats of the questionnaire: pen and paper, online, email, telephonic, etc.	

Self Assessment Questions

1. What is the benefit of a questionnaire over other methods of conducting a survey?
   a. Personal rapport with the recorder
   b. Easy to convey feelings and emotions
   c. Speedy results
   d. None of these
2. Questionnaires with lengthy, well-formed questions elicit more response than those with to-the-point questions. (True/False)
3. A question that subtly prompts the respondents to answer in a particular way is called a _____ question.
   a. Double-barrelled question
   b. Focussed question
   c. Repetitive question
   d. Leading question

7.3 TYPES OF QUESTIONS IN QUESTIONNAIRE DESIGNING

You can add various types of questions in a questionnaire, including:

- Open-ended or close-ended questions
- Fixed alternative or multiple choice questions
- Dichotomous questions
- Rating scale (continuum) questions
- Agree to disagree scale questions
- Rank ordering questions
- Projective methods questions

Let us discuss each type.

- **Open-ended vs close-ended questions:** Open-ended questions enable respondents to elaborate their answers and express what they really want to say. Such questions are usually asked during interviews and are most useful in exploratory research.

  In open-ended (or unstructured) questions, respondents give answers in their own words, whereas in close-ended (or structured) questions, they get to choose from a limited number of choices provided to them. The open-ended questions take a longer time to administer and analyse. Close- ended questions help the respondents to interpret the questions in the same manner. Respondents are more likely to find such questions less stressful. These questions may be multiple choice, dichotomous (yes/no) or rating scale questions.

  Table 2 helps you to understand open-ended questions by comparing them with close-ended ones:

Table 2: Close-Ended Questions vs Open-Ended Questions

Close-Ended Questions	Close-Ended Questions
Do you like working with us? • Yes • No	Tell us about your experience with our organisation so far.
How satisfied are you with your current job role? • Very satisfied • Somewhat satisfied • Somewhat unsatisfied • Very unsatisfied	What do you expect from this appraisal?
How satisfied are you with your manager? • Very satisfied • Somewhat satisfied • Somewhat unsatisfied • Very unsatisfied	How will you describe your relationship with your manager?

Notes

- **Fixed alternative or multiple choice questions:** These questions provide multiple-choice answers. These questions are usually asked when the possible responses are limited and clear, such as age, gender, etc. For example:

  1. How old are you?

     ✓ 12 or younger
     ✓ 13 to 19
     ✓ 20 to 39
     ✓ 40 to 59
     ✓ 60 to 79
     ✓ 80 or older

  2. Which product would you like to see in the showroom?

     ✓ Sports Utility Vehicle
     ✓ Sedan
     ✓ Hatchback
     ✓ Convertible
     ✓ All of these

- **Dichotomous questions:** These are also close-ended questions which can be answered as Yes/No, True/False or Agree/Disagree. Examples:

  1. Have you ever purchased a product or service from our website?

     a. Yes
     b. No

  2. Do you intend to buy a new car within the next six months?

     a. Yes
     b. No

- **Rating scale/continuum questions:** These are close-ended questions where you can assign weights to each answer choice on a scale. The commonly used rating scales are:

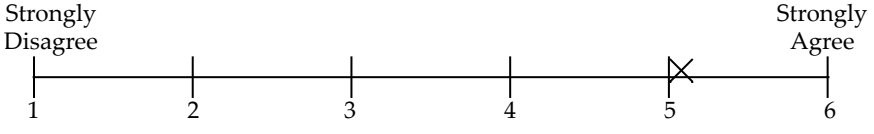
  - **Likert rating scale:** It is typically a five-, seven- or nine- point scale used to measure respondents' agreement with a variety of statements. For example:

    The website has a user-friendly interface.

    a. Strongly disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly agree

  - **Graphic rating scale:** This is a line on which respondents place a cross 'X' on any point on the line. For example:

    The customer service person used check-back to confirm orders.

  - **Itemised rating scale:** This scale is similar to the graphic scale, except that there are a number of categories which can be marked. For example:

    Evaluate each of the following attributes of our product by checking the appropriate box.

	Excellent	Very Good	Good	Average	Below Average	Poor
1. Quality	□	□	□	□	□	□
2. Size	□	□	□	□	□	□
3. Durability	□	□	□	□	□	□
4. Brand name	□	□	□	□	□	□

- **Agree-to-disagree questions:** In this type of question, respondents need to answer on the agree and disagree responses. For example:

  The sales representative spent enough time to explain the product features:

  - Strongly agree
  - Somewhat agree
  - Neutral
  - Somewhat disagree
  - Strongly disagree

- **Rank-ordering questions:** In this type of question, the respondent is asked to rank a set of items against each other. For example:

  - Rank the following in order of importance from 1 to 4 where 1 is most important to you and 4 is least important to you.

Speed of service	□
Ease of parking	□
Cleanliness	□
Friendliness of staff	□

- **Projective test questions:** Projective tests are designed to develop an in-depth understanding of hidden motivations. These questions allow respondents to 'project' their own thoughts or attitude in the response. These questions can use techniques, such as word associations or fill in the blanks. They are difficult to analyse and are usually used in exploratory research. For example:

  Complete the following sentences with the first word or phrase that comes into your mind.

  1. My father seldom _____.
  2. Most people don't know that I am afraid of _____.
  3. When I was a child, I _____.
  4. When encountering frustration, I usually _____.

7.3.1 ERRORS IN RESPONSES

While creating questionnaires, you should be aware of the following errors which may occur during responses:

- **Telescoping error:** This error occurs where people remember recent events as being more remote than they are (backward telescoping), or distant events as being more recent than they are (forward telescoping). These errors may lead to faulty marketing campaigns:

Notes

- In case of backward telescoping, respondents may overstate their intention to buy a replacement product, as they remember a recent purchase as distant.
- In case of forward telescoping, respondents may inaccurately recall the time of their last purchase.

❍ **Recall loss:** This error occurs when people forget that an event occurred at all. For events that happened in the distant past, recall loss dominates.

❍ **Differences in responses:** Sometimes responses may be inconsistent or inaccurate due to the following reasons:

- Different response styles
- Different personal factors, such as laziness, tiredness, etc.
- Different situations, such as crowded atmosphere
- Difference in administration of questionnaire, such as wording of questions
- Difference due to lack in clarity

Self Assessment Questions

4. Which question below is an open-ended question?
   a. Are you satisfied with this product?
   b. Did it act as expected?
   c. What more were you expecting?
   d. Will you purchase it?
5. Dichotomous questions are a type of _____ questions.
6. Which is not a rating scale used in questions?
   a. Comparative
   b. Multiple choice
   c. Graphic
   d. Itemised
7. You want to rate three items against each other, with 1 as most important and 3 as least important. Which type of question should you create?
   a. Rank-ordering question
   b. Agree-to-disagree question
   c. Itemised question
   d. Open-ended question
8. What do you call an error when people remember events as being more recent than they are?
   a. Recency error
   b. Recall loss
   c. Halo effect
   d. Telescoping error

7.4 STEPS OF QUESTIONNAIRE DESIGNING

The process of designing a questionnaire involves ten steps, as illustrated in Figure 3:

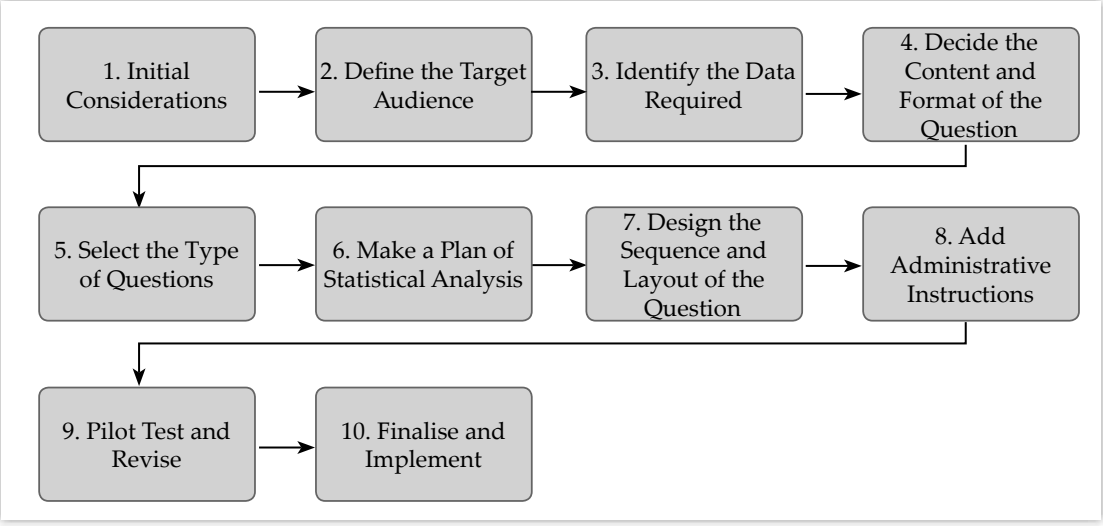


Figure 3: Steps of Questionnaire Designing

Let us discuss each step.

1. **Initial considerations:** Decide the purpose of your questionnaire. To do so, get familiar with the subject, do a literature review, formulate a hypothesis and then define the information required to test the hypothesis.
2. **Define the target audience:** Identify the target audience. Depending on it, you can choose whether the questionnaire should be administered to males/females, a particular ethnic group or race, or to people belonging to a particular country, or any such criteria.
3. **Identify the data required:** Make a list of the information/data required.
4. **Decide the content and format of the question:** Develop the questions as required. Decide on their phrasing and response format. A well-phrased question results in more accurate and useful data, as they can be easily understood by the target audience.
5. **Select the type of questions:** Choose the type of questions to be used. In explorative studies, open-ended questions are used, whereas in quantitative one, close-ended questions are used.
6. **Make a plan of statistical analysis:** This should include the statistical tests which you intend to use. It is helpful to draw a dummy table with the data of interest. This will be helpful in determining the type of results you wish to get.
7. **Design the sequence and layout of the question:** Design the sequence of questions and the layout of the questionnaire. Start with easy questions and then go on to the more difficult questions. Sensitive questions should be placed somewhere in the middle. Avoid putting the most important questions last.

Notes

8. **Add administrative instructions:** Add instructions for the administrator. Also, add definitions of keywords for the ease of participants.
9. **Pilot test and revise:** Conduct a pilot test and do revisions as necessary.
10. **Finalise and implement:** Finalise the questionnaire. Ensure that each question is clear, simple and brief, and the layout is clear. Finally, launch it on the appropriate media formats.

Self Assessment Questions

9. What is the first step to design a questionnaire?
   a. Define the target audience
   b. Decide the statistical tests to be used
   c. Define the purpose
   d. Select the type of questions to be used
10. You want to administer a questionnaire to different groups simultaneously. Which design should you use for your questionnaire?
   a. Latitudinal design
   b. Longitudinal design
   c. Cross-purpose design
   d. Cross-sectional design
11. Where should you place sensitive questions in a questionnaire?
   a. In the beginning
   b. In the middle
   c. In the last
   d. They should not be placed
12. The most important questions should be asked at the end of a questionnaire. (True/False)

7.5 DESIGNING OF AN EFFECTIVE QUESTIONNAIRE

Finally, the effectiveness of your questionnaire depends on its layout — respondents should be able to easily read, understand and answer each question you ask. Below are some tips to consider:

- **Introduction:** Start your questionnaire with a brief introduction that:
  - Informs the purpose of the questionnaire
  - Explains how the information collected will be used
  - Assures that the personal information of respondents will remain confidential
- **Typeface:** Use a clearly legible typeface. Allow for some blank space between questions.
- **No breaks:** Avoid breaks between question text or instructions to turn pages. Keep all text together for each question.
- **Instructions:** Give instructions in italics or bold font to distinguish them from the questions.

- **Answer format:** Arrange answers vertically under each question. If you need to place any explanatory text or definition, then place them in parenthesis immediately after the question.
- **Logical:** As far as possible, the questionnaire should reflect some natural flow of thoughts, a sequence of events, or a logical conversation, depending upon the subject matter.
- **Sensitive information:** Sensitive topics, whether personal or societal, should be explored appropriately through indirect questions and are best suited to be placed at the end of survey.
- **Pilot study:** Always pilot the questionnaire either with some colleagues or people from the target audience. This will help in detecting any flows prior to the main survey.
- **Grouping:** Section heading may be used appropriately, and similar questions related to a particular topic should be grouped together.
- **Neutral language:** The terminology used should be such that it does not lead the respondents to answer in one particular way, i.e., positive or negative.
- **Brevity:** Make use of relevant, clear, concise and efficient questions. Clear and concise questions will be able to achieve the desired results rather than including too many questions.

Self Assessment Questions

13. What should not be used while designing a questionnaire?
    a. Introduction stating the purpose of the questionnaire
    b. Legible typeface
    c. Blank space between questions
    d. Breaks between question text
14. What can you use to distinguish instructions from the questions?
    a. Black regular font
    b. Bold or italicised font
    c. Black underlined font
    d. Red font
15. When should the important topics ideally be covered in a questionnaire?
    a. In the beginning
    b. In the middle
    c. In the last
    d. Somewhere between the middle and the last
16. A good idea is to start a questionnaire with specific questions and then move on to general topics towards the end. (True/False)

Notes

Activity

Develop a complete questionnaire for a survey that you will administer to fellow students in your university. Develop a topic for your questionnaire, determine the set of constructs you want to measure in the questionnaire and draft each questionnaire item. Make sure of the following requirements:

- The questionnaire will be administered to fellow students, so should be appropriate for this population.
- The questionnaire must include the following:
  - An introduction describing the purpose of the survey
  - At least 15 questions
  - At least three open-ended questions
  - At least three close-ended questions
  - At least one potentially sensitive question

7.6 SUMMARY

- Questionnaires are used to collect statistical data from a group of respondents. They are economical, quick, easily implementable and cover a wide range of population. However, they have the disadvantage of inviting limited response. Therefore, it is important to design effective questionnaires.
- A well-designed questionnaire has the following features:
  - They are visually appealing, intriguing, engaging and brief.
  - The questionnaire should be to the point and without any unnecessary questions.
- You can add various types of questions in a questionnaire, depending on the purpose, question content and responses required:
  - Open-ended questions
  - Fixed alternative or multiple-choice questions
  - Dichotomous questions
  - Rating scale/continuum questions
  - Agree-to-disagree questions
  - Rank-ordering questions
  - Projective method questions
- Questionnaires are vulnerable to the following types of errors from respondents:
  - Telescoping error
  - Recall loss
  - Differences in responses

- There are ten steps to design a questionnaire:
  1. Initial considerations
  2. Define the target audience
  3. Identify data required
  4. Decide question content and format
  5. Select the type of questions
  6. Make a plan of statistical analysis
  7. Design the sequence and layout of the question
  8. Add administrative instructions
  9. Pilot test and revise
  10. Finalise and implement
- While designing an effective questionnaire, you should consider the following tips:
  - Start with a brief introduction
  - Use a legible typeface
  - Avoid breaks between question text/instructions
  - Give instructions in italics or bold
  - Arrange answers vertically under each question
  - Give easy questions in the beginning, which cover important topics of interest
  - Go from generic to specific questions
  - Use logical flow of questions
  - Use a transitional statement when switching to different topic areas
  - Be crisp and comprehensive

7.7 KEY WORDS

- **Questionnaire:** This is a set of written questions with a choice of answers for the purpose of a survey.
- **Face validity:** It indicates whether a questionnaire appears to measure what it claims to.
- **Content validity:** Content validity refers to the extent to which a questionnaire fully measures the construct of interest.
- **Construct validity:** It measures the extent to which a questionnaire captures a specific trait.
- **Concurrent validity:** It measures the degree to which a questionnaire compares to a currently existing criterion.

Notes

- **Predictive validity:** It measures the degree to which a questionnaire predicts a future criterion.
- **Test-retest reliability:** It measures how close the results are when measured successively under the same conditions.
- **Internal consistency reliability:** It measures how well a questionnaire is actually measuring what you want to measure.
- **Open-ended questions:** These are unstructured questions which enable respondents to elaborate their answers and express what they really want to say.
- **Close-ended questions:** These are structured questions where respondents get to choose from a limited number of choices provided to them. These questions can be of multiple choices, dichotomous or rating scale questions.

7.8 CASE STUDY: QUESTIONNAIRE DESIGNING FOR MARKET RESEARCH IN THE PET CARE INDUSTRY

The pet care industry is growing tremendously in India. From 2012 to 2017, the industry moved ahead with the Compound Annual Growth Rate (CAGR) of 23%. The industry is likely to grow with a CAGR of at least 20% up to 2021–22. Dog food contributed to a majority share of 80% in value in the year 2017. The growth of the pet care industry can be attributed to the following factors:

- Rise in disposable income
- Change in consumption patterns
- Urban lifestyle

In such a setup, various pet care and grooming companies have sprung up. Buddy-Pets is one such venture. It assists people who would like to take their pets along while they go on a vacation. The founder Amit Kumar got the idea for the start-up when he needed to step out of town for a break and could not find a suitable boarding facility for his 5-month-old Labrador Lucy. So, he decided to set up a start-up to help like-minded people.

Buddy-Pets helps plan their vacations by providing a 24x7 boarding and day care facility for pets. It also helps find the right grooming and pet supplies services. It even provides a pet-friendly environment where owners can come with pets to dine in, socialise and play in a garden cafe.

Buddy-Pets faces the challenge of drawing out a strategic marketing plan to make its venture fundable by the right target group. It wants to position itself in the operational gap in the current pet care setup, which mostly consists of pet shops, clinics and grooming centres with referral tie-ups for boarding establishments. It also wants to study customer preferences regarding pet care facility. Thus, Buddy-Pets wants to do a market research to:

- Analyse customer preferences for the desired pet care facility in a major city, including Delhi, Mumbai and Bangalore
- Identify and evaluate opportunities available in these cities

- Develop implementable marketing strategies
- Evaluate competitive dynamics from traditional pet shops and boarding facilities

The purpose of this research is to design a marketing strategy for Buddy-Pets.

QUESTIONS

1. What considerations should you keep in mind while designing a questionnaire for the market research?

   (**Hint:** Initial considerations, target audience, type of design, data required, type of questions, tips, etc.)

2. What steps will you take to design a questionnaire?

   (**Hint:** Initial considerations, define the target audience, make a plan of statistical analysis, etc.)

3. What challenge does Buddy-Pets face?

   (**Hint:** The challenge of making a marketing strategic plan which attracts venture fund by the right target group)

4. What was the purpose of the research in the case?

   (**Hint:** To design a market strategy for Buddy-Pets)

5. How did Buddy-Pets want to position itself in the existing market?

   (**Hint:** To position itself as an operational gap filler by studying customer preferences for pet care facility.)

7.9 EXERCISE

1. What are the attributes of a well-designed questionnaire?
2. List any five dos and don'ts of questionnaire design.
3. Explain any five types of questions which may be included in a questionnaire.
4. Describe the differences between open-ended and close-ended questions.
5. Enumerate the steps in a questionnaire designing.

7.10 ANSWERS FOR SELF ASSESSMENT QUESTIONS

Topic	Q. No	Answer
Concept of Questionnaire Designing	1.	c. Speedy results
	2.	False
	3.	d. Leading question
Types of Questions in Questionnaire Designing	4.	c. What more were you expecting?
	5.	close-ended
	6.	b. Multiple choice
	7.	a. Rank-ordering question
	8.	d. Telescoping error

Notes

Topic	Q. No	Answer
Steps of Questionnaire Designing	9.	c. Define the purpose
	10.	d. Cross-sectional design
	11.	b. In the middle
	12.	False
Designing of an Effective Questionnaire	13.	d. Breaks between question text
	14.	b. Bold or italicised font
	15.	a. In the beginning
	16.	False

7.11 SUGGESTED BOOKS AND E-REFERENCES

SUGGESTED BOOKS

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CHAPTER 8

Data Processing and Analysis

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LEARNING OBJECTIVES

After studying this chapter, you will be able to:

- Explain the concept of data processing
- Describe the concept of data analysis
- Discuss the measures of central tendency
- Explain the measures of skewness
- Discuss the measures of relationship
- Describe various charts used in data analysis

8.1 INTRODUCTION

In the previous chapter, you studied about questionnaire designing. Now, you will learn the significance and ways of processing and analysing data retrieved from such questionnaires.

Data in its raw form does not convey any useful information. It needs to be organised properly to extract the relevant information and make it fit for research. This is done with the help of data processing that involves various steps, including editing, coding, classification, data entry and tabulation.

After processing data, you need to analyse it to find answers to the research problem. You can use various statistical measures, such as the measures of central tendency, dispersion, skewness and relationship to analyse data. The selection of a measure depends upon the type of the research problem. For example, if you wish to find out the average marks of students of class IX in English, then you would use the measures of central tendency. However, if you want to know the relationship between the eating habits of children and problems of obesity, then you would use the measures of relationship. It is important to note that no single statistical measure is complete in itself to analyse a data series. Therefore, you should use an optimum combination of different measures to address the problem at hand in the most effective manner. Any carelessness in data processing and data analysis can result in erroneous research findings. Moreover, these data tasks form a major part of research and consume considerable time and effort of the researcher. Therefore, it is advisable to remain extra vigilant while processing and analysing data for making the research as authentic as possible.

The chapter begins by explaining the concept of data processing and data analysis. Next, it talks about the measures of central tendency, including mean, median and mode. Information is also provided about the measures of dispersion and the measures of skewness. It also explains the measures of relationship, including correlation analysis, regression analysis and multiple regression. Towards the end, the chapter discusses other statistical measures used for data analysis.

Notes

8.2 CONCEPT OF DATA PROCESSING

Data processing is a process of converting raw data (quantitative or qualitative) into a form which is fit for analysis. The process involves various steps shown in Figure 1:

Figure 1: Steps of Data Processing

Let us now discuss each step of data processing in the following section.

8.2.1 EDITING

Editing refers to reviewing the collected data to check whether it is valid or not. Data is examined to detect errors and omission. Errors are corrected, omitted data is filled in, and data is prepared for further processing. The data is retained for analysis.

The editor is responsible for ensuring that the data is accurate, uniform, as complete as possible and acceptable for tabulation. Editing helps in filtering ambiguous information that can create a problem at the time of data analysis. Ambiguous information can be in the form of biased or incorrect responses in a questionnaire and such information needs to be deleted.

8.2.2 CODING

Coding is the process of providing some codes to the data in the form of symbols, characters and numbers. It helps the researcher in interpreting the data and deriving accurate results. If the data is generated with the help of a questionnaire, it can be coded either at the time of framing the questionnaire or after collecting the data.

- The data that is already coded is known as **precoded data**.
- The data that is coded at the time of data processing is known as **postcoded data**.

Generally, a questionnaire may contain the following types of questions:

- **Interval-scale questions:** An interval scale is any range of values that have a relevant mathematical difference but no true zero. Any question where the respondent must enter a temperature value is an interval scale question because degrees are interval measurements. The data collected through interval-scale and closed-ended questions is an example of precoded data.
- **Closed-ended questions:** These questions are those for which a researcher provides respondents with options from which to choose a response.
- **Open-ended questions:** These questions are those which require more thought and more than a simple one-word answer. The data collected through open-ended questions is an example of postcoded data. Apart from these, the questionnaire can also include questions based on nominal scale, ordinal scale and ratio scale.

Precoded data has certain advantages over postcoded data:

- It is easier to code.
- It reduces the effort in data processing.
- It leads to fewer chances of human error during data processing. Let us understand the concept of coding with the help of an example.

Following questionnaire aims to measure the comfort level of women in a job after marriage. Questions 1 to 5 are multiple-choice questions (close-ended questions), questions 6 to 14 are interval-scale questions and questions 15–16 are dichotomous questions.

Questions 1–5: Tick all the options that apply to you.

1.	**Age Group (years)**	a. 20-30	b. 30-40	c. 40-50	d. 50 and above				
2.	**Marital Status**	a. Married	b. Unmarried	c. Divorced	d. Please specify… (for example, engaged, widow or whatever)				
3.	**Children**	a. None	b. One	c. Two	d. More than two				
4.	**Working Status**	a. Working	b. Non-working	c. Retired from the job	d. Searching for the job	e. On leave			
5.	**Work Type**	a. Full-time	b. Part-time	c. Not Applicable					

Questions 6–14: Give the ratings in the following questions as per your choice. The rating of 1 means the lowest and 5 means the highest.

6.	**My work gives me satisfaction more than anything.**	1	2	3	4	5
7.	**I am able to manage my professional and personal life perfectly.**	1	2	3	4	5
8.	**I go for holidays with my family frequently.**	1	2	3	4	5
9.	**I am able to reach office on time.**	1	2	3	4	5
10.	**I reach my home on time in the evening.**	1	2	3	4	5
11.	**I complete most of my work projects on time.**	1	2	3	4	5
12.	**I play with my children daily.**	1	2	3	4	5
13.	**I reach home late at nights.**	1	2	3	4	5
14.	**I most often extend the deadline for submission of my projects.**	1	2	3	4	5

Questions 15–16: Answer in Yes or No.

15. I have kept a mind for household work. ☐ Yes ☐ No

Notes

16. **I have kept babysitters to look after my children.** ☐ Yes ☐ No ☐ Not Applicable

8.2.3 CLASSIFICATION

Classification refers to categorising the coded questions into different segments as per their relevance. This is done to simplify data processing and analysis to a great extent. It is important to note that variables in a segment possess certain similar characteristics. For example, demographic information is a segment that includes variables, such as age, education and work experience of the respondents.

Questions in a questionnaire can be classified into qualitative and quantitative questions:

- **Qualitative questions:** The classification of qualitative questions is called statistics of attributes. These attributes cannot be measured directly in numbers. However, qualitative attributes can be quantified. Examples of attributes are honesty and attitude of the respondents.
- **Quantitative questions:** The classification of quantitative questions is called statistics of variables. These variables can be expressed in numeric form, such as demographic factors including age and income.

These variables can be grouped in the form of class intervals. A class interval contains a lower limit and an upper limit. The difference between the two limits is called class magnitude. For example, in the class interval 25-35, 25 is the lower limit and 35 is the upper limit.

Class intervals can be inclusive or exclusive.

- **Inclusive class intervals**: If the value of the upper limit is included in the class magnitude, it is an **inclusive class interval**. For example, the value 35 would be included in the inclusive class 25-35. Thus, the inclusive class intervals would be 25-35, 36-45, 46-55, and so on.
- **Exclusive class intervals**: If the value of the upper limit is not included in the class magnitude, then it is known as an **exclusive class interval**. For example, the value 35 would not be included in the class 25-35, but it would be included in group 35-45. Thus, the exclusive class intervals would be 25-35, 35-45, 45-55, and so on.

Another important term to remember during classification is frequency. **Frequency** is the number of occurrences of a repeating event per unit of time. Table 1 shows the number of respondents in each age group:

Table 1: Frequency Distribution

Age Group (Class Interval)	Number of Respondents
25-35	10
35-45	4
45-55	7
55-65	2

In Table 1, 10 respondents are in the age group of 25-35. Thus, 10 is the frequency of the class interval 25-35. When class intervals and frequencies are represented in a tabular form, as in Table 1, such a representation is known as **frequency distribution**.

8.2.4 DATA ENTRY

After classifying data, the researcher enters data in the computer. If wrong data is entered, then the result would be inaccurate. There are various statistical or database management software for data entry, such as:

- Bio-Medical Data Package (BMDP)
- Statistical Programming Language (S-PLUS)
- Statistical Analysis System (SAS)
- Statistical Package for Social Sciences (SPSS)

Out of all this software, SPSS is widely used by researchers for data entry.

8.2.5 TABULATION

Tabulation refers to presenting data in the form of a table so that it can be easily analysed. In this stage, the frequencies of the dataset are also computed.

There are three types of frequencies, namely absolute frequency, relative frequency and cumulative frequency.

- **Absolute frequency** is the exact frequency given by the respondents.
- **Relative frequency** is calculated with relation to the frequency of the other class intervals. It is the percentage of all respondents who have given a particular response.
- **Cumulative frequency** is the percentage of all respondents who have given a response equal or less than a particular value.

There are two types of frequency distributions, which can be put into a tabular form:

1. **Two-way frequency distribution:** In this type of frequency distribution, two variables can be analysed at a time. This frequency distribution is also known as cross tabulation.
2. **One-way frequency distribution:** In this type of frequency distribution, a single variable is analysed.

Table 2 shows an example of the one-way frequency distribution.

Table 2: One-Way Frequency Distribution

Age Group (Class Interval)	Number of Persons (Frequency or Absolute Frequency)	Relative Frequency	Cumulative Frequency
20-30	10	17.86	17.86
30-40	14	25.00	42.86
40-50	20	35.71	78.57
50 and above	12	21.43	100.00
Total	56	100	100

Notes

In Table 2, age group is taken as a variable and different types of frequencies are calculated. As already discussed, absolute frequency is the precise frequency given by the respondents. Relative frequency can be calculated by dividing the absolute frequency with the total frequency. For example, in case of the 20-30 age group, absolute frequency is 10 and the total frequency is 56; therefore, the relative frequency is 17.86 (10/56×100). Cumulative frequency can be calculated by adding up the relative frequency of the present class interval (whose cumulative frequency we are calculating) and the relative frequency for the following class interval. For example, in case of the 20-30 and 30-40 age groups, the relative frequencies are 17.86 and 25.00, respectively. Therefore, the cumulative frequency in the case of the 30-40 age group is 42.86 (17.86 + 25.00).

Self Assessment Questions

1. _____ helps in filtering ambiguous information that can create a problem at the time of analysis.
2. Ambiguous information can be in the form of biased or incorrect responses given by the respondents. (True/False)
3. The data that is coded at the time of data processing is known as _____ data.
4. Data entry refers to presenting data in the form of a table so that it can be easily analysed. (True/False)

8.3 CONCEPT OF DATA ANALYSIS

After processing data, a researcher analyses it to retrieve meaningful information. Data analysis is broadly classified into two types, as shown in Figure 2:

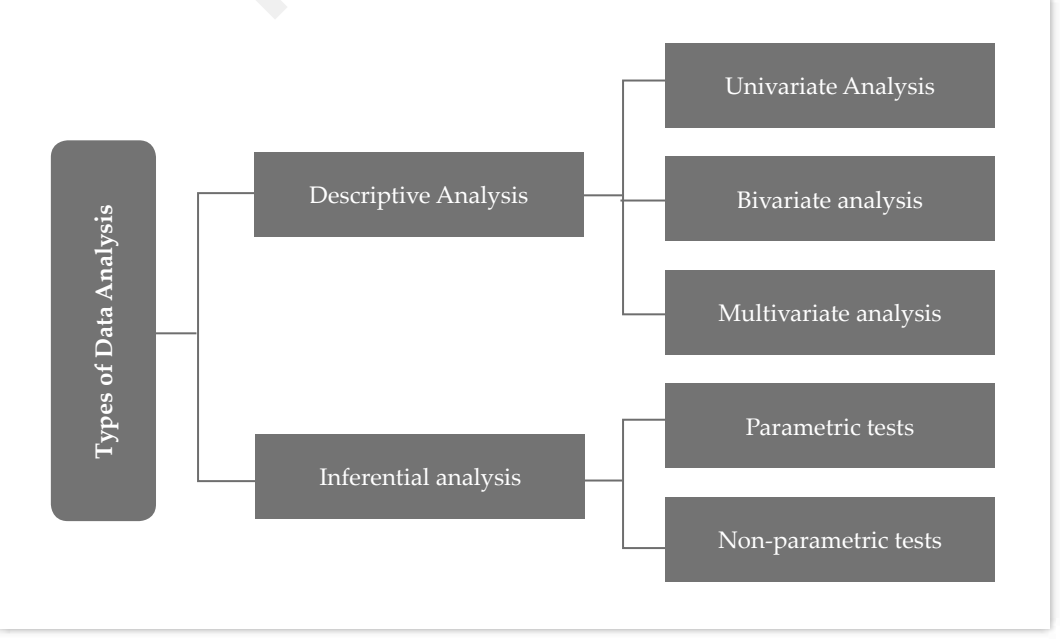


Figure 2: Types of Data Analysis

Let us now discuss each type in detail:

- **Descriptive analysis**: In this type of data analysis, the distribution patterns and characteristics of different types of variables are analysed. There are three types of descriptive analysis:
  - **Univariate analysis:** This analysis studies a single variable. Examples include measures of central tendency, dispersion and skewness. However, sometimes these measures can also be used for bivariate and multivariate analysis.
  - **Bivariate analysis:** In this analysis, two variables are studied. One variable can be classified as independent and the other as dependent. Examples are rank correlation, simple correlation and simple regression.
  - **Multivariate analysis:** In this analysis, more than two variables are studied. Among the variables being studied, there can be more than two independent variables and more than one dependent variable. Examples include multiple correlations and regressions.
- **Inferential analysis:** In this type of data analysis, significance tests are used to check the validity of a hypothesis for studying a problem. There are two types of significance tests:
  - **Parametric tests:** These tests make assumptions about the parameters of the population from which a sample is derived. Examples of parametric tests include z-test and t-test.
  - **Non-parametric tests:** These tests do not make any assumptions about the parameters of the population from which the sample is derived. An example of a non-parametric test is the Kruskal Wallis test.

SELF ASSESSMENT QUESTIONS

5. Simple regression is which type of data analysis?
   a. Univariate analysis
   b. Bivariate analysis
   c. Multivariate analysis
   d. Inferential analysis
6. Descriptive analysis uses tests of significance to check the validity of a hypothesis for studying a problem. (True/False)

8.4 MEASURES OF CENTRAL TENDENCY

The measures of central tendency are used to study the distribution pattern of a dataset. These measures give a central value that represents the large chunk of data analysed. The central value is nothing but the average of data collected.

Notes

Figure 3 displays the various measures of central tendency:

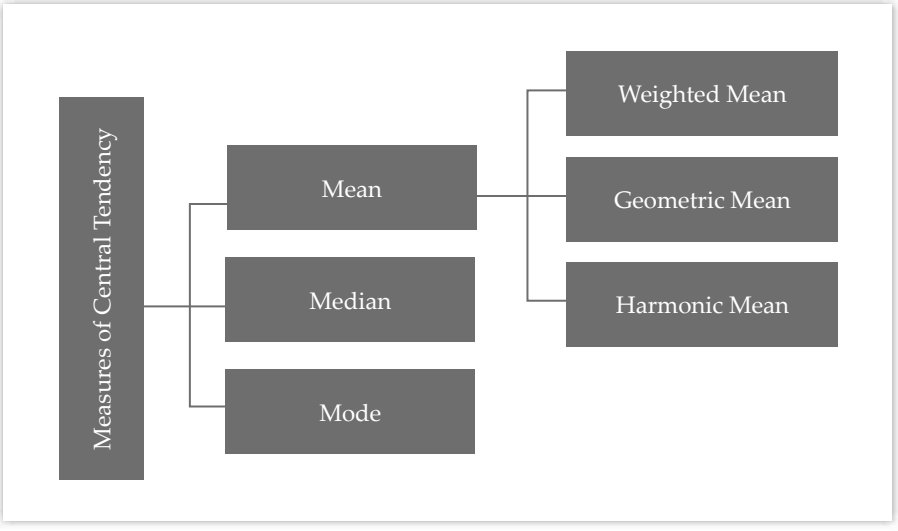


Figure 3: Measures of Central Tendency

Let us now discuss each measure.

8.4.1 MEAN

Mean represents the value calculated after dividing the sum of observations by the total number of observations (n) taken. It is also known as arithmetic mean.

Following formula is used to calculate mean:

Mean (X) = $\overline{X} = \sum X_i/n$

Where, $\overline{X}$ = Symbol for mean

$\sum X_i$ = Sum of all observations/frequency

$X_i = X_1 + X_2 + \ldots + X_n$

n = Number of observations

Let us understand the concept of arithmetic mean with the help of an example.

Suppose you want to find the average weight of a group of five friends. Table 3 shows the weight of each person in the group:

Table 3: Weights of Five Friends

People	Weight (kg)
Jenny	35
Robert	40
Ella	34
Andy	39
Eliza	42

The average weight of five friends can be calculated as follows:

$\overline{X} = \sum X_i/n$

Where, $\overline{X}$ = Average weight of five friends

$\sum X_i$ = Sum of the weights of five friends $X_i = 90$

n = 5

$\overline{X} = (35 + 40 + 34 + 39 + 42)/5$

$\overline{X} = 190/5$

$\overline{X} = 38$ kg

Therefore, the average weight of five friends is 38 kg.

You can calculate different types of mean:

- **Weighted mean:** This mean is calculated after considering the weight attached to each item. The formula used to calculate weighted mean is as follows:

  Weighted Mean $(\overline{X}_w) = \sum W_i X_i/w_i$

  Where, $\overline{X}_w$ = Symbol for weighted mean

  X_i = Value of the i^{th} item

  W_i = Weight assigned to the i^{th} item

  w_i = Number of weights assigned

  Example of Weighted Mean

  A school grades its students by using weighted mean scores as follows: 15% weightage is assigned for homework, 15% weightage is assigned for extracurricular activities, and 70% weightage is assigned for the examination. Aditya scored 60 marks, 70 marks and 55 marks for homework, extracurricular activities and in examination, respectively. Find the weighted score of Aditya if the total score is 100.

  Now, we calculate the weighted mean as follows:

  Weighted Mean ($\overline{X}_w$) = (0.15 × 60) + (0.15 × 70)+(0.70 × 55)

  = 9 + 10.5 + 38.5

  = 58

- **Geometric mean:** Geometric mean represents the nth root of the product of all the values or observations involved in a research. The formula used to calculate geometric mean is as follows:

  $\overline{X}_g = \sqrt{n (x_1)(x_2)(x_3)...(x_n)}$

  Where, $X_1, X_2, ...X_n$ = Observations

  n = Number of observations

  Example of Geometric Mean

Notes

You want to calculate the geometric mean of four observations: 10, 12, 10 and 11.

The calculation of geometric mean is shown as follows:

$X_1, X_2, X_3, X_4 = 10, 12, 10, 11$

n = 4

$$\overline{X}_g = \sqrt[4]{X_1 \times X_2 \times X_3 \times X_4}$$

$$\overline{X}_g = \sqrt[4]{10 \times 12 \times 10 \times 11}$$

$$\overline{X}_g = \sqrt[4]{1320} = 10.718$$

Therefore, the geometric mean of four observations is 10.7 years.

- **Harmonic mean:** Harmonic mean refers to reciprocal of the average of the reciprocals of the values in a data series (or observations). The formula to calculate harmonic mean is as follows:

Harmonic mean $(\overline{X}_H)$ = Rec. (Rec. X_1 + Rec. X_2 +…....+ Rec. X_n)/n

Where, Rec. X_1, Rec. X_2 …. Rec. X_n = Reciprocal of observations 1, 2,....., n

n = Number of observations

Example of Harmonic Mean

Calculate the harmonic mean of four observations: 10, 12, 10 and 11.

Harmonic mean is calculated as:

$(\overline{X}_H)$ = Rec. [(Rec. X_1 + Rec. X_2 + + Rec. X_4)/n]

Where, Rec. X_1, Rec. X_2 …. Rec. X_4 = 1/10, 1/12, 1/10, 1/11

n = 4

$$\overline{X}_H = \text{Rec.}\left[\left(\frac{1}{10}+\frac{1}{12}+\frac{1}{10}+\frac{1}{11}\right)\Big/4\right]$$

$$\overline{X}_H = \text{Rec.}\frac{\left(\frac{247}{660}\right)}{4} = \text{Rec.}\frac{247}{660\times 4} = \frac{660\times 4}{247}$$

$$\overline{X}_H = \text{Rec.}\frac{\left(\frac{247}{660}\right)}{4} = \text{Rec.}\frac{247}{660\times 4} = \frac{660\times 4}{247} = 10.68$$

Therefore, the harmonic mean of the four observations is 10.7 years. It is used for units that add up as reciprocals in a sequence, such as speed, distance, capacitance in series or resistance in parallel.

8.4.2 | MEDIAN

Median is defined as a central or mid-value of a dataset. Median divides a dataset into two halves – one half contains the values greater than the mid-value (or median) and the other half contains the values less than the mid-value.

Before calculating median, you need to arrange the dataset in the ascending or descending order. The formula to calculate median is as follows:

n = Number of observations

Now, if n is an odd number

Median = Value of $(n + 1/2)^{th}$ observation

Now, if n is an even number

Median = Value of {[$(n/2)^{th}$ observation + $(n + 1/2)^{th}$ observation]/2}

Let us understand the concept of median with the help of an example.

A group of 17 people gave the following ratings to a book on a 5-pointer scale (where 1 is the lowest rating and 5 is the highest rating):

2, 5, 3, 4, 1, 5, 4, 3, 1, 2, 5, 4, 3, 2, 1, 5, 4

Now you want to calculate the average rating by using median. To do so, arrange the data in the ascending order, as follows:

1, 1, 1, 2, 2, 2, 3, 3, 3, 4, 4, 4, 4, 5, 5, 5, 5

Since the number of observations is odd, the following formula will be used to calculate median:

Median = Value of $(n + 1/2)^{th}$ observation

Median = $(17 + 1/2)^{th}$ observation

Median = 9^{th} observation

Median = 3

Therefore, the median rating for the book is 3.

Now, if n is an even number, then we calculate median as the simple average of the middle two numbers. In other words, median is the simple average of the $n/2^{th}$ and $(n/2 + 1)^{th}$ terms.

Now, if a group of 20 people gave their ratings to a movie on a 5-point scale as:

2, 5, 3, 4, 1, 5, 4, 3, 1, 2, 5, 4, 3, 2, 1, 5, 4, 1, 2, 3

Where, 1 is the lowest rating and 5 is the highest rating

Now, to calculate the average rating using median, all the 20 observations are arranged in ascending order as:

1, 1, 1, 1, 2, 2, 2, 2, 3, 3, 3, 3, 4, 4, 4, 4, 5, 5, 5, 5

Here, median is the average of middle two values, i.e., values at 10th and 11th positions. This is calculated as:

Median = (3 + 3)/2 = 3

Notes

8.4.3 MODE

Mode refers to the value that has the highest frequency in a data series.

According to Croxton and Cowden, *the mode of a distribution is value at the point around which the items tend to be most heavily concentrated. It may be regarded as the most typical of a series of values.*

Let us learn to calculate mode with the help of an example. Suppose the marks of five friends in a science paper are 70, 90, 50, 70, and 30. You want to find the mode of their marks.

You need to find the highest frequency of the present data to calculate mode. Here, the number having the highest frequency is 70 as it occurs two times; therefore, the mode of students' marks is 70.

Mode is used as the most important statistic for nominal data where values are names rather than numbers. In such cases, there is no concept of centre because there are no numbers. In addition, when we are dealing with continuous variables, probability that observations occurring in the data sample are different is 1. Therefore, mode cannot be used for continuous variables.

Mode is not considered a true measure of central tendency because of two reasons:

i. It is not necessary that one data series has only one mode because many numbers in the data series can have the highest frequency.

ii. Mode does not consider all the frequencies to arrive at the central value of the data series. Therefore, the results of mode are not reliable.

iii It is possible that a series has observations that occur only once. In such cases, mode does not exist.

Let us summarise mean, median and mode as follows:

- **Mean:** Mean represents the average value in a dataset.
- **Median:** Median represents the middle value in a dataset.
- **Mode:** Mode represents the most common value in a dataset.

The measures of central tendency used for different types of variables are shown in Table 4 as follows:

Table 4: Types of Variables and Measures of Central Tendency

Types of Variables	Best Measure of Central Tendency
Nominal	Mode
Ordinal	Median and Mode
Interval/Ratio (not skewed)	Mean, Median and Mode
Interval/Ratio (not skewed)	Median and Mode
* For skewed data, median is better than mean	

Self Assessment Questions

7. Mean represents the value that you get after dividing the sum of observations by the total number of observations taken. (True/False)
8. _____ mean represents the nth root of the product of all the values or observations involved in the research.
9. Median can be defined as a central value that divides a dataset into two halves. (True/False)

8.5 MEASURES OF DISPERSION

Using different measures of central tendency, you can find out the mean value, but these measures do not explain the scattering of values near the mid-value in a data series. The measures of dispersion can be used to study the dispersed values near the mean value. Figure 4 shows the measures of dispersion:

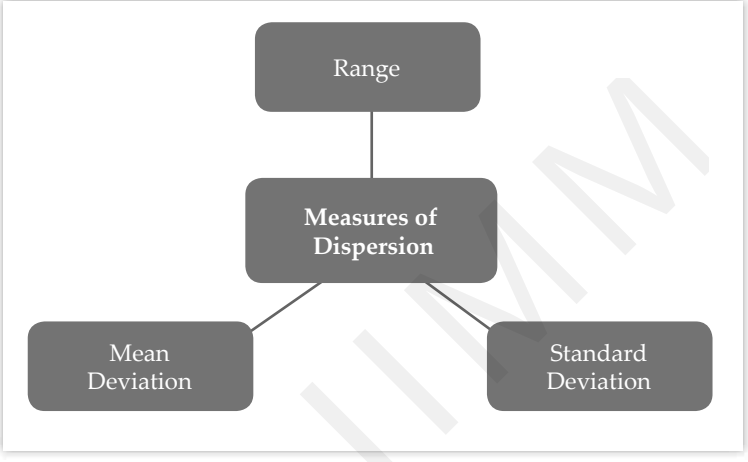


Figure 4: Measures of Dispersion

Let us now discuss each measure of dispersion.

8.5.1 RANGE

Range represents the difference between the highest value and the lowest value in a data series. It is considered as a rough measure of variability because it depends on the size of the data series. When the highest (H) and/or the lowest (L) data point in a data series changes, the range also changes.

The formula used to calculate range is as follows:

Range = (Highest value of data series – Lowest value of data series)

Let us learn to calculate range with the help of the preceding example in which a group of 17 people rated a book on a 5-pointer scale, where 1 is the lowest rating and 5 is the highest rating. The rating given by the 17 people is as follows:

2, 5, 3, 4, 1, 5, 4, 3, 1, 2, 5, 4, 3, 2, 1, 5, 4

Notes

Now, you want to calculate the range for the data series.

To do so, you need to find the highest and lowest values of the data series. In the present case,

Highest value of data series = 5

Lowest value of data series = 1.

Therefore, the range would be:

Range = (Highest value of data series – lowest value of data series)

Range = (5 – 1)

Range = 4

Therefore, the range of the ratings given by 17 people to a book is 4.

8.5.2 | MEAN DEVIATION

Mean deviation represents the extent of deviation of values from the mean.

According to **Clark and Schkade**, *average deviation is the average amount of scatter of the items in a distribution from either the mean or the median, ignoring the signs of the deviations. The average that is taken of the scatter is an arithmetic mean, which accounts for the fact that this measure is often called the mean deviation.*

Mean Deviation is used to measure variability across a data series.

The formula used to calculate Mean Deviation is as follows:

Mean Deviation (MD) = $\sum |X_i - \overline{X}| / n$

Where X_i = Individual observation

$\overline{X}$ = Mean/Median/Mode

n = Number of observations

With the help of MD, you can also calculate the coefficient of MD. The coefficient of MD refers to the relative measure of dispersion that can be calculated by dividing MD with mean/median/mode.

The formula to calculate the coefficient of mean deviation is as follows:

Coefficient of MD = $MD/\overline{X}$

Where

$\overline{X}$ = Mean/Median/Mode

Let us understand the concept of MD and the coefficient of MD with the help of an earlier example in which you calculated the average weight of five friends.

Table 5 shows the data used for calculating mean deviation:

Table 5: Weights of Five Friends

People	Weight (kg)	$\lvert X_i - \bar{X} \rvert$
Jenny	35	$\lvert 35 - 38 \rvert = 3$
Robert	40	$\lvert 40 - 38 \rvert = 2$
Ella	34	$\lvert 34 - 38 \rvert = 4$
Andy	39	$\lvert 39 - 38 \rvert = 1$
Eliza	42	$\lvert 42 - 38 \rvert = 4$
Total		14

The formula to calculate MD is shown as follows:

$$\bar{X} = \frac{35 + 40 + 34 + 39 = 42}{5} = 38$$

Mean Deviation (M.D.) = $\sum \lvert X_i - \bar{X} \rvert / n$

M.D. = 14/5

M.D. = 2.8

Coefficient of Mean Deviation = M.D./$\bar{X}$

= 2.8/38

= 0.074

Therefore, the dispersion of the weight of five friends from the mean value is 2.8. Therefore, the weight of all friends is dispersed more or less by 2.8 kg from the average weight. The relative measure of weight is 0.074.

8.5.3 | STANDARD DEVIATION

Standard Deviation is used to calculate the scattering of values in a given dataset. The symbol used to represent standard deviation is sigma (σ). Standard Deviation (SD) is the square root of variance of a data series. The formula used to calculate SD is as follows:

For research where the entire population is considered,

SD of population $\sigma = \sqrt{\frac{\sum (X_i - \bar{X})^2}{n}}$

and σ = Parameter of the population

For research where only a sample is considered,

SD of Sample $S = \sqrt{\frac{\sum (X_i - \bar{X})^2}{n}}$

Notes

and S = Statistics of sample

Also note that the square of SD is called variance

Population variance = σ^2 and Sample variance = S^2

Sample statics is used to estimate population parameter. S^2 is an unbiased estimate of σ^2.

If the observations are grouped into a frequency table, then the formulae for SD and variance change as follows:

$$\sigma = \sqrt{\frac{\sum (X - \bar{X})^2 f}{n}}$$

$$\text{and } \bar{X} = \frac{\sum Xf}{\sum f}$$

$$n = \sum f$$

$$\text{Therefore, } \sigma^2 = \frac{\sum (X - \bar{X})^2 f}{n}$$

The coefficient of SD can be calculated by dividing SD with the mean of the series. It is a relative measure of dispersion.

Let us understand the concepts of SD, the coefficient of SD, and the coefficient of variance with the help of an example.

Suppose you want to calculate the standard deviation of the weights of five friends shown in the preceding example. Table 6 shows the data used to calculate the standard deviation, the coefficient of standard deviation, and the coefficient of variance:

Table 6: Weights of Five Friends

People	Weight (kg) (X_i)	$(X_i - \bar{X})$	$(X_i - \bar{X})^2$
Jenny	35	– 3	9
Robert	40	2	4
Ella	34	– 4	16
Andy	39	1	1
Eliza	42	4	16
Total			$\Sigma(X_i - \bar{X})^2 = 46$

The calculation of standard deviation is as follows:

$$\bar{X} = \frac{35 + 40 + 34 + 39 = 42}{5} = 38$$

$(\sigma) = \sqrt{\sum} (X_i - \overline{X})^2/n$

$= \sqrt{46/5} = \sqrt{9.2}$

$= 3.033$

The calculation of coefficient of SD is as follows:

Coefficient of Standard Deviation = SD/X

$= 3.03/38$

$= 0.0798$

SELF ASSESSMENT QUESTIONS

10. _____ is used to study the scattered value near the mean value of a data series.
11. Which formula is used for calculating the range of a data series?
    a. Highest value of series – Lowest value of series
    b. Lowest range – Highest range
    c. Lowest value of series – Highest value of series
    d. None of these
12. Coefficient of Mean Deviation = _____
13. The symbol used to represent Standard Deviation is _____.

8.6 MEASURE OF SKEWNESS

A frequency distribution can be represented by drawing a curve or a graph. The measure of skewness is used to study the shape of a curve that can be drawn by plotting the data of a frequency distribution on a graph.

As you have learned in the preceding sections, through a measure of central tendency, you measure the concentration of values of a data series in the middle of a frequency distribution. Through a measure of dispersion, you measure the scattering of values near the middle value of the data series.

It may be possible that two data series, which are widely different in nature and composition, have the same mean and standard deviation. However, when you plot the data of such series on graphs, you obtain curves with different shapes. This shows that the measures of central tendency and dispersion are not sufficient to study the frequency distribution of a data series because they do not talk about the shape of the frequency distribution curves. Therefore, you need skewness to gain an understanding of the different shapes of various frequency distribution curves.

The measure of skewness is used when the concentration of values of a data series is more on a single side that is either positive or negative.

NOTES

Skewness can be classified as positive skewness and negative skewness. This is shown in Figure 5:

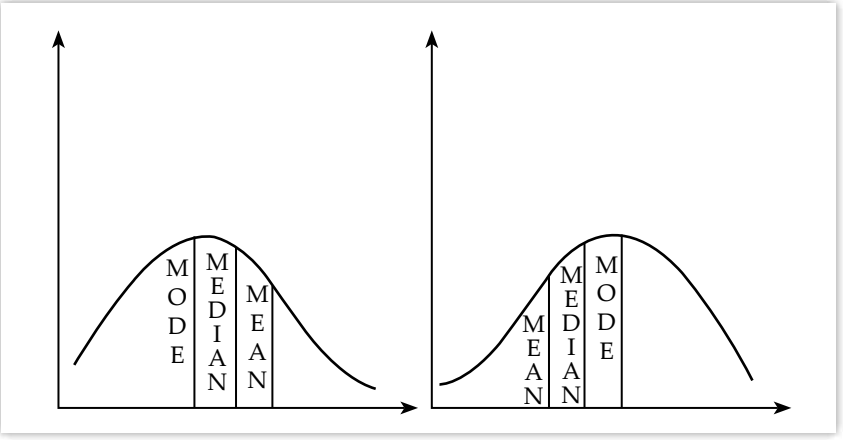
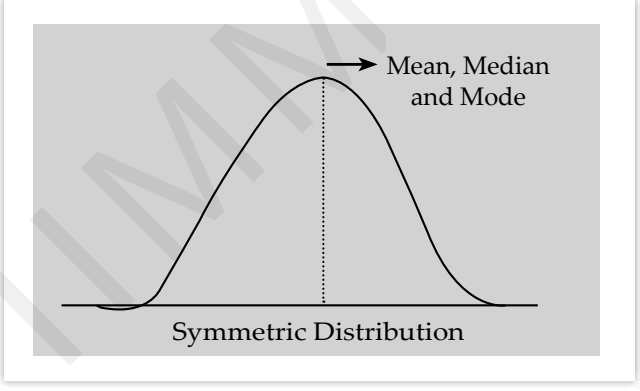


FIGURE 5: Positive Skewness and Negative Skewness – Asymmetric Distribution

If curve of frequency distribution is symmetrical, then skewness = 0 and mean = median = mode.



Positive skewness implies that the concentration of values is on the right side of the curve, whereas negative skewness implies that the concentration of values is on the left side of the curve. Skewness is calculated by taking the difference of mean and mode. In positive skewness, the values of these three measures of central tendency are in the following order:

Mean ($\overline{X}$) > Median (M) > Mode (Z)

However, in the case of negative skewness, the values of these three measures of central tendency are in the following order:

Mean ($\overline{X}$) < Median (M) < Mode (Z)

The formula to calculate skewness is as follows:

Skewness = $\overline{X}$ – Z

For moderately asymmetrical curves,

Mode = 3 Median – 2 Mean or

$Z = 3M - 2\overline{X}$

The coefficient of skewness is the relative measure of skewness that can be calculated by dividing skewness with standard deviation.

The formula used to calculate the coefficient of skewness is as follows:

Coefficient of skewness = $S_k = \frac{\overline{X} - Z}{\sigma}$

Pearson's coefficient of skewness

S_k = {Mean – (3 Median – 2 Mean)}/σ

= [Mean – 3 Median + 2 Mean]/σ

S_k = (3 Mean – 3 Median)/σ

For a moderately skewed, if there is more than one mode or if there is no mode, then you need to calculate skewness and the coefficient of skewness using the method of Moments.

Let us now calculate skewness and the coefficient of skewness with the help of an example. Suppose you want to calculate the skewness and the coefficient of skewness of the data given in Table 7**:**

Table 7: Ages of Five Friends

People	Age (Years)	$(X_i - \overline{X})$	$(X_i - \overline{X})^2$
Jenny	18	0.2	0.04
Robert	17	– 0.8	0.64
Ella	18	0.2	0.04
Andy	17	– 0.8	0.64
Eliza	19	1.2	1.44
Total	$\sum X_i = 89$		$\sum(X_i - \overline{X})^2 = 2.80$

The mean of age is calculated as follows:

Mean of Age, $\overline{X} = \sum X_i/n$

$\overline{X}$ = 89/5

$\overline{X}$ = 17.8

The median of age is calculated as follows:

Median, M = Value of $(n + 1/2)^{th}$ observation

M = $(5 + 1/2)^{th}$ observation

M = 3^{rd} observation = 18

Since the data contains two modes (17 and 18), you do not consider mode in this case.

Notes

The SD of age is calculated as follows:

$\sigma = \sqrt{\sum} (X_i - \overline{X})^2/n$

$= \sqrt{2.80/5} \cong 0.75$

Skewness is calculated as follows:

Skewness = 3(17.8 – 18) = 0.6

The coefficient of skewness is calculated as follows:

Coefficient of skewness = 0.6/0.75 = 0.8

The skewness in the ages of five friends is 0.6 and the relative measure of skewness is 0.8.

Self Assessment Questions

14. Negative skewness implies that the concentration of values is on the right side of the curve. (True/False)

8.7 MEASURES OF RELATIONSHIP

The measures of relationship study the relationship between two or more variables in a given data series. When you study the relationship between two variables in a population, it is known as bivariate population. When you study more than two variables in a population, it is known as multivariate population. The relationship among variables can be of two types – correlation and cause and effect. Based on these relationships, there are two types of analysis, as shown in Figure 6:

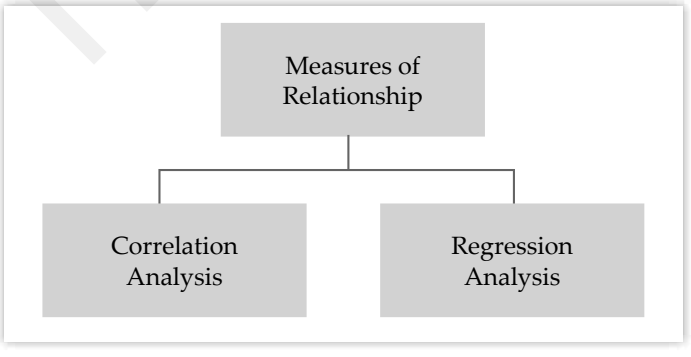


Figure 6: Measures of Relationship

Let us now discuss each type of relationship among variables.

8.7.1 CORRELATION ANALYSIS

Correlation analysis is used to study the association between different types of variables. It measures the extent to which one variable is linearly related to the other variables.

Different tools are used to study the correlation pattern between variables. These include: Rank correlation and Simple correlation.

Let us discuss each tool.

- **Rank correlation:** Rank correlation refers to the correlation between two data series in which the data is ranked. Generally, it is found when the data is qualitative in nature. It was given by Charles Spearman. Therefore, it is also known as Spearman's coefficient of correlation. It calculates the degree of relationship between two types of variables.

  The formula to calculate rank correlation is as follows:

  $$\text{Rank Correlation } \rho = 1 - \frac{6\sum d_i^2}{n\left(n^2 - 1\right)}$$

  Where, d_i = Difference between the individual/i^{th} pair of variables

  n = Number of pairs of observations

- **Simple correlation:** Simple correlation is used to find the degree of linear relationship between two variables. It is the most commonly used measure to describe relationship between two linearly related variables. It was given by Karl Pearson. Therefore, it is also known as Karl Pearson's coefficient of correlation.

  Simple correlation can be of three types, as given in Figure 7:

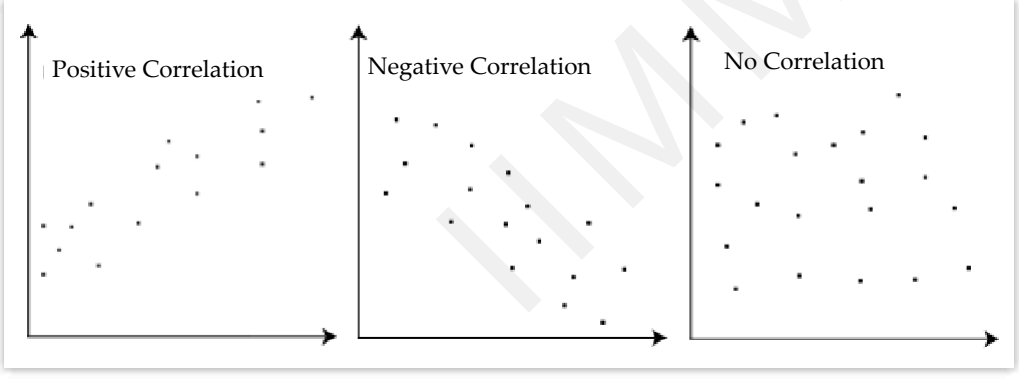


FIGURE 7: Types of Simple Correlation

The strength of association between two variables depends on the calculated value of the correlation coefficient and the sample size. The value of the correlation coefficient lies between a range of –1 and +1.

- If the value of the correlation coefficient is close to –1 and the sample size is sufficiently large, then there is a **strong negative correlation** between two variables. For example, if the coefficient of correlation is –0.8, then there is a strong negative association between variables.
- If the value of the correlation coefficient is close to +1 and the sample size is sufficiently large, then there is a **strong positive correlation** between two variables. For example, if the coefficient of correlation is 0.8, then there is a strong positive association between variables.
- If the correlation coefficient is not close to –1 or +1 and the sample size is sufficiently large, then there is **weak correlation** between two variables. For example, if the coefficient of correlation is 0.3 or –0.3, then the association between variables is weak.

Notes

The formula used to calculate simple correlation is as follows:

Correlation (r) = $\sum (X_i - \overline{X})(Y_i - \overline{Y})/(n-1)S_x S_y$

or

$$r_{x,y} = \frac{Cov(X,Y)}{SD(X)\,SD(Y)}$$

$$r = \frac{\frac{1}{n}\sum X_i Y_i - \overline{X}\overline{Y}}{\sqrt{\left(\frac{1}{n}\sum X_i^2 - \overline{X}^2\right)\left(\frac{1}{n}\sum Y_i^2 - \overline{Y}^2\right)}}$$

$$r = \frac{n\sum XY - \sum(X)\sum(Y)}{\sqrt{\left[n\sum X^2 - \left(\sum X\right)^2\right]\left[n\sum Y^2 - \left(\sum Y\right)^2\right]}}$$

Where, X_i = i^{th} value of X variable

$\overline{X}$ = Mean of X variable

Y_i = i^{th} value of Y variable

$\overline{Y}$ = Mean of Y variable

n = Number of pairs of observations

S_x = Standard deviation of X

S_y = Standard deviation of Y

Let us learn to calculate simple correlation between two variables with the help of an example. Suppose you want to study the correlation between the age and weight of a group of people to find out the relation between the two. Table 8 shows the required data:

Table 8: Ages and Weights of a Group of People

Number of Observations	Age (X_i)	Weight (Y_i)	X_i^2	Y_i^2	X_iY_i
1	18	35	324	1225	630
2	20	38	400	1444	760
3	25	50	625	2500	1250
4	30	65	900	4225	1950
5	35	70	1225	4900	2450
6	24	50	576	2500	1200
7	17	35	289	1225	595
8	16	39	256	1521	624
9	49	76	2401	5776	3724
10	45	72	2025	5184	3240
11	50	85	2500	7225	4250

Number of Observations	Age (X_i)	Weight (Y_i)	X_i^2	Y_i^2	X_iY_i
12	18	32	324	1024	576
13	20	34	400	1156	680
14	25	57	625	3249	1425
15	24	50	576	2500	1200
16	17	35	289	1225	595
17	16	39	256	1521	624
18	23	44	529	1936	1012
19	22	45	484	2025	990
20	34	60	1156	3600	2040
21	36	65	1296	4225	2340
22	31	63	961	3969	1953
23	43	70	1849	4900	3010
24	44	72	1936	5184	3168
25	16	35	256	1225	560
Total	$\sum X_i$=698	$\sum Y_i$=1316	$\sum X_i^2$=22458	$\sum Y_i^2$=75464	$\sum X_iY_i$=40846

The calculation of correlation is as follows:

Correlation (r) = $(n\sum X_iY_i - \sum X_i\sum Y_i)/\sqrt{n\sum X_i^2 - (\sum X_i)^2 \times n\sum Y_i^2 - (\sum Y_i)^2}$

$r = (25 \times 40846 - 698 \times 1316)/\sqrt{(25 \times 22458 - 698 \times 698)(25 \times 75464 - 1316 \times 1316)}$ $r = 102582/\sqrt{74246 \times 154744}$

$r = 0.96$

8.7.2 REGRESSION ANALYSIS

Correlation need not necessarily imply causality. But it can be said that if correlation between any two variables is very high, then it might be indicative of causality, i.e., a situation where one variable denotes the cause and the other variable denotes its effect. For example, if X and Y are correlated, the causal relationship inferred from correlation between them may indicate that X is a cause of Y, Y is a cause of X, or both X and Y are caused by some other variable Z, etc.

Correlations are employed through methods such as regression analysis. In common parlance, regression analysis (whether simple or multiple) is also termed as causal analysis. Causality between different variables can be understood using causal analysis.

Cause and effect analysis is measured using simple regression or multiple regression.

Regression is one step ahead of correlation in identification of relationship between two variables. This is because regression allows for prediction of values within the given data range. In simple language, if we know X, we can predict Y and if we know Y, we can predict X. This is possible with the help of an equation called regression equation.

The variable Y is generally termed as dependent or criterion variable and the variable X is termed as independent or predictor variable. Regression equation

Notes

is used to generally predict the values of Y based on the values of X. However, it cannot be rightly said that Y is caused by X. Before making such an interpretation, it is extremely imperative for the researcher to thoroughly understand the variables under study and the circumstances or context under which they operate.

The regression equation can be written as below:

$Y = \alpha + \beta X$

Where,

Y represents scores on Y variable

X represents scores on X variable

α represents regression constant in the sample

β represents regression coefficient in the sample

α and β are calculated with the following formula:

$$\beta = \frac{n\sum XY - \sum X \sum Y}{n\sum X^2 - (\sum X)^2}$$

$$\alpha = \frac{1}{n}\left[\sum Y - \beta \sum X\right]$$

Simple regression analysis is useful in a number of situations, for example, it is used in analysing the relationship between number of consumers (independent variable) and product sales of a month (dependent variable). The regression equation to the data is fitted with the use of least squares method in regression analysis.

Let us take an example with data of number of customers and monthly sales for 10 number of observations (N) as shown in Table 9:

Table 9: Customers and Monthly Sales

S. No.	No. of Consumers (X) (in '00)	Monthly Sales (Y (in '000)	XY	X^2
1	2.0	12	24.0	4.0
2	3.4	6	20.4	11.6
3	6.2	7	43.4	38.4
4	7.6	11	83.6	57.8
5	6.5	13	84.5	42.3
6	8.2	33	270.6	67.2
7	7.6	31	235.6	57.8
8	9.3	22	204.6	86.5
9	3.1	36	111.6	9.6
10	8.1	24	194.4	65.6
Total	**62.0**	**195**	**1,272.7**	**440.7**

Now, regression equation is given by:

$Y = \alpha + \beta X$

Using the formula for β

$$\beta = \frac{10 \times 1272.7 - (62)(195)}{10 \times 440.7 - (62)(62)} = 637 \div 563 = 1.1314$$

Using the formula for α

$$\alpha = \frac{1}{10}\left[195 - 1.1314 \times 62\right] = 12.485$$

Thus, the regression equation for the above data is given as:

$Y = 12.485 + 1.1314X$

With this equation, the values of Y (monthly sales) can be computed for any given value of X (no. of customers) as depicted in Table 10 below:

Table 10: Monthly Sales for Given Number of Customers

S. No.	No. of Consumers (X) (in '00)	Y=12.485+1.1314X	Monthly Sales (Y) (in '000)
1	2.0	14.75	(12.485 + 1.1314×2.0)
2	3.4	16.33	(12.485 + 1.1314×3.4)
3	6.2	19.50	(12.485 + 1.1314×6.2)
4	7.6	21.08	(12.485 + 1.1314×7.6)
5	6.5	19.84	(12.485 + 1.1314×6.5)
6	8.2	21.76	(12.485 + 1.1314×8.2)
7	7.6	21.08	(12.485 + 1.1314×7.6)
8	9.3	23.01	(12.485 + 1.1314×9.3)
9	3.1	15.99	(12.485 + 1.1314×3.1)
10	8.1	21.65	(12.485 + 1.1314×8.1)
Total	**62.0**	**195.00**	

Self Assessment Questions

15. _____ is the study of the association between different types of variables.
16. Causal analysis is used to study the cause and effect relationship of two variables. (True/False)

8.8 DIFFERENT CHARTS USED IN DATA ANALYSIS

Graphical illustrations are visually appealing and bring life to a report so as to give the target audience refreshing breaks from the monotony caused by texts and tables.

If the research report contains many descriptive tables, it can be made more readable and attractive if the most important tables are presented through graphs and diagrams. In the graphical presentation, facts and figures are gathered first and then they are depicted in the form of graphs and charts to present the statistical information.

Notes

The most frequently used graphs and charts include the following:

- **Bar chart:** A bar chart represents categorical data with the help of rectangular bars, plotted vertically or horizontally. The heights or lengths of rectangular bars are proportional to the values represented by them. The data can be in the form of absolute frequencies or relative frequencies.

  Figure 8 below shows a bar chart to depict the relative frequency/percentage of shortages of anti-inflammatory medicines in the rural health organisations:

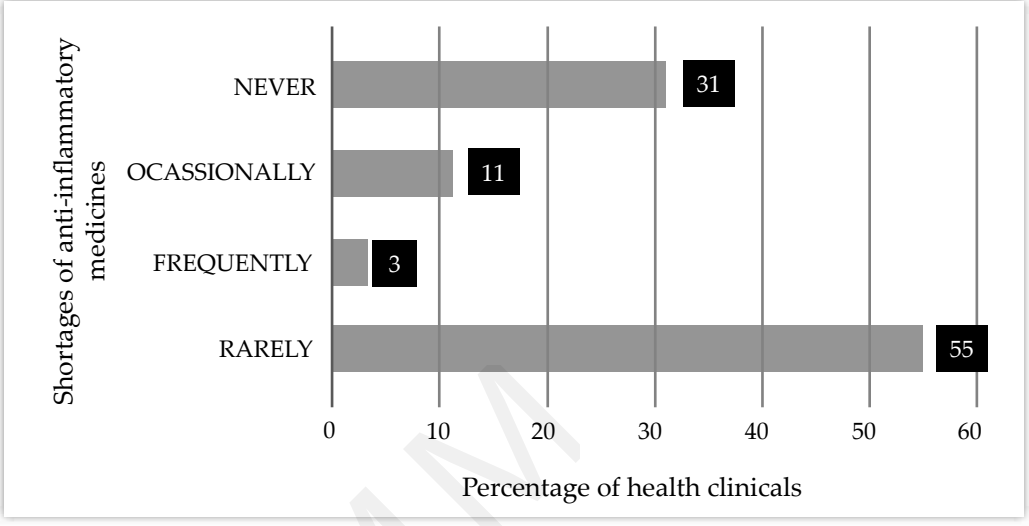


Figure 8: Relative Frequency of Shortages of Anti-inflammatory Medicines in Rural Health Organisations in Bar Chart

- **Pie chart:** A pie chart is a circular statistical graphic, segregated into different segments to illustrate the numerical proportions/relative frequency of a number of items. The arc length of each segment shows the proportionate quantity represented by it. Pie charts provide a quick overview of the data presented to the readers. All segments of the pie chart should be added up to 100%.

  Figure 9 shows a pie chart to depict the relative frequency/percentage of shortages of anti-inflammatory medicines in the rural health organisations:

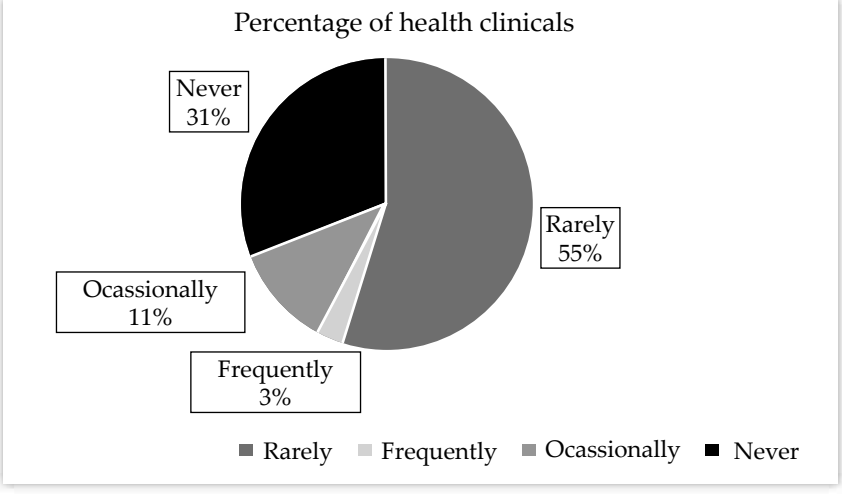


Figure 9: Relative Frequency of Shortages of Anti-inflammatory Medicines in Rural Health Organisations in Pie Chart

- **Histogram:** A histogram is an accurate representation of the probability distribution of a continuous data variable grouped into bins. They are very similar to bar charts used to show categorical data. The only difference between the two is that the histogram bars are connected to each other (so long as there is no gap in the data) to represent continuous data, whereas the bars in a bar chart are not connected as they represent different categorical entities. Figure 10 shows a histogram to depict the frequency of sales effected by different salespersons in a month, indicating how many salespersons fall within a particular sales range:

Figure 10: Absolute Frequency of Sales Effected by Different Salespersons in a Month (n=60)

- **Line graph:** A line graph or a line chart is generally used to visualise the value of a particular variable over time. They are useful to show the trend of numerical data over a period of time. Two or more distributions (each depicted by a separate line) can be shown in one graph as long as the difference between them is easily distinguishable. They also make it possible to compare the distributions of different groups, for example, age distribution between males and females. Figure 11 shows a line graph to depict the frequency of daily number of patients being treated at the rural health organisations in District Y:

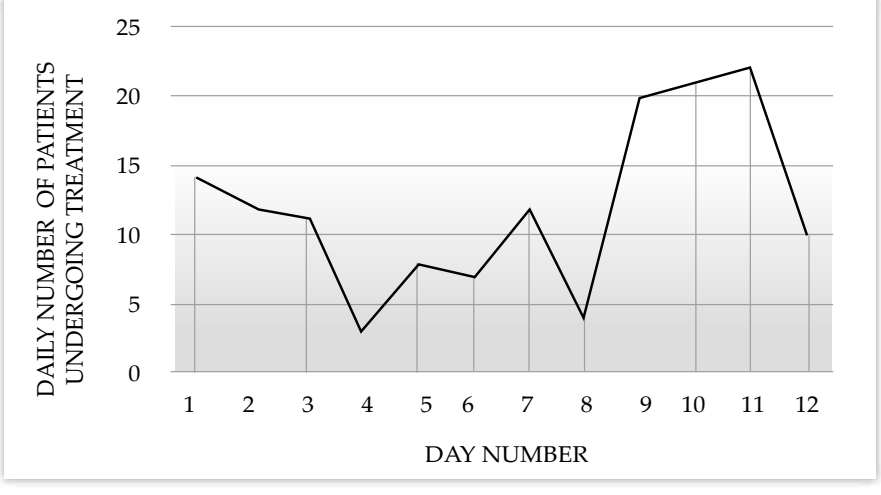


Figure 11: Daily Number of Patients Being Treated at the Rural Health Organisations in District Y in Line Chart

Notes

- **Box and whisker plot:** This is a method of graphically representing different groups of numerical data through their quartiles. The box plots can also have vertical lines extending from the boxes (called whiskers) to indicate the variability outside the upper and lower quartiles. For example, variability between sales patterns effected in Area X and Area Y is shown through box plots in Figure 12:

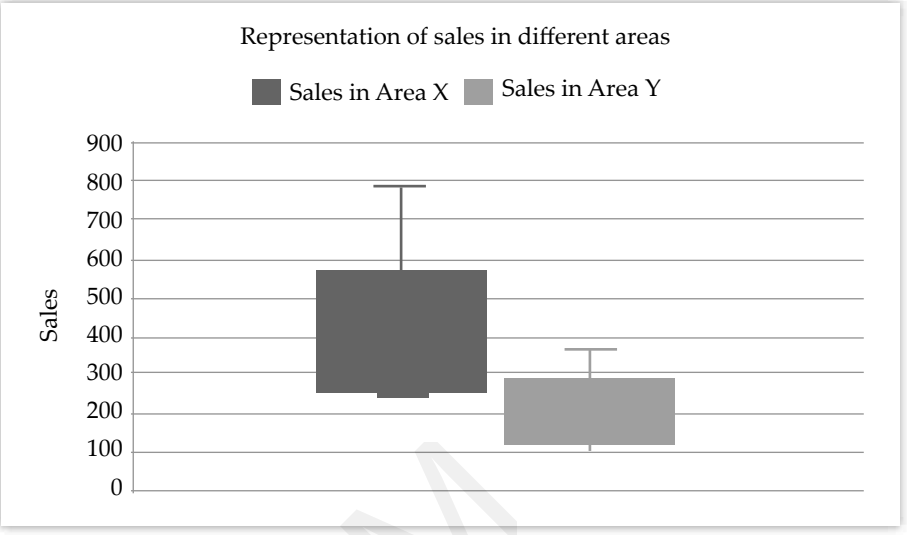


Figure 12: Sales Patterns of Food Grains Effected in Area X and Area Y

Self Assessment Questions

17. Bars in a histogram are not connected as they represent different categorical entities. (True/False)
18. In a boxplot, vertical lines extending from the boxes are called _____.

8.9 SUMMARY

- A researcher collects any type of data, quantitative and qualitative, in raw form. After that, he/she needs to process the collected data to make it fit for analysis.
- Editing refers to reviewing the collected data to check whether it is valid or not. This helps in eliminating the extra information and retaining the relevant matter for analysis.
- When the data is generated with the help of a questionnaire, it can be coded either at the time of framing the questionnaire or after collecting the data.
- Classification refers to categorising the coded questions into different segments as per their relevance.
- Tabulation refers to presenting the data in the form of a table so that it can be analysed easily.
- Descriptive analysis is used to study the relationship pattern among variables.
- Inferential analysis uses various types of test of significance to check the validity of a hypothesis for studying a problem.

- The measures of central tendency are used to study the distribution pattern of a dataset.
- Mean represents the value received after dividing the sum of observations by the total number of observations.
- Median refers to the central value of the given dataset.
- Mode refers to the value that has the highest frequency in a data series.
- The measures of dispersion refer to the measures that are used to study the dispersed value near the mean value.
- Standard deviation is used to calculate the scattering of values in a given dataset.
- The measure of skewness is used to study the shape of the curve that can be drawn by plotting the data of a frequency distribution on a graph.
- The measures of relationship study the relationship between two or more variables in a given data series.

8.10 KEY WORDS

- **Base period:** This refers to the period that acts as a benchmark for measuring economic and financial data.
- **Hypothesis:** This is a proposed explanation of a phenomenon, which needs to be tested.
- **Measures of central tendency:** These measures are used to find the central value of a data series.
- **Measures of dispersion:** These measures are used to find the scattering of values around the mean value of a data series.
- **Measures of relationship:** These measures are used to find the relationship between different variables.
- **Univariate analysis:** This is the analysis of a single variable.

8.11 CASE STUDY: QUALITY STANDARDS IN A SERVICE SECTOR COMPANY

TPR Inc. was a multi-cuisine restaurant based in India. It had several outlets in the major Indian cities. The restaurant management wanted to find out if its various outlets were meeting the established standards of quality and customer service. It hired a consultancy firm for the purpose.

The consultants collected a large scale of data with the help of questionnaires, interviews, and observations in the restaurants' outlets. Then, they carefully followed the data processing steps to analyse it and retrieve relevant and meaningful information from it.

While processing the responses in the questionnaires, they found that quite a large number of questions were left unanswered. Instead of ignoring such questions, they

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proceeded in a systematic manner. Each questionnaire comprised a series of interval questions, closed-ended questions and open-ended questions.

In case of interval questions, they gave a mid-value to the unanswered questions. In case of open-ended questions, they went back to the customers and requested them to fill in the answers.

After retrieving sufficient data from the questionnaires, they classified the collected data. To do so, they combined customers' responses from different cities and then sub-grouped them according to their cities. Next, they formed a table to analyse the relationship between customers' satisfaction and the sales of the company:

Calculating the Correlation between Customer Satisfaction and Sales of the Company					
Number of Observations	Customer Satisfaction (X_i)	Sales of Company (Y_i)	X_{i2}	Y_{i2}	X_iY_i
1	4	5	16	25	20
2	6	6	36	36	36
3	7	6	49	36	42
4	8	4	64	16	32
5	9	6	81	36	54
6	10	9	100	81	90
7	8	10	64	100	80
8	7	2	49	4	14
9	1	3	1	9	3
10	2	4	4	16	8
11	9	9	81	81	81
12	8	8	64	64	64
13	7	9	49	81	63
14	10	11	100	121	110
15	6	5	36	25	30
16	9	12	81	144	108
17	8	15	64	225	120
18	10	12	100	144	120
19	9	16	81	256	144
20	8	20	64	400	160
21	10	20	100	400	200
22	4	6	16	36	24
23	5	8	25	64	40
24	10	14	100	196	140
25	10	19	100	361	190
Total	185	239	1525	2957	1973

The correlation between the customers' satisfaction and the sales of company is as follows:

Correlation (r) = $(n\sum X_iY_i - \sum X_i\sum Y_i) / \sqrt{n\sum X_i^2}$

$r = (25 \times 1973 - 185 \times 239) / \sqrt{(1525 \times 25 - 185 \times 185)(25 \times 2957 - 239 \times 239)}$

$r = 5110/8095.41$

$r = 0.6$

Since the correlation coefficient is positive and close to 1, it indicates that the relationship between the customers' satisfaction and the sales is positive and strong.

Similarly, the consultants studied the relationship between different variables, such as quality of service and customer satisfaction, quality of service and established standards, and so on. Finally, they concluded that the satisfaction level of the restaurant's customers was positive and strong. However, the restaurant's service level was far behind the established quality standards.

QUESTIONS

1. What are the different steps of data processing used in the case study?

   (**Hint:** The consultants used all the steps of data processing, that is, first they extracted the relevant data. Then, they classified and organised the information and studied the relationship between variables.)

2. Which type of measure is used in analysing the table and what type of analysis is used?

   (**Hint:** The measure of relationship is used to analyse the table.)

3. What was done to unanswered questions of the questionnaires filled by customers?

   (**Hint:** Unanswered questions were not ignored and a systematic procedure was followed to retrieve sufficient data.)

4. How was the data retrieved from questionnaire collected and classified?

   (**Hint:** The customers' responses from different cities were combined and then sub grouped according to their cities.)

5. How the relationship between customers' satisfaction and the sales of the company was derived?

   (**Hint:** By forming a table and calculating correlation between customers' satisfaction and the sales of the company)

8.12 EXERCISE

1. Explain the different steps of data processing.
2. What are the different types of data analysis?
3. What are the measures of central tendency? Why are they used?
4. What are the measures of dispersion? Why are they used?
5. What do you understand by 'skewness'? What is the measure of skewness? What does its calculated value indicate?
6. What is the purpose of casual analysis?

8.13 ANSWERS FOR SELF ASSESSMENT QUESTIONS

Topic	Q. No.	Answer
Concept of Data Processing	1.	Editing
	2.	True
	3.	postcoded
	4.	False
Concept of Data Analysis	5.	b. Bivariate analysis
	6.	False
Measures of Central Tendency	7.	True
	8.	Geometric
	9.	True
Measures of Dispersion	10.	Measures of Dispersion
	11.	a. Highest value of series – Lowest value of series
	12.	MD/X Where, MD = Mean Deviation $\overline{X}$ = Mean/Median/Mode
	13.	Sigma (σ)
Measure of Skewness	14.	False
Measures of Relationship	15.	Correlation analysis
	16.	True
Different Charts Used in Data Analysis	17.	False
	18.	whiskers

8.14 SUGGESTED BOOKS AND E-REFERENCES

SUGGESTED BOOKS

- Cahoon, M. (1987). *Research Methodology*. Edinburgh: Churchill Livingstone.
- Panneerselvam, R. (2014). *Research Methodology*. Delhi: PHI Learning.
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- What are Mean, Median, Mode and Range?. (2020). Retrieved 9 April 2020, from https://searchdatacenter.techtarget.com/definition/statistical-mean-median-mode-and-range
- Introduction to Correlation and Regression Analysis. (2020). Retrieved 9 April 2020, from http://sphweb.bumc.bu.edu/otlt/MPH-Modules/BS/BS704_Multivariable/BS704_Multivariable5.html

CHAPTER 9

Concept of Hypothesis

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LEARNING OBJECTIVES

After studying this chapter, you will be able to:

- Explain the concept of hypothesis
- Describe various types of hypothesis
- Explain the use of null and alternative hypotheses in hypothesis testing
- Differentiate between two-tailed and one-tailed tests
- Describe the procedure of hypothesis testing

9.1 INTRODUCTION

In the previous chapter, you studied the concept of data processing. The chapter discussed the concept of data analysis. The latter sections of the chapter described the measures of central tendency, measures of dispersion and measures of skewness. The chapter concluded with the explanation of the different charts used in data analysis.

A hypothesis refers to an assumption that is made in the population parameter and a sample statistic is used to verify the same. It is a very useful tool to solve various research problems and issues. A researcher first forms a hypothesis about a problem and then tests it to check its validity by using statistical measures. The procedure to utilise test statistics to check whether a hypothesis is true is known as hypothesis testing.

Suppose a researcher is asked to check whether an organisation's new advertisement has resulted into enhanced sales or not. In this case, the researcher would first form the hypothesis that the new advertisement has no impact on the organisation's sales. This hypothesis is known as null hypothesis. After that, the researcher would form another hypothesis, known as alternative hypothesis, which states that the new advertisement has a positive impact on the organisation's sales. Then, the researcher would analyse the data to find the relationship between the new advertisement and the organisation's sales. If he/she finds a relationship between the new advertisement and the sales, he/she would reject the null hypothesis and accept the alternative hypothesis.

In the field of research, the concept of hypothesis and hypothesis testing hold a very special place. The formation of hypothesis helps the researcher remain focussed on the research problem. In addition, it gives direction to the research project by clearly defining the scope of research. Hypothesis testing assists the researcher in deriving realistic results, as it takes into consideration the errors due to sampling.

In this chapter, you will learn about the concept of hypothesis and explore the characteristics and types of hypothesis. The chapter also provides information about

hypothesis testing, null and alternative hypotheses, decision rules, one-tailed test and two-tailed test.

9.2 DEFINING HYPOTHESIS

Hypothesis is a proposed explanation given for an observed situation. It is a specific prediction, which can be tested, about what you expect to happen in a study or research. It represents a tentative relationship between two or more variables, which is predicted by the researchers. For example, a study designed to look at the relationship between stress and common cold might have a hypothesis that states, "This study is designed to assess the hypothesis that people with high-stress levels will be more likely to catch common cold after being exposed to the virus than are people who have low stress levels."

Some definitions of hypothesis by experts are given below:

According to **Mouton**, hypothesis is: *A statement postulating a possible relationship between two or more phenomena or variables.*

According to **Guy**, hypothesis is: *A statement describing a phenomenon or which specifies a relationship between two or more phenomena.*

Both hypothesis and problem statements arise from a predefined situation. However, there is a difference between the two. A problem statement cannot be directly tested, while a hypothesis statement is derived from a problem statement. The hypothesis is formulated after a problem has been stated and the researcher has done a detailed theoretical study of the problem. It is formulated to solve the problem by testing it with the help of various tests of significance.

9.2.1 CHARACTERISTICS OF A GOOD HYPOTHESIS

A hypothesis is a supposition (assumed or tentative) statement regarding the relationship that exists between two or more variables. Following are the characteristics of a good hypothesis:

- **Clear topic:** A hypothesis should clearly define its topic. The topic should also be meaningful.
- **Precise:** A hypothesis should be clear and specific to facilitate a deep and comprehensive study, and enable researchers to draw reliable inferences on its basis.
- **Testable:** A hypothesis should be capable of being tested. Hypothesis is specific and it may either agree or disagree with the research question.
- **Limited in scope:** A hypothesis should be limited in scope, as narrower hypotheses are generally more testable.
- **Consistent:** A hypothesis should be based on previous research.

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9.2.2 TYPES OF HYPOTHESES

There are six types of hypotheses, which are classified on the basis of their derivation and formulation are shown in Figure 1:

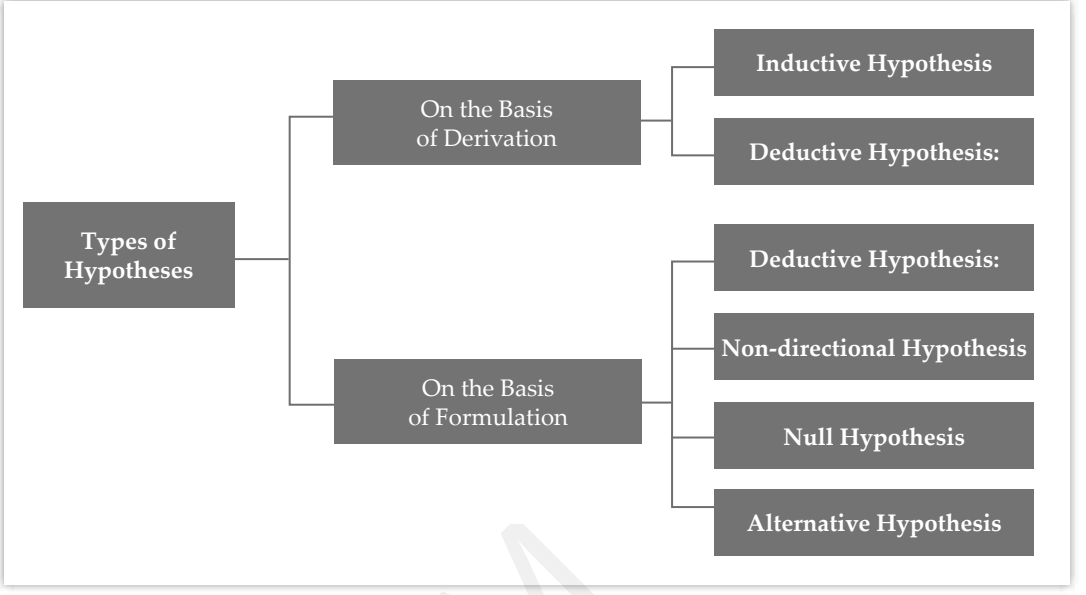

Figure 1: Types of Hypotheses

On the basis of derivation, there are two types of hypotheses, which are explained as follows:

- **Inductive hypothesis:** In inductive hypothesis, you move from specific observations to broad generalisations. First, you observe a phenomenon.

  Then, you form a pattern from your observations. After that, you form a hypothesis to study the pattern. Finally, you form a theory on the basis of your study of the pattern. The inductive hypothesis is used to conduct qualitative studies of subjective variables. In this type of hypothesis, you should ask open-ended and process-oriented questions.

- **Deductive hypothesis:** In this type of hypothesis, you move from a general statement to a specific, logical conclusion. You start from a theory and, based on it, you make a prediction of its consequences. In other words, you predict what the observations should be if the theory were correct. Finally, analysis is done to arrive at a conclusion whether the theory is rejected or accepted with respect to the problem. In deductive hypothesis, a research goes from general theory to specific observation. In this type of hypothesis, you should ask closed-ended and outcome-oriented questions.

On the basis of formulation, there are four types of hypothesis which are explained as follows:

- **Directional hypothesis:** This hypothesis checks the direction of relationship between two variables. In directional hypothesis, you use terms, such as more than, less than, negative and positive. An example of the directional hypothesis is: In an organisation, women are more productive than men.

- **Non-directional hypothesis:** In this hypothesis, the direction of relationship between two variables cannot be specified. For example, an organisation wants to get feedback from its employees about their job satisfaction level. In this example, the test result can be positive or negative depending on the job satisfaction of the employees.
- **Null hypothesis:** In this hypothesis, there is no relation between two variables under study. It is denoted by H_0. Null hypothesis is used as the first statement in a hypothesis, which you (or the researcher) want to reject. For example, a null hypothesis is: There is no relation between the number of years of experience held by an individual and his performance. Therefore, researchers are more interested in disproving or rejecting the null hypothesis. This is an example of null hypothesis that would be tested for rejection because it is generally held that experience and performance are related.
- **Alternative hypothesis:** This hypothesis states that there is a relationship between two variables under study. It is denoted by H_1. It is used as the second statement in a hypothesis that you want to accept. For example, an alternative hypothesis can be: There is a relation between the qualification of an individual and better job opportunities. Since these two variables are related, you would want to accept this statement.

Before studying the concept of null hypothesis and alternative hypothesis in detail, one must understand how the process of hypothesis testing works.

The researchers initially state the null hypothesis and alternative hypothesis. After this, they conduct certain specific tests and at the end of test, they make statements regarding the likelihood that a research hypothesis is FALSE.

It is true that the researchers make probability statements regarding the likelihood of hypothesis being false instead of it being true, i.e., researchers are interested in rejecting null hypothesis rather than accepting the null hypothesis because they never know how much type II error they might be making.

Self Assessment Questions

1. _____ is a specific prediction, which can be tested, about what you expect to happen in a study or research.
2. Match the following:

1.	Inductive hypothesis	i.	General statement to a specific conclusion
2.	Deductive hypothesis	ii.	Second statement in a hypothesis
3.	Null hypothesis	iii.	From specific observations to broad generalisations
4.	Alternative hypothesis	iv.	First statement in a hypothesis

a. 1–iv, 2–iii, 3–ii, 4–i

b. 1–iii, 2–iv, 3–i, 4–ii

c. 1–iii, 2 – i, 3–iv, 4–ii

d. 1–i, 2–ii, 3–iii, 4–iv

Notes

9.3 HYPOTHESIS TESTING

Hypothesis testing is a process to make decisions for research problems by using sample data. It is a logical method of taking and validating decisions.

In hypothesis testing, you take two statements:

i. The first statement states that there is no relationship or no difference between two variables under study. You take this statement (also known as **null hypothesis**) as true. A null hypothesis statement involves equality (≤, ≥, or =) about a population parameter.

ii. The second statement states that there is a relationship or difference between two variables under study. You take this statement (also known as **alternative hypothesis**) as false. Alternative hypothesis contradicts null hypothesis and must not involve equality (<, ≠, >).

After that, you test the null hypothesis to accept or reject it. The null hypothesis is tested with the help of the levels of significance. A significance level is the probability of rejecting null hypothesis in a statistical test when it is true. It is expressed in percentage and its value can be calculated from the tables of various test statistics. Examples of test statistics are t-test, z-test, and F-test. You would learn about these tests in detail in the upcoming chapters.

After the null hypothesis and alternative hypothesis have been stated, the researcher sets the decision criteria for which he/she needs to state the level of significance of test. If the null hypothesis is true, the sample mean will be equal to population mean on average.

The most commonly used levels of significance in statistics are 1%, 5% and 10%. For example, if 5% is the most commonly used level of significance in behavioural studies, it implies that the 5% area of the normal curve would be used for testing the hypothesis and the value for this area is taken from the table of the respective test statistic. For instance, the z-values for various levels of significance are shown in Figure 2:

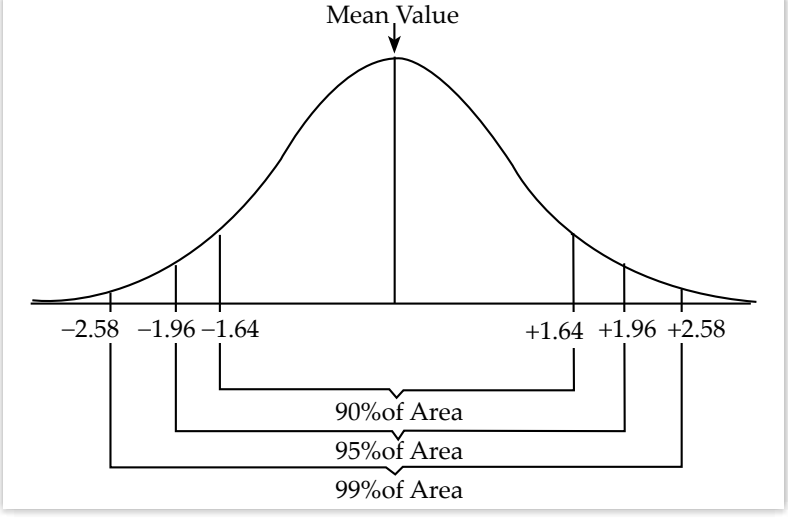

Figure 2: z-Values for the Levels of Significance

In Figure 2, you can see that the areas expressed in percentage and their values are given on X-axis. Table 1 provides the levels of significance and their z-values:

Table 1: z-values of Levels of Significance

Level of Significance	z-value
1%	+/– 2.58 (for two-tailed)
1%	+/– 2.33 (for one-tailed)
5%	+/– 1.96 (for two-tailed)
5%	+/– 1.64 (for one-tailed)
10%	+/– 1.64 (for two-tailed)
10%	+/– 1.28 (for one-tailed)

In hypothesis testing, the value level of significance is very important as it helps you in rejecting or accepting a null hypothesis. You should be careful while formulating or determining the level of significance for a problem/topic. The reason is that you may reject a true hypothesis on the basis of a level of significance. If the level of significance is 5%, it implies that the probability of rejecting a true hypothesis is 0.05 (max).

After the level of significance has been set, the researcher then proceeds to compute the test statistic which basically describes how far a sample mean is from the population mean. The greater the value of test statistic, the farther is the sample mean from the population mean described in null hypothesis. Thereafter, on the basis of value of test statistic, a decision is made.

If the null hypothesis is true and the probability of obtaining a sample mean is less than 5%, then we reject the null hypothesis. On the contrary, if null hypothesis is true and the probability of obtaining a sample mean is more than 5%, then the null hypothesis is retained.

9.3.1 NULL HYPOTHESIS AND ALTERNATIVE HYPOTHESIS

Null hypothesis represents the first statement of a hypothesis that is assumed to be true. This statement indicates that there is no relationship between two variables under study and if there exists, any relation that is there is purely due to chance. Alternative hypothesis represents the second statement of a hypothesis that is assumed to be false. This statement indicates that there is a relationship between the two variables.

Let us understand these through the following example:

Example 1: Assume that if a patient takes physiotherapy sessions two times instead of three times in a week post operation, then his/her recovery time would be greater. Assume that if the average recovery time after operation is 7 weeks:

H_0: The average recovery time after operation is less than or equal to 7 weeks.

H_1: The average recovery time after operation is greater than 7 weeks.

From the preceding two examples, it is clear that H_0 is totally opposite of the statement the researcher wants to study. The researchers always test H_0 for significance, not H_1 because they are usually interested in disproving H_0.

Notes

H_0 and H_1 are in the descriptive form. The researcher must convert them into the quantitative form to compute them.

In Example 1, the quantitative forms of H_0 and H_1 are as follows:

H_0: $\mu \leq 7$

H_1: $\mu > 7$

Where,

μ = Population mean

You can also formulate a hypothesis for testing with the help of a benchmark. This benchmark is a numerical digit with which you have to compare your results and test the hypothesis. This is one of the finest and widely used methods for framing null and alternate hypotheses because it represents null and alternate hypotheses in quantitative form. This makes hypothesis testing easier.

For example, in a school, the average weight of every class is 100 (population mean). You consider all sections of class 10 as a sample (assume there are 5 sections of class 10) and calculate their average weight (sample mean). Now, you want to check whether the sample mean is equal to the population mean or not. In this case, H_0 and H_1 would be as follows:

H_0: $\overline{X} = 100$

H_1: $\overline{X} < 100$

Where,

$\overline{X}$ = Sample mean

μ_p = Population mean = 100

The researchers assume that the null hypothesis is true and proceed further to find out various methods/possibilities to solve the problem. They try to reject the null hypothesis.

A hypothesis can never be right or wrong. Rather, it is judged by what you want to analyse. If a hypothesis is framed in such a way that it can answer your problem, then it would be right.

9.3.2 DECISION RULE

Decision rule refers to the process or criteria that a researcher uses to decide whether to accept or reject the null hypothesis. For example, a researcher forms a hypothesis that the mean age of a population is equal to 30. The researcher then collects a sample of observations to test this hypothesis. He/she will then create a decision criteria. For instance, the researcher may decide to accept the hypothesis if the sample mean was in the range of 10% on either side of 30; i.e., 30 ± 10% = between 27 and 33. It means that the researcher would reject the hypothesis if mean of sample was below 27 or above 33.

It is important to note that different types of errors may occur while testing a hypothesis. Therefore, the researcher should take into consideration the possibilities of these errors while taking decisions.

The decision grid helps the researcher in taking decisions, which is shown in Figure 3:

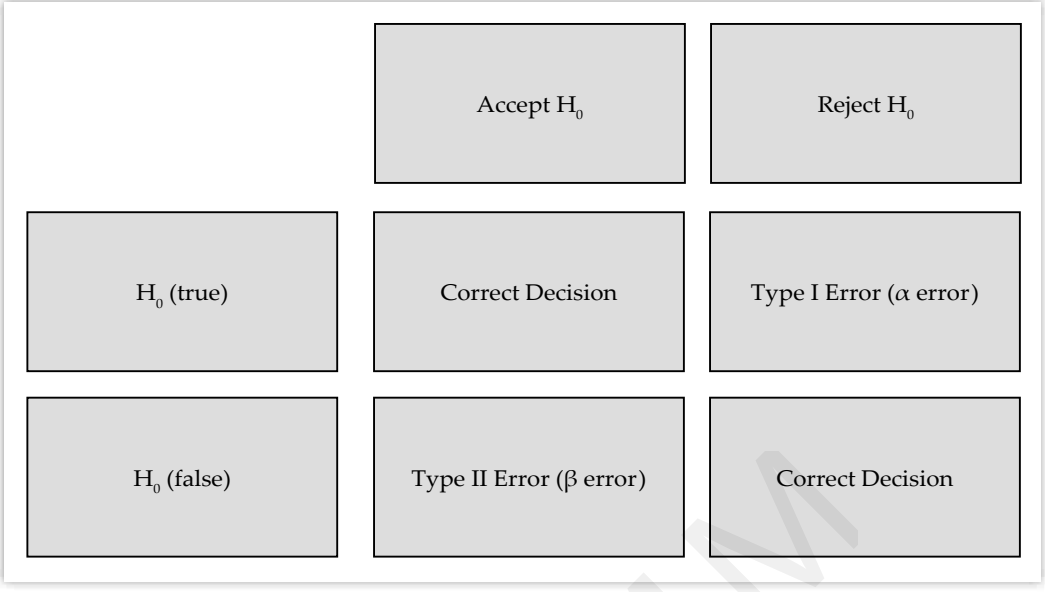

Figure 3: Decision Grid

As per the grid shown in Figure 3, if H_0 is true and it is accepted, then the decision is correct. If H_0 is false and it is rejected, then also the decision is right. However, if the decision is wrong, two types of errors can occur, which are explained as follows:

- **Type I errors**: These errors occur when the researcher rejects a null hypothesis (H_0) when null hypothesis was true. In this case, the decision taken by the researcher is wrong. Type I errors are also known as the first kind of error or false positive. These errors are represented by α.
- **Type II errors**: Type II errors occur when the researcher accepts a null hypothesis (H_0) that should have been rejected. In this case, the decision taken by the researcher is wrong. Type II errors are also known as the second kind of error or false negative. These errors are represented by β. The probability of rejecting the null hypothesis when it is false = $1 - \beta$ and is called the power of test.

If you minimise Type I errors, Type II errors would increase or vice versa. Therefore, you have to be very careful while minimising one type of error. You must remember that both the types of errors can be limited using an appropriate sample size.

9.3.3 TWO-TAILED TEST

Two-tailed test is a part of non-directional hypothesis that talks about the relationship between two variables, but does not explain anything about the direction of the relationship.

For example, a company produces tennis balls and it has laid down that the ball should weigh 55 grams in order to get good ratings. The samples are drawn on

Notes

hourly basis and checked for ideal weight. In a given hour, 11 balls are checked randomly and their mean is calculated as 55.006 grams and SD of 0.029 grams. If the production line gets out of sync with more than 1% level of significance, the production line is shut down. Let us see if the production line should be shut down in this case.

Here,

$\mu_p = 55$ g;

H_0: $\mu p = 55$ g

H_1: $\mu p \neq 55$ g

$\alpha = 1\% = 0.01$

Therefore, $\alpha/2 = 0.005$

$p = 1 - (\alpha/2) = 0.995$

Degree of freedom of sample = n – 1 = 11 – 1 = 10 Here,

$t_p = 3.169$

Now, calculate t_c.

$$t_c = \frac{\bar{X} - \mu}{s/\sqrt{n}}$$

$$t_c = \frac{55.006 - 55}{0.029/\sqrt{10}}$$

$$t_c = \frac{0.006}{0.0091} = 0.659$$

The two-tailed test can be shown on a normal curve in Figure 4:

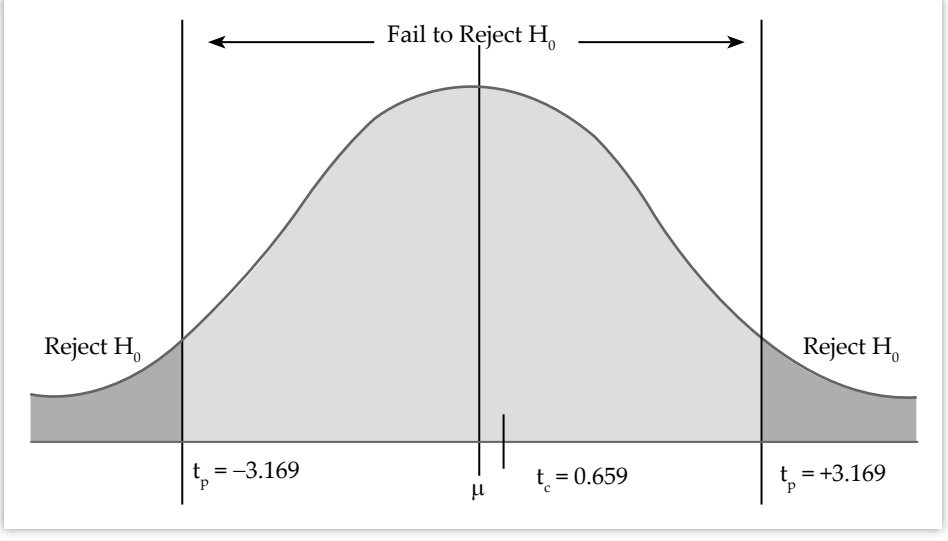

Figure 4: Two-tailed Test

In Figure 4, at the 1% level of significance, the t value would be ±3.169. If the calculated value of test statistics lies in between the range of –3.169 and +3.169, then H_0 would be accepted. However, if the calculated value of test statistics lies outside this range, it would be rejected. Here, the rejection region is equally divided between two tails of the distribution (–0.005 is upper tail and 0.005 is lower tail). In this example, the null hypothesis is accepted.

9.3.4 ONE-TAILED TEST

One-tailed test is a part of directional hypothesis that talks not only about the relationship between two variables, but also the direction of relationship. It is considered when you want to test a hypothesis on either positive or negative side of a normal curve. When the hypothesis testing involves rejection region only on one side of the sampling distribution, it is called a one-tailed hypothesis test.

For example, assume that the null hypothesis states that mean weight of people is 60 kg or more. In this case, the alternative hypothesis would be that the mean weight of people is less than 60 kg. Here, the rejection region comprises the range of numbers 0 to 60 located on the left side of sampling distribution (set of numbers that are less than 60).

The one-tailed test also forms a normal curve as shown in Figure 5:

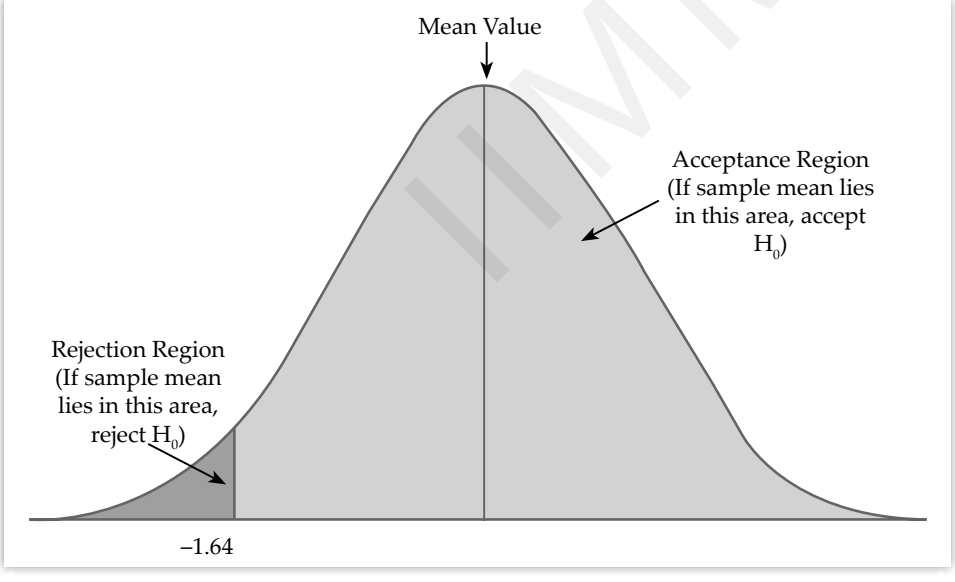

Figure 5: One-tailed Test

In Figure 5, at the 5% level of significance, z value would be –1.64. If the sample mean is greater than –1.64, then H_0 is accepted. Else, H_0 is rejected.

The level of significance can be represented with the help of α and $\alpha/2$ in one-tailed test and two-tailed test, respectively. For example:

- In one-tailed test, if the level of significance is 5%, then α is 5%. In this case, the value of test statistics would be determined at 0.05.
- In two-tailed test, if the level of significance is 5%, then the value of test statistics would be determined at 0.025% ($\alpha/2$).

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Self Assessment Questions

3. _____ is a process to make decisions for research problems by using the available data.
4. Null hypothesis is tested with the help of the levels of significance. (True/False)
5. _____ errors are also known as the first kind of error or false positive.
6. Which one of the following tests is a part of non-directional hypothesis?
   a. Two-tailed test
   b. One-tailed test
   c. Both a and b
   d. None of these

9.4 PROCEDURE OF HYPOTHESIS TESTING

Hypothesis testing is a step-by-step process that starts with the formulation of hypothesis and ends with decision-making. The steps involved in hypothesis testing are shown in Figure 6:

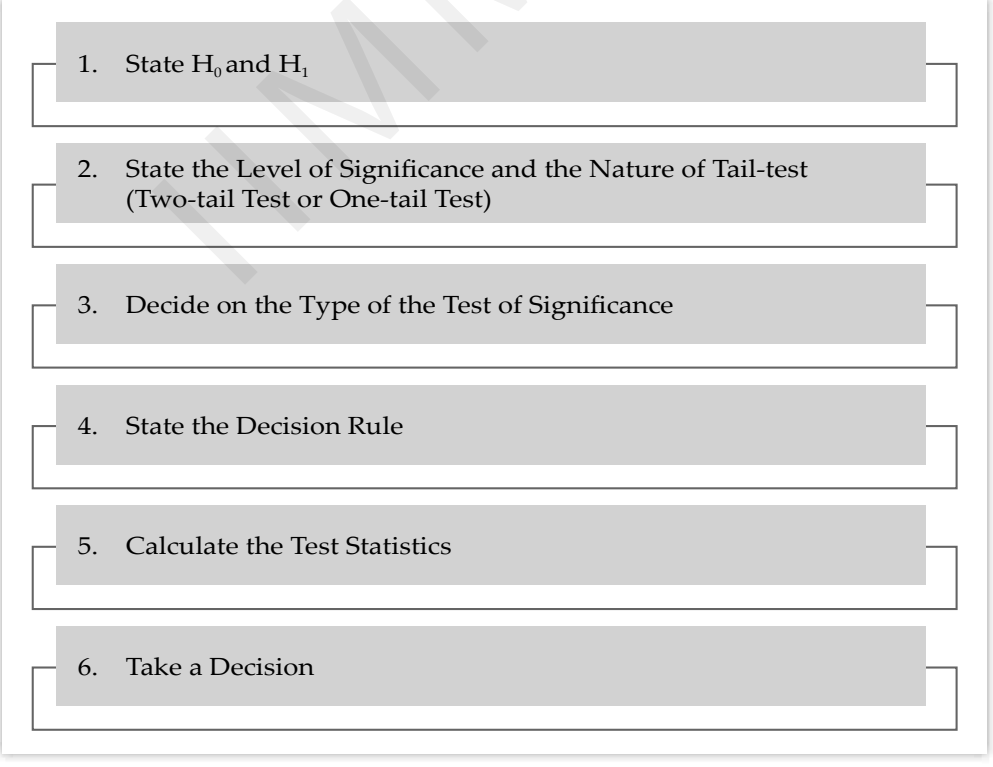


Figure 6: Process of Hypothesis Testing

Let us now discuss the process of hypothesis testing in detail.

1. **State H_0 and H_1:** In this step, null hypothesis and the alternative hypothesis are framed.

For example, a research organisation wants to perform a significance test to determine whether the mean weight of Indian children aged 5 is 20 kg or not (as claimed by reports). In this case, H_0 and H_1 would be as follows:

$\mu_p = 20$

H_0: $\mu_p = 20$ kg

H_1: $\mu_p \neq 20$ kg

Where, μ_p = Population mean

2. **State the level of significance:** This refers to deciding the level of significance (α) for the hypothesis test. The most commonly used level of significance is 5%. This happens because the range 5% is neither too big nor too small to accept or reject a hypothesis.
3. **Decide on the type of the test of significance:** The test of significance is used to check the hypothesis at a given level of significance. There are various types of tests of significance, such as t-test, z-test, and F-test. The selection of a test depends on various factors, such as the sample size, variance and type of population. For example, you use the t-test when the sample size is less than 30 and the z-test when the sample size is more than 30.
4. **State the decision rule:** It refers to determining the conditions under which the null hypothesis is accepted or rejected. If the decision rule is not determined correctly, then there are chances of committing Type I and Type II errors. Therefore, you should be careful while making the decision rule.
5. **Calculate the test statistics:** It refers to ascertaining the value of test statistics to accept or reject the hypothesis.
6. **Take a decision:** It refers to either accepting or rejecting H_0 on the basis of the calculated value of test statistics. If the calculated probability is equal to or smaller than α value (in one-tailed test) or smaller than $\alpha/2$ (in two-tailed test), then null hypothesis is rejected. However, if calculated probability is greater than α value, then null hypothesis is accepted. Rejecting H_0 may lead to Type I error, whereas accepting H_0 may lead to Type II error.

Self Assessment Questions

7. Hypothesis testing is a step-by-step process that starts with the formulation of hypothesis and ends with _____.
8. What does μp stand for in hypothesis testing?
   a. Sample mean
   b. Population mean
   c. Level of significance
   d. Coefficient of correlation

Notes

9. Which one of the following is the commonly used level of significance for minimising Type I and Type II errors?

   a. 10% b. 12%

   c. 5% d. 7%

10. Which of the following are the types of test of significance?

   a. t-test b. z-test

   c. F-test d. All of these

Activity

Prepare a PowerPoint presentation on hypothesis and hypothesis testing.

9.5 SUMMARY

- Hypothesis is a proposed explanation given for an observed situation.
- Inductive hypothesis is a type of derivation hypothesis where you move from specific observations to broad generalisations.
- Deductive hypothesis is a type of derivation hypothesis in which you move from a general statement to a specific conclusion.
- Directional hypothesis refers to the formulation hypothesis that checks the direction of relationship between two variables.
- Non-directional hypothesis refers to the formulation hypothesis where the direction of the relationship between two variables cannot be specified.
- Null hypothesis refers to the hypothesis in which there is no significant relation between two variables under study. It is denoted by H_0. It represents the first statement of a hypothesis that is assumed to be true.
- Alternative hypothesis states that there is a relationship between two variables under study. It is denoted by H_1. It represents the second statement of a hypothesis that is assumed to be false.
- The decision rule states that before accepting or rejecting a null hypothesis, the researcher should keep in mind all the criteria set for the hypothesis.
- Two-tailed test is a part of non-directional hypothesis that talks about the relationship between two variables under study, but does not explain anything about the direction of the relationship.
- One-tailed test is a part of directional hypothesis that talks not only about the relationship between two variables under study, but also the direction of relationship.
- Hypothesis testing is a step-by-step process that starts with the formulation of hypothesis and ends with decision-making.

9.6 KEY WORDS

- **Alternative hypothesis:** The hypothesis that finds out the relation between two variables.
- **Deductive hypothesis:** The type of hypothesis that moves from a general observation to a specific conclusion.
- **Directional hypothesis:** The hypothesis that checks the direction of relationship between two variables under study.
- **Non-directional hypothesis:** The hypothesis where the direction of relationship between two variables under study cannot be specified.
- **Null hypothesis:** The hypothesis that says there is no relationship between two variables under study.

9.7 CASE STUDY: ONE-TAILED HYPOTHESIS TESTING FOR TESTING PRODUCTION QUALITY

AM Pvt. Ltd. is a manufacturer which produces alternators. The Indian government has a policy that an alternator can be sold in the market if it can run at less than 71.1° C under stress test assuming 95% confidence. To test the quality, the samples are chosen randomly on a daily basis by the quality department of the company. On a particular date (say, D), 7 samples were drawn having a mean 71.3° C and a standard deviation of 0.214°. The quality department of the company wants to find out if there is any quality issue or not.

For testing the above-stated problem, the null hypothesis and alternate hypothesis are stated as:

H_0: $\mu_p \leq 71.1°$

H_0: $\mu_p > 71.1°$

Now, the researcher (quality department) finds the p and α values:

p = 95% = 0.95

Level of significance $\alpha = 1 - p = 0.05$

Degree of freedom (df) for the sample = 7 – 1 = 6

Thereafter, the researcher finds out the value of t-statistic at 95% confidence and df at 6 using t-table, which comes out to be 1.943.

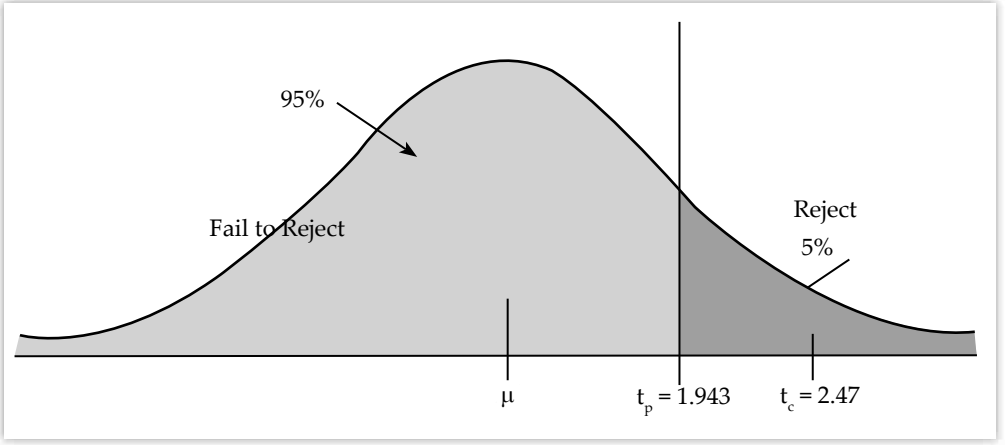
Now, the researcher calculates the value of t-statistic as:

$$t_c = \frac{\bar{X} - \mu}{s/\sqrt{n}}$$

$$t_c = \frac{71.3 - 71.1}{0.214/\sqrt{7}}$$

$$t_c = \frac{0.2}{0.0809} = 2.47$$

The researcher draws a detailed graph to represent his research as:



It can be seen that the critical t-value (t_c) lies in the rejection region. Therefore, the researcher rejects the null hypothesis. Rejecting the null hypothesis means that the sample was not acceptable and it can be stated that there is some issue in the production of alternators at AM Pvt. Ltd., which it must find out and resolve.

QUESTIONS

1. What would be the value of t_c if the sample had 49 alternators in it?

   (**Hint:**

   $$\frac{\bar{} - \mu}{s/\sqrt{n}}$$

   $$t_c = \frac{71.3 - 71.1}{0.214/\sqrt{49}}$$

   $$t_c = \frac{0.2}{0.0305} = 6.65$$

2. What would be the value of t_c if the standard deviation was changed to 0.851?

   (**Hint:**

   $$t_c = \frac{\bar{X} - \mu}{s/\sqrt{n}}$$

   $$t_c = \frac{71.3 - 71.1}{0.815/\sqrt{7}}$$

   $$t_c = \frac{0.2}{0.321} = 0.623$$

   In this case, the null hypothesis would have been accepted.)

3. State the policy of the Indian government for selling an alternator in the market.

   (**Hint:** If an alternator can run at less than 71.1° C under stress test assuming 95% confidence.)

4. How were the samples collected to test the quality?

   (**Hint:** Samples were chosen randomly.)

5. What did the quality department of the company want to find out?

   (**Hint:** The department wanted to find if there was any quality issue or not.)

9.8 EXERCISE

1. Describe the hypothesis and its types in detail.
2. What are the characteristics of a good hypothesis?
3. Explain the hypothesis testing in detail.
4. Explain the following terms:
   a. Null hypothesis
   b. Two-tailed test
   c. Decision rule

9.9 ANSWERS FOR SELF ASSESSMENT QUESTIONS

Topic	Q. No.	Answer
Defining Hypothesis	1.	Hypothesis
	2.	c. 1–iii, 2–i, 3–iv, 4–ii
Hypothesis Testing	3.	Hypothesis testing
	4.	True
	5.	Type I
	6.	a. Two-tailed test
Procedure of Hypothesis Testing	7.	decision-making
	8.	b. Population mean
	9.	c. 5%
	10.	d. All of these

9.10 SUGGESTED BOOKS AND E-REFERENCES

SUGGESTED BOOKS

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CHAPTER 10

Parametric Tests

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LEARNING OBJECTIVES

After studying this chapter, you will be able to:

- Distinguish between parametric and non-parametric tests for testing hypotheses
- Describe the different types of parametric tests
- Explain the concepts of one-sample test and two-sample test
- Describe the concept of ANOVA

10.1 INTRODUCTION

In the previous chapter, you studied to test a hypothesis to find the solution of a research problem. To check the validity of a hypothesis, you can use two main types of tests, namely parametric tests and non-parametric tests.

Parametric tests are statistical measures used in the analysis phase of research to draw inferences and conclusions to solve a research problem. There are various types of parametric tests, such as z-test, t-test and F-test. Selection of a particular test for a research depends upon various factors, such as the type of population, sample size, Standard Deviation (SD) and variance of population. It is important for a researcher to identify the appropriate test to maintain the authenticity and validity of research results.

In this chapter, you will learn about the concept of parametric tests. You will learn about one-sample and two-sample tests. You will also learn to apply z-test, t-test and F-test in different conditions and scenarios for one-sample and two-sample tests.

10.2 TYPES OF HYPOTHESIS TESTING

A hypothesis can be tested by using a large number of tests. Therefore, researchers have found it more convenient to categorise these tests on the basis of their similarities and differences. Hypothesis tests are divided into two types, as shown in Figure 1:

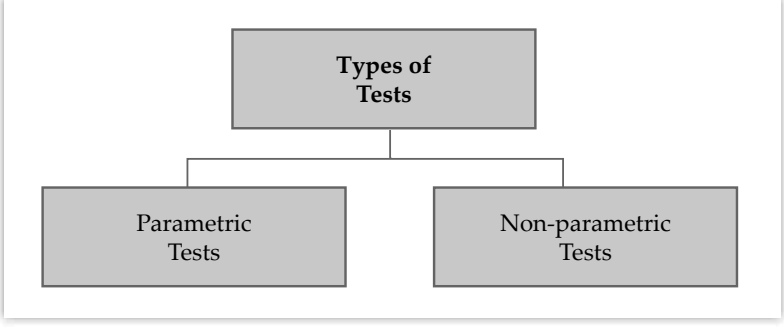

Figure 1: Types of Hypothesis Tests

- **Parametric tests:** In these tests, the researcher makes assumptions about the parameters of the population from which a sample is derived. An example of a parametric test is z-test.

Notes

- **Non-parametric tests:** These are distribution-free tests of hypotheses. Here, the researcher does not make assumptions about the parameters of the population from which a sample is derived. An example of a non-parametric test is the Kruskal -Wallis test.

Self Assessment Questions

1. What do you call the hypotheses tests where the researcher makes assumptions about the parameters of the population from which a sample is derived?
   a. Non-parametric tests
   b. Parametric tests
   c. Chi-Square test
   d. Distribution-free tests

10.3 PARAMETRIC TESTS

In parametric tests, researchers assume certain properties of the parent population from which samples are drawn. These assumptions include properties, such as the sample size, type of population, mean and variance of population and distribution of the variable.

For example, t-test assumes that the variable under study in population is normally distributed. Researchers calculate the parameters of population using various test statistics. Then, they test the hypothesis by comparing the calculated value of parameters with the benchmark value given in the problem. The scale used for dependent value in parametric tests is mostly the interval scale or ratio.

There are various types of parametric tests, as shown in Figure 2:

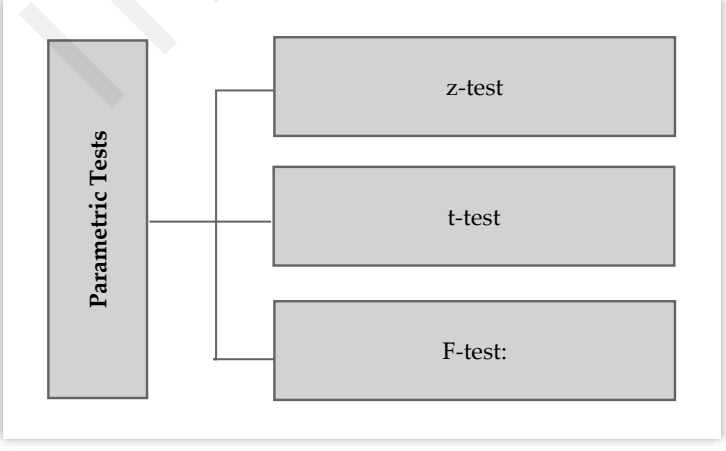

Figure 2: Types of Parametric Tests

Let us now discuss each type of test in detail:

- **z-test**: This test is used to study the mean and proportion of samples having a sample size of more than 30. It involves comparison of means of two different and unrelated samples drawn from the same population whose variance in known. The z-value (test statistic) is calculated for the present data and compared with the z-value at that level of significance, which is decided earlier in the question/

problem. After comparison, researcher may decide to reject or support null hypothesis. The z-test is used in the following cases:

- To compare the mean of a sample with the mean of a hypothesised population when the sample size is large and the population variance is known
- To compare the significant difference between the means of two independent samples in the case of large samples or when the population variance is known
- To compare the proportion of a sample with the proportion of the population

❍ **t-test:** This test is used to study the mean of samples when the sample size is less than 30 and/or the population variance is unknown. It is based on t-distribution. A t-distribution is a type of probability distribution that is appropriate for estimating the mean of a normally distributed population where the sample size is small and population variance is unknown.

The t-value (test statistic) is calculated for the present data and compared with the t-value at a specified level of significance for concerning degrees of freedom for accepting/rejecting the null hypothesis. The degree of freedom is calculated by subtracting one observation from the number of observations. It is used to check the t-value in the t-distribution table.

Sometimes, the t-test is used to compare the means of two related samples when the sample size is small and the population variance is unknown. In such a situation, it is known as the paired t-test.

❍ **F-test**: This test is used to compare the ratio of variances of two samples under study. It involves comparing the ratio of two variances of two samples. The F-distribution is a right-skewed distribution that is used most commonly in Analysis of Variance (ANOVA). Here, the test statistic has an F-distribution.

The F-value (test statistic) is calculated for the present data and compared with the F-value at that level of significance, which is decided earlier in the question/ problem. In an F-test, these are two independent degrees of freedom in numerator and denominator, respectively. The degrees of freedom (d.f.) of two samples are calculated separately by subtracting one from the number of observations. After that, the F-value is calculated from the F-distribution table.

Parametric tests are further divided into two parts – one-sample tests and two-sample tests. You will learn more about them in the next sections.

ASSUMPTIONS OF F-TEST

F-distribution is usually asymmetric with minimum value of zero. However, the maximum value is infinity.

Assumptions for using an F-test include:

1. Both the samples come from normal distribution.
2. Observations in each sample are selected randomly.

F-statistic can never be negative as it is a ratio of two squared numbers.

Notes

The degrees of freedom for different tests are calculated in different ways as follows:

Test	Degree of Freedom
One sample t-test	n – 1; where, n = sample size
Paired data t-test	n – 1; where, n = number of pairs of data points
t-test for two independent populations	$(n_1 - 1) + (n_2 - 1)$; where, n_1 and n_2 are sizes of two samples
Chi-square test for independence	(r–1) (c–1); where r equals number of levels for one category of variable and c equals number of levels for second category of variable
Chi-square test for goodness of fit	n – 1; where, n = the number of levels of a single categorical variable
One factor ANOVA (F-test)	Degree of Freedom of Numerator (dfn) = $k - 1$; and Degree of Freedom of Denominator (dfd) = N – k; Where, n = total number of data values in an experiment, and k = the number of groups

Self Assessment Questions

2. Which of the following parametric tests is used to study the mean and proportion of samples having a sample size more than 30?
   a. t-test
   b. F-test
   c. Chi-square test
   d. z-test
3. The _____ is used to compare the mean of samples when the sample size is less than 30 and the population variance is unknown.
4. Which test is used to compare the significant difference between the variances of two samples under study?
   a. z-test
   b. Chi-square test
   c. t-test
   d. F-test
5. The degree of freedom is calculated by subtracting _____ from the _____ for t-test.

10.4 ONE-SAMPLE TEST – DIFFERENT SITUATIONS IN WHICH ONE-SAMPLE TEST IS USED

In a one-sample test, the researcher compares the mean of a sample to a pre-specified value and tests for deviation from that value. In this test, you can determine the mean, variance and proportion of the sample and population with the help of z-test and t-test.

The one-sample test is used in various situations as mentioned in Table 1:

Table 1: Cases of One-Sample Test

Case	Population	Sample Size	Population Mean	Sample Mean	Population Variance	Sample Variance	Test
Case-I	Normal and finite and n/N < 0.05	Large			Unknown	Known	Two-tailed or one-tailed
Case-II	Normal and finite	Large			Known	Known	Two-tailed or one-tailed
Case-III	Normal and infinite	Large			Unknown	Known	Two-tailed or one-tailed
Case-IV	Population proportion and sample proportion are known						
Case-V	Normal and infinite	Large			Unknown	Known	Two-tailed or one-tailed
Case-VI	Normal and infinite	Large			Unknown	Known	Two-tailed or one-tailed

Let us study these cases in detail.

10.4.1 EXPLORING CASE-I

In this case, the population is normal and finite, the sample size is large and the population variance is unknown. The researcher uses the following test statistics:

$t = \overline{X} - \mu/(s/\sqrt{n})\ (\sqrt{(N - n)/(N - 1)})$

Where,

μ = Population mean

N = Population size

n = Sample size

s = Standard Deviation of the sample

$\overline{X}$ = Sample mean

10.4.2 EXPLORING CASE-II

In Case-II, the population is normal and finite, the sample size is large and the population variance is known. In this case, the researcher uses the following test statistics:

$z = \overline{X} - \mu/(\sigma_p/\sqrt{n})\ (\sqrt{(N - n)/(N - 1)})$

Where,

μ = Population mean

n = Sample size

σ_p = Standard Deviation of the population

Notes

$\overline{X}$ = Sample mean

Let us understand the application of Case-II with the help of an example.

Example 1: The population mean diameter of all products produced by an organisation is presumed to be 8 cm, with an SD of 2.5. The size of the population is 50. Now, the organisation has taken a random sample of 35 pieces of product A to know whether the average diameter of sample production of this product is the same or more than the overall production. The average mean for product A is 10 cm. Use 5% as the level of significance. Construct the hypothesis and carry out the test of significance for this problem.

Solution: The null hypothesis and the alternative hypothesis are as follows:

H_0: The average of production of product A is the same as the overall production of all products combined.

H_1: The average of production of product A is more than the overall production of all products combined.

Or,

H_0: $\mu_s = 8$ cm

H_1: $\mu_s > 8$ cm

Where, μ_s = Sample mean, that is, the average amount of production of product A

Assumed Population mean (μ) = 8 cm

Population size (N) = 50

Sample size (n) = 35

Sample mean (X) = 10

Standard Deviation of sample (σ_p) = 2.5

Since the population is finite, the researcher uses the following formula for z-test to test the hypothesis for significance:

$z = \overline{X} - \mu/(\sigma_p/\sqrt{n})\ (\sqrt{(N-n)/(N-1)})$

$$z = \frac{\overline{X} - \mu}{\sigma_p / \sqrt{n}} \times \sqrt{\frac{N-n}{N-1}}$$

$$z = \frac{10-8}{2.5/\sqrt{35}} \times \sqrt{\frac{50-35}{50-1}}$$

$$z = \frac{2}{2.5/5.91} \times \sqrt{\frac{15}{49}}$$

$z = 4.728 \times 0.5532 = 2.6155$

The z-value for the 5% level of significance for one-tailed test is + 1.64.

The graphical representation of the preceding solution is given in Figure 3:

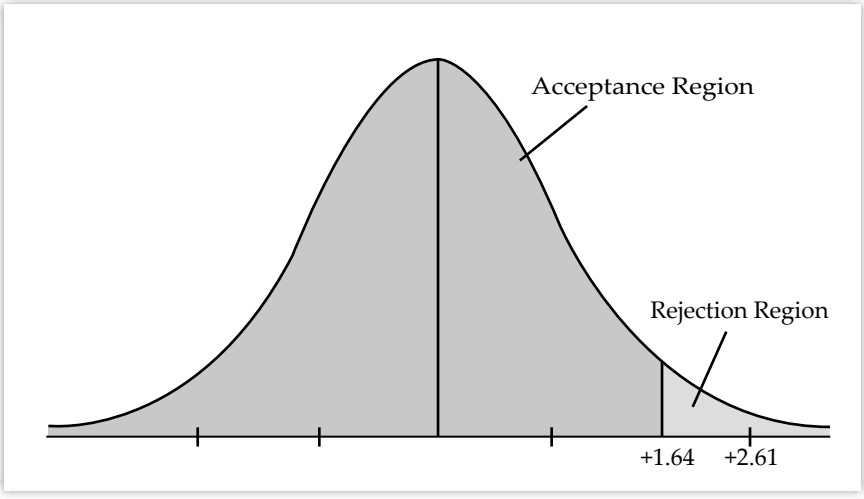

Figure 3: Rejecting Calculated z-Value

In Figure 3, it can be observed that the calculated value of z lies in the rejection region; therefore, H_0 is rejected. This implies that the average diameter production of product A is more than the overall production.

10.4.3 | EXPLORING CASE-III

In Case-III, the population is normal and infinite, the sample size is large and the population variance is unknown. In this case, the following test statistic is used:

$t = \overline{X} - \mu/(\sigma_s/\sqrt{n})$

Where,

μ = Population mean

n = Sample size

σ_s = Standard Deviation of sample

$\overline{X}$= Sample mean

Let us understand the application of Case-III with the help of an example.

Example 2: The rating given by 36 existing customers of an organisation from the south part of a city to a newly launched product is as follows (1 being the lowest rating and 10 being the highest rating):

5, 6, 10, 9, 8, 7, 2, 3, 8, 9, 7, 9, 10, 4, 3, 2, 10, 8, 9, 6, 2, 6, 5, 8, 9, 7, 7, 7, 7, 2, 4, 5, 5, 5, 10, 10

The marketers have the average rating from the whole city as 7.5. Now, the organisation wants to know whether the south part also has the same rating. Use 5% as the level of significance.

Notes

Solution: The null hypothesis and the alternative hypothesis are as follows:

H_0: The average rating of the south part of the city is the same as the average rating of the city

H_1: The average rating of the south part of the city is not the same as the average rating of the city

Or,

H_0: $\mu_p = 7.5$

H_1: $\mu_p \neq 7.5$

Where, μ_p = Sample mean, that is, the rating given by the customers in the south part of the city

The data and the calculation part of the previous problem are shown in Table 2:

Table 2: Ratings Given by Customers

No. of Observations	Rating Given by Customers (X_i)	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
1	6	–1.4	1.96
2	7	–0.4	0.16
3	10	2.6	6.76
4	9	1.6	2.56
5	8	0.6	0.36
6	7	–0.4	0.16
7	5	–2.4	5.76
8	8	0.6	0.36
9	8	0.6	0.36
10	9	1.6	2.56
11	7	–0.4	0.16
12	9	1.6	2.56
13	10	2.6	6.76
14	4	–3.4	11.56
15	8	0.6	0.36
16	5	–2.4	5.76
17	10	2.6	6.76
18	8	0.6	0.36
19	9	1.6	2.56
20	6	–1.4	1.96
21	6	–1.4	1.96
22	6	–1.4	1.96
23	8	0.6	0.36

No. of Observations	Rating Given by Customers (X_i)	$X_i - \overline{X}$	$(X_i - \overline{X})^2$
24	8	0.6	0.36
25	9	1.6	2.56
26	7	–0.4	0.16
27	7	–0.4	0.16
28	7	–0.4	0.16
29	7	–0.4	0.16
30	5	–2.4	5.76
31	4	–3.4	11.56
32	6	–1.4	1.96
33	8	0.6	0.36
34	5	–2.4	5.76
35	10	2.6	6.76
36	10	2.6	6.76
Total	$\sum X_i = 266$	$\sum(X_i - \overline{X})^2 = 0.4$	$\sum(X_i - \overline{X})^2 = 106.56$

Sample mean $(\overline{X}) = \sum X_i/n$

$\overline{X} = 266/36$

$\overline{X} = 7.38$

Population mean $(\mu_p) = 7.5$

Sample size (n) = 36

Since the standard deviation for the population is not given, the researcher needs to calculate the SD for the sample.

Standard Deviation of sample $(\sigma_s) = \sqrt{\sum} (X - \overline{X})^2/(n - 1)$

$\sigma_s = \sqrt{106.56/35}$

$\sigma_s = 3.044$

The population is infinite; therefore, the researcher uses the following formula for z-test to test the hypothesis for significance:

$t = \overline{X} - \mu/(\sigma_s/\sqrt{n})$

$$t = \left(7.38 - 7.5\right) / \left(3.044 / \sqrt{36}\right)$$

$$t = -0.12 / \left(3.044/6\right) = \frac{-0.12 \times 6}{3.044} = -0.236$$

The t-value for the 5% level of significance for two-tailed test is + 2.03.

Notes

After checking the t-value for significance, the researcher applies two-tailed test. The graphical representation of the preceding solution is shown in Figure 4:

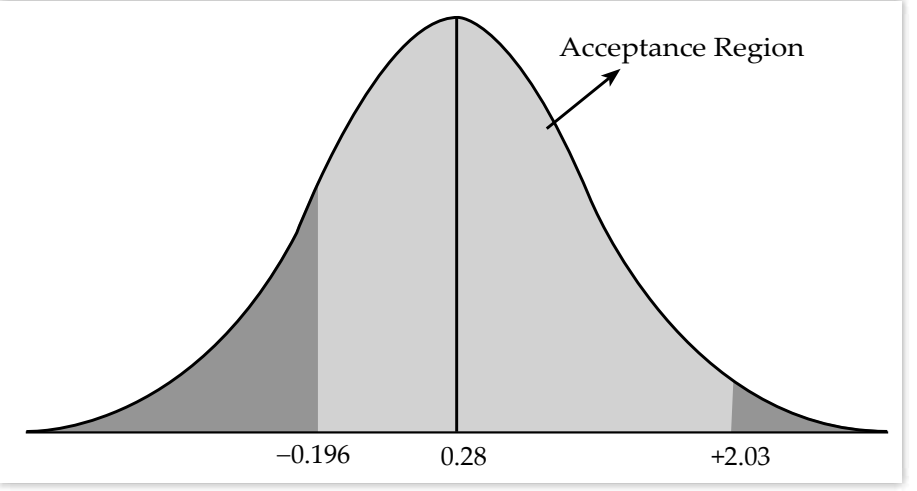

Figure 4: Position of Calculated z-Value

In Figure 4, it can be observed that the calculated z-value lies in the acceptance region; therefore, H_0 is accepted. This implies that the average rating of the south part of the city is the same as the average rating of the city.

10.4.4 EXPLORING CASE-IV

In Case-IV, the observed sample proportions are known. In such a situation, the researcher uses the following test statistic:

$$z = \frac{\hat{p} - p}{\sqrt{\frac{pq}{n}}}$$

$$\hat{p} = \frac{x}{n}$$

Where, p = Proportion of success of population (assumed)

n = Sample size

q = Proportion of failure of population

x = value to be standardised

$\hat{p}$ (Pronounced as p-hat) = Observed sample proportion

$\hat{p}$ can be an unbiased measure of p

Example 3: According to a record of a college, the proportion of girl students presumed in the college is 40%. The college principal conducted a survey of 3,000 students to validate the college record. Out of 3,000 students, 1,450 are girls and the rest are boys. Now, the principal wants to check the authenticity of the survey through the test of significance to know the degree of validity of the record. Use 5% as the level of significance.

Solution: The null hypothesis and the alternative hypothesis are as follows:

H_0: The proportion of girl students observed in the survey is the same as in the college record.

H_1: The proportion of girl students observed in the survey is different from their proportion in the college record.

Or,

H_0: p = 0.40

H_1: p ≠ 0.40

Where,

p = Probability of success, that is, the actual proportion of girls in the college

p = 0.40

q = 1 – 0.40

q = 0.60

Sample size (n) = 3000

Observed sample proportion, ($\hat{p}$) = 1450/3000

($\hat{p}$) = 0.4833

$$z = \frac{\hat{p} - p}{\sqrt{\frac{pq}{n}}}$$

z = 0.0833/0.009

z = 9.26

The z-value for the 5% level of significance for two-tailed test is ± 1.96. The graphical representation of the preceding solution is shown in Figure 5:

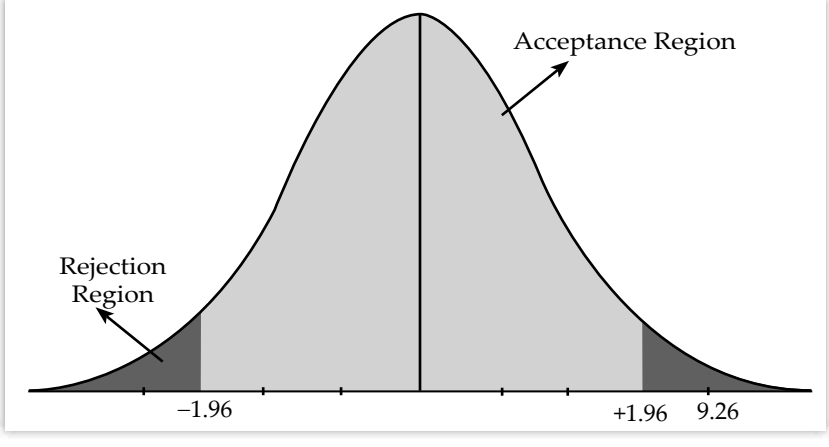

Figure 5: Calculated z-Value When the Proportion of Population and Sample Means are Given

Notes

In Figure 5, it can be observed that the z-value lies in the rejection region; therefore, H_0 is rejected. This implies that the proportion of girl students observed in the survey is different from their proportion in the college record. It can be interpreted from the calculated z-value that the average number of girls in the college has increased.

10.4.5 EXPLORING CASE-V

In Case-V the population is normal and infinite, the sample size is small, and the population variance is unknown. In this case, the researcher uses the following test statistic:

$t = (\overline{X} - \mu)/(\sigma_s/\sqrt{n})$

Where,

μ = Population mean

n = Sample size

σ_s = Standard deviation of sample

$\overline{X}$ = Sample mean

Let us understand the application of case V with the help of an example.

Example 4: A researcher wants to study the average income of a group of 25 people working as marketing executives in different organisations (especially small and medium enterprises). The salary of the sample of 25 marketing executives included in a study sample is recorded as:

No. of Observations	Income (Lakhs)
3	2
4	2
5	1.9
6	2
7	1.9
8	2
9	1.9
10	2
11	2
12	1.9
13	2
14	1.9
15	2
16	2
17	1.8
18	2
19	2
20	2
21	2

No. of Observations	Income (Lakhs)
22	1.9
23	2
24	1.9
25	2
Total	

The average recorded package for the marketing executive post is ₹ 2 lakhs. The researcher wants to know whether the average recorded package is valid for this group or not. Use 5% as the level of significance.

Solution: The null hypothesis and the alternative hypothesis are as follows:

H_0: The average recorded package and the sample average income of group are the same.

H_1: The average recorded package and the sample average income of group are different.

H_0: μs = 2,00,000

H_1: μs ≠ 2,00,000

Where,

μ_s= Sample mean, that is, the sample mean for the income of the group

The data and the calculation part for this example are shown in Table 3:

Table 3: Income of People at the Marketing Executive's Post

No. of Observations	Income (Lakhs)	$X_i - \bar{X}$	$(X_i - \bar{X}^2)$
1	2	0.04	0.0016
2	1.9	– 0.06	0.0036
3	2	0.04	0.0016
4	2	0.04	0.0016
5	1.9	– 0.06	0.0036
6	2	0.04	0.0016
7	1.9	– 0.06	0.0036
8	2	0.04	0.0016
9	1.9	– 0.06	0.0036
10	2	0.04	0.0016
11	2	0.04	0.0016
12	1.9	– 0.06	0.0036
13	2	0.04	0.0016

Notes

No. of Observations	Income (Lakhs)	$X_i - \overline{X}$	$(X_i - \overline{X}^2)$
14	1.9	– 0.06	0.0036
15	2	0.04	0.0016
16	2	0.04	0.0016
17	1.8	– 0.16	0.0256
18	2	0.04	0.0016
19	2	0.04	0.0016
20	2	0.04	0.0016
21	2	0.04	0.0016
22	1.9	– 0.06	0.0036
23	2	0.04	0.0016
24	1.9	– 0.06	0.0036
25	2	0.04	0.0016
Total	$\sum X_i = 49$		$\sum(X_i - \overline{X})^2 = 0.08$

Population mean (μ) = 2 lakhs (assumed)

Sample size (n) = 25

Sample mean ($\overline{X}$) = $\sum X_i/n$

$\overline{X}$ = 49/25

$\overline{X}$ = 1.96

Since the standard deviation for the population is unknown, the researcher needs to calculate the standard deviation for the sample as follows:

Standard deviation of sample (σ_s) = $\sqrt{\sum} (X_i - \overline{X})^2/(n - 1)$

$\sigma_s = \sqrt{0.08/24}$

σ_s = 0.058

The population is infinite; therefore, the researcher uses the following formula for t-test to test the hypothesis for significance:

$t = \overline{X} - \mu/(\sigma_s/\sqrt{n})$

t = – 0.04/0.0116

t = – 3.45

Degree of freedom (d.f.) = n – 1

= 25 – 1

= 24

The t-value for the 5% level of significance for two-tailed test and 24 d.f. is ±2.064. The graphical representation of the preceding solution is shown in Figure 6:

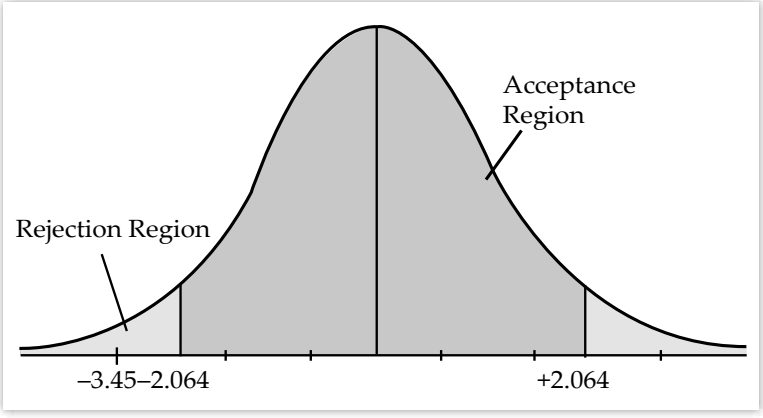

Figure 6: Position of Calculated t-Value

In Figure 6, it can be observed that the calculated t-value lies in the rejection region; therefore, H_0 is rejected. This implies that the average recorded package and the sample average of the income of the group are different. It can be interpreted that the average income for the marketing executive post has decreased in the market.

10.4.6 EXPLORING CASE-VI

In Case-VI, the population is normal and finite, the sample size is small, and the population variance is unknown. In this case, the researcher uses the following test statistic:

$$t = \frac{\bar{X} - \mu}{\left(\sigma_s / \sqrt{n}\right)} \sqrt{\frac{(N-n)}{(N-1)}}$$

Where,

μ = Population mean

n = Sample size

s = Standard deviation of sample

$\bar{X}$ = Sample mean

Let us understand the application of Case-VI with the help of an example.

Self Assessment Questions

6. One-sample test helps in determining _____, _____ and _____ of a sample population with the help of z-test, t-test and chi-square test.
7. In the given formula $z = X - \mu/(\sigma_s/\sqrt{n})\ (\sqrt{(N-n)/(N-1)})$, what does μ stand for?
   a. Sample size
   b. Population mean
   c. Standard deviation of sample
   d. Sample mean

10.5 TWO-SAMPLE TESTS

In a two-sample test, a researcher wants to study the relationship between two samples drawn from two different or same populations. In this section, you will learn about the application of z-test, t-test, and F-test in different situations. These situations are as follows:

- Differences between two independent samples
- Differences between two proportions
- Comparing two related samples
- Equality of the variances of two populations

The two-sample test in different situations is discussed in detail in the upcoming sections.

10.5.1 DIFFERENCES BETWEEN TWO INDEPENDENT SAMPLES

In this study, a researcher finds the relationship between two samples that are taken from two independent groups in terms of their means. The samples are compared to find out whether they are significantly different in terms of their mean value or they are drawn from the same population. The formula and method of conducting the two-sample test are different in different situations.

Table 4 lists the different situations for conducting two-sample tests:

Table 4: Situations to Find Differences between Two Samples (Two-Sample Tests)

Situation	Population	Sample Size	Population Variance	Test
Situation I	Normal	Large	Unknown	One-tailed or two-tailed
Situation II	Normal	Normal	Known	One-tailed or two-tailed
Situation III	Normal	Small	Unknown	One-tailed or two-tailed

These different situations with examples are discussed in the following sections.

Situation-I

In this situation, the population is normal, the sample size is large and the population variance is unknown. The researcher can use either two-tailed test or one-tailed test depending on the alternate hypothesis of the research. If the researcher wants to compare the two samples drawn from two different populations, then he/she would use the following test statistic:

$$t = \bar{X}_1 - \bar{X}_2 / \sqrt{\left(\sigma_{s_1}^2 / n_1\right) + \left(\sigma_{s_2}^2 / n_2\right)}$$

Where,

$\bar{X}_1$ = Sample mean of the first sample

$\bar{X}_2$ = Sample mean of the second sample

σ_{s1}= Standard deviation of the first sample

σ_{s2} = Standard deviation of the second sample

n_1 = Sample size of the first sample

n_2 = Sample size of the second sample

When, in any research problem, the value of population variance in known, then the researcher should use t-statistic.

Example 5: A researcher wants to compare the popularity of Brand A and Brand B. Therefore, he/she takes a sample of 35 people and asks them to rate the two brands on a 10-point scale (10 being the highest and 1 being the lowest). Use 5% as the level of significance.

Solution: The null hypothesis and the alternative hypothesis are as follows:

H_0: The popularity of Brand A and Brand B is the same.

H_1: The popularity of Brand A and Brand B is different.

Or,

H_0: $\mu_1 = \mu_2$

H_1: $\mu_1 \neq \mu_2$

Where,

μ_1 = Population mean of Brand A

μ_2 = Population mean of Brand B

The data and the calculation part of the preceding problem are shown in Table 5:

Table 5: Calculating the Popularity of Brand A and Brand B

No. of Observations	Brand A (X_{1i})	Brand B (X_{2i})	$(X_{1i} - \bar{X}_1)$	$(X_{1i} - \bar{X}_1)^2$	$(X_{2i} - \bar{X}_2)$	$(X_{2i} - \bar{X}_2)^2$
1	7	9	– 2	4	– 0.4	0.16
2	8	9	– 1	1	– 0.4	0.16
3	9	9	0	0	– 0.4	0.16
4	10	9	1	1	– 0.4	0.16
5	10	9	1	1	– 0.4	0.16
6	9	9	0	0	– 0.4	0.16
7	10	9	1	1	– 0.4	0.16
8	10	9	1	1	– 0.4	0.16
9	10	9	1	1	– 0.4	0.16
10	6	10	– 3	9	0.6	0.36
11	9	10	0	0	0.6	0.36
12	8	10	– 1	1	0.6	0.36
13	8	10	– 1	1	0.6	0.36

Notes

No. of Observations	Brand A (X_{1i})	Brand B (X_{2i})	$(X_{1i} - \overline{X}_1)$	$(X_{1i} - \overline{X}_1)^2$	$(X_{2i} - \overline{X}_2)$	$(X_{2i} - \overline{X}_2)^2$
14	9	9	0	0	– 0.4	0.16
15	7	10	– 2	4	0.6	0.36
16	9	10	0	0	0.6	0.36
17	10	10	1	1	0.6	0.36
18	8	10	– 1	1	0.6	0.36
19	9	10	0	0	0.6	0.36
20	10	9	1	1	– 0.4	0.16
21	10	9	1	1	– 0.4	0.16
22	9	9	0	0	– 0.4	0.16
23	9	9	0	0	– 0.4	0.16
24	8	9	– 1	1	– 0.4	0.16
25	9	9	0	0	– 0.4	0.16
26	9	9	0	0	– 0.4	0.16
27	10	9	1	1	– 0.4	0.16
28	10	9	1	1	– 0.4	0.16
29	10	9	1	1	– 0.4	0.16
30	10	9	1	1	– 0.4	0.16
31	10	9	1	1	– 0.4	0.16
32	9	10	0	0	0.6	0.36
33	9	10	0	0	0.6	0.36
34	8	10	– 1	1	0.6	0.36
35	9	10	0	0	0.6	0.36
Total	$\Sigma X_{1i} = 315$	$\Sigma X_{2i} = 328$		$\Sigma(X_{1i} - \overline{X}_1)^2 = 36$		$\Sigma(X_{2i} - \overline{X}_2)^2 = 8.2$

Sample mean of Brand A $(\overline{X}_1) = \sum X_{1i}/n$

$\overline{X}_1 = 315/35$

$\overline{X}_1 = 9$

Sample mean of Brand B $(\overline{X}_2) = \sum X_{2i}/n$

$X_2 = 328/35$

$X_2 = 9.37 \approx 9.4$

Standard Deviation of Sample A

$$\left(\sigma_{s_1}\right) = \sqrt{\frac{\sum\left(X_{1i} - \overline{X}_1\right)^2}{\left(n_1 - 1\right)}}$$

$$= \sqrt{\frac{36}{34}} = \sqrt{1.058} = 1.028$$

Standard Deviation of Sample B

$$\left(\sigma_{s_2}\right) = \sqrt{\frac{\sum\left(X_{2i} - \bar{X}_2\right)^2}{\left(n_2 - 1\right)}}$$

$$= \sqrt{\frac{8.2}{34}} = \sqrt{0.2411} = 0.491$$

Since the sample size is more than 30 and two samples are under study, the researcher applies the following z-test:

$$t = \bar{X}_1 - \bar{X}_2 \,/\, \sqrt{\left(\sigma_{s_1}^2 / n_1\right) + \left(\sigma_{s_2}^2 / n_2\right)}$$

$$t = \left(9 - 9.4\right) / \sqrt{\frac{\left(1.028\right)^2}{35} + \frac{\left(0.491\right)^2}{35}}$$

$$t = -0.4 \,/\, \sqrt{\frac{1.056 + 0.241}{35}}$$

$$t = -0.4 \,/\, \sqrt{\frac{1.297}{35}} = 0.037$$

$$t = -0.4 / 0.037 = -10.81$$

The t-value for the 5% level of significance for two-tailed test is ± 2.032 (degree of freedom = 35 – 1 = 34).

The graphical representation of the preceding solution is shown in Figure 7:

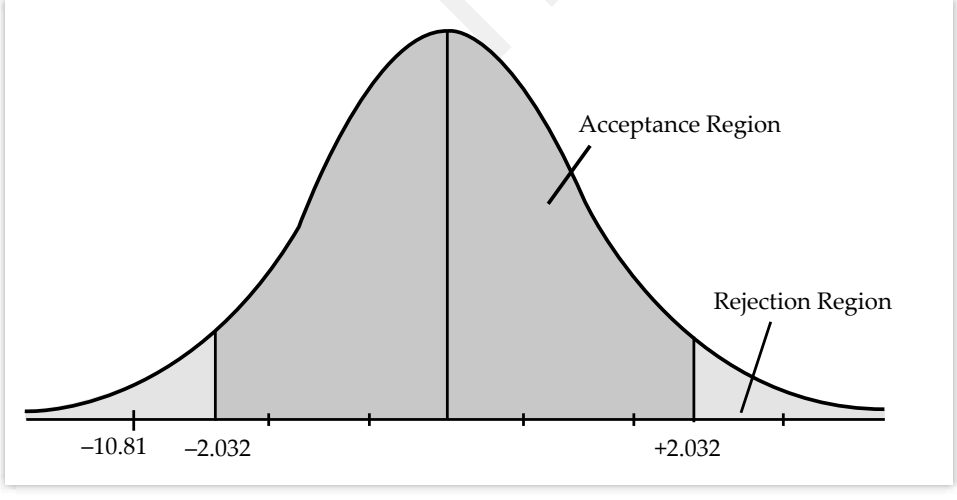

Figure 7: Position of Calculated z-Value in Case of Two Samples

In Figure 7, it can be observed that the z-value lies in the rejection region; therefore, H_0 is rejected. The popularity of Brand A is not the same as the popularity of Brand B.

NOTES

Situation-II

In this situation, the population is normal, the sample size is large, and the population variance is known. The populations are equal. The researcher can use either two-tailed test or one-tailed test depending on the alternate hypothesis of the research. If the researcher wants to compare two samples drawn from the same population, then he/she would use the following test statistic:

$$z = \left(\overline{X}_1 - \overline{X}_2\right) / \sqrt{\sigma_p^2 \left(1/n_1\right) + \left(1/n_2\right)}$$

Where,

$\overline{X}_1$ = Sample mean of the first sample

$\overline{X}_2$ = Sample mean of the second sample

σ_p = Standard deviation of the populations

n_1 = Sample size of the populations

n_2 = Sample size of the second sample

Example 6: A researcher has collected two samples from various production houses of an organisation. He has taken a sample of Product P from 500 production houses. He has found that the average production of Product P is equal to 1,000 pieces/month with a standard deviation of 13 pieces. He has also taken a sample of product Q from 400 production houses. He finds that the average production of product Q is 1,200 pieces/month with a standard deviation of 15 pieces. The standard deviation of the production houses of the organisation is 14. Is this the same organisation from where the researcher has collected the samples? Use 5% as the level of significance.

Solution: The null hypothesis and alternative hypothesis are as follows:

H_0: Population means of products P and Q are the same.

H_1: Population means of products P and Q are different.

Or,

H_0: $\mu_1 = \mu_2$

H_1: $\mu_1 \neq \mu_2$

Where, μ_1 = Population mean of product P

μ_2 = Population mean of product Q

Details are given as follows:

Sample mean of product P ($\overline{X}_1$) = 1000

Sample mean of product Q ($\overline{X}_2$) = 1200

Standard deviation of sample P ($\sigma S1$) = 13

Standard deviation of sample Q ($\sigma s2$) = 15

Standard deviation of population (σ_p) = 14

Number of observations of sample P (n_1) = 500

Number of observations of sample Q (n_2) = 400

Since the sample size is more than 30, the population variance is known, and two samples are under study, the researcher would apply the following z-test:

$$z = \left(\bar{X}_1 - \bar{X}_2\right) / \sqrt{\sigma_p^2 \left(1/n_1\right) + \left(1/n_2\right)}$$

$$z = \left(1000 - 1200\right) / \sqrt{(14)^2 \left[\frac{1}{500} + \frac{1}{400}\right]}$$

$$z = \left(-200\right) / \sqrt{196 \left[\frac{4+5}{2000}\right]}$$

$$z = \left(-200\right) / \sqrt{1764 / 2000}$$

z = (–200) / 0.939

z = –212.99

The z-value for the 5% level of significance for two-tailed test is ± 1.96. The graphical representation of the preceding solution is shown in Figure 8:

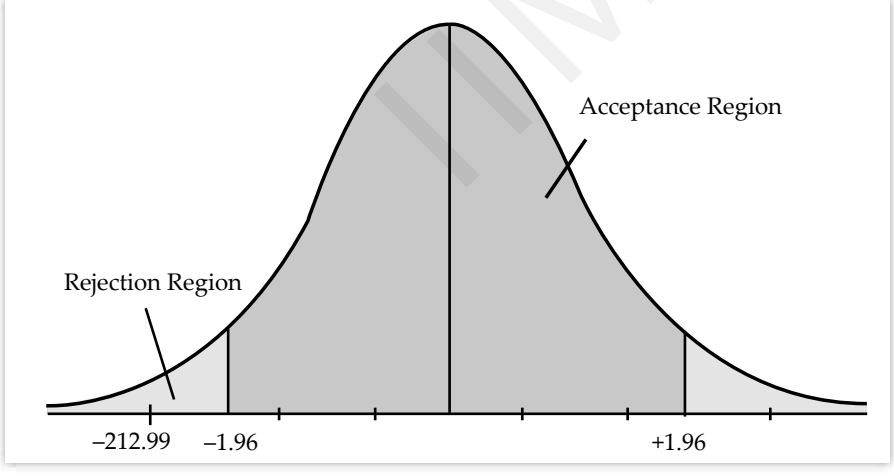

Figure 8: Representation of Calculated z-Value in Case of Two Samples

In Figure 8, it can be observed that the z-value lies in the rejection region; therefore, H_0 is rejected. This implies that the population means of products P and Q are different. It can be interpreted that the calculated z-value showing the difference between means of two samples is statistically significant.

Situation-III

In this situation, the population is normal, the sample size is small, and the population variance is unknown. The researcher can use either two-tailed test or one-tailed test on the basis of research problem and the alternative hypothesis. If the researcher

Notes

wants to compare two samples drawn from two different populations, then he/she would use the following test statistic:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{SE}$$

Where,

SE = Standard Error

$$SE = S_p\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}$$

Where S_p = Pooled standard deviation and

$$S_p = \sqrt{\frac{\sigma_1^2(n_1 - 1) + \sigma_2^2(n_2 - 1)}{(n_1 - 1) + (n_2 - 1)}}$$

$$\therefore t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\left[\frac{\sigma_1^2(n_1 - 1) + \sigma_2^2(n_2 - 1)}{(n_1 - 1) + (n_2 - 1)}\right]\left[\frac{1}{n_1} + \frac{1}{n_2}\right]}}$$

Where

$\bar{X}_1$ = Sample mean of the first sample

$\bar{X}_2$ = Sample mean of the second sample

σ_1 = Standard deviation of the first sample

σ_2 = Standard deviation of the second sample

n_1 = Sample size of the first sample

n_2 = Sample size of the second sample

Example 7: The average sales volume of two cities, A and B, for an organisation in 10 retail outlets is 100 and 200, respectively. The standard deviation for A is 5.5 and for B is 6.5. Test the hypothesis for the difference in sales of the two cities by using 5% as a test of significance.

Solution: The null hypothesis and the alternative hypothesis are as follows:

H_0: Average sale of City A is equal to the average sale of city B.

H_1: Average sale of City A is not equal to the average sale of city B.

Or,

H_0: $\mu_1 = \mu_2$

H_1: $\mu_1 \neq \mu_2$

Where,

μ_1 = Population mean of city A

μ_2 = Population mean of city B

Sample mean of city A ($\overline{X}_1$) = 100

Sample mean of city B ($\overline{X}_2$) = 200

Standard deviation of sample A (σ_1) = 5.5

Standard deviation of sample B (σ_2) = 6.5

Number of observations of samples A and B (n) = $n_1 = n_2 = 10$

Since the sample size is less than 30 and two samples are under study, the researcher would apply the following t-test:

$$t = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{\left[\frac{\sigma_1^2(n_1-1)+\sigma_2^2(n_2-1)}{(n_1-1)+(n_2-1)}\right]\left[\frac{1}{n_1}+\frac{1}{n_2}\right]}}$$

$$t = \frac{(100-200)}{\sqrt{\left[\frac{(5.5)^2(10-1)+(6.5)^2(10-1)}{(10-1)+(10-1)}\right]\left[\frac{1}{10}+\frac{1}{10}\right]}}$$

$$t = \frac{-100}{\sqrt{\left[\frac{9(30.25+42.25)}{18}\right]\left[\frac{1}{5}\right]}}$$

$$= \frac{-100}{\sqrt{7.25}}$$

$$= \frac{-100}{2.692} = \frac{-100}{2.7}$$

$= -37.03$

The t-value for the 5% level of significance for two-tailed test with 18 as degree of freedom is ± 2.101. The graphical representation of the preceding solution is shown in Figure 9:

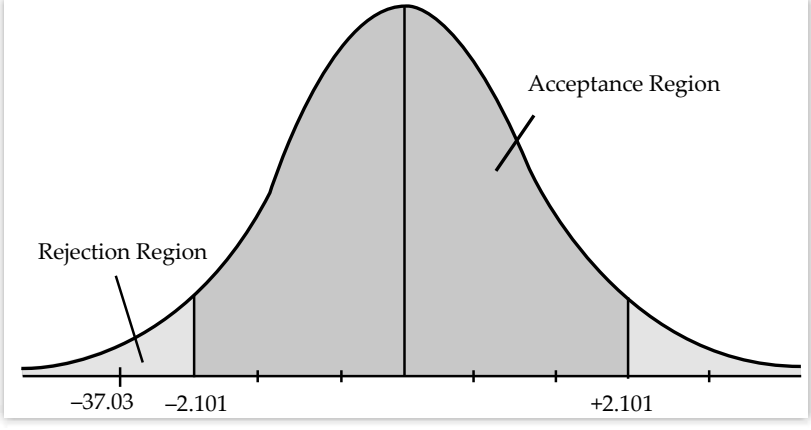

Figure 9: Rejection of Calculated t-Value in Case of Two Samples

Notes

In Figure 9, it can be observed that the t-value lies in the rejection region; therefore, H_0 is rejected. This implies that the average sales volume of City A is not equal to the average sales volume of city B. It can be interpreted from the calculated t-value that the difference between the means of the two samples is statistically significant.

10.5.2 DIFFERENCES BETWEEN TWO PROPORTIONS

In this study, a researcher finds the relationship between two samples that are given in the form of proportions. The researcher tries to find whether the two proportions are significantly different from each other or not. The samples are drawn from the same or different populations. This study can also be used to compare the proportions of a sample and a population:

Difference between the proportion of two samples belonging to two independent groups can be tested if the population is normal, the sample size is large, and the proportion of samples is known. The researcher can use either two-tailed test or one-tailed test on the basis of the nature of research question. If the researcher wants to compare the proportions of two samples drawn from two different populations, then he/she would use the following test statistic:

$$z = \frac{p_1 - p_2}{\sqrt{\left(\frac{p_1 q_1}{n_1}\right) + \left(\frac{p_2 q_2}{n_2}\right)}}$$

Where,

p_1 = Proportion of success of the first sample

p_2 = Proportion of success of the second sample

q_1 = Proportion of failure of the first sample

q_2 = Proportion of failure of the second sample

n_1 = Sample size of the first sample

n_2 = Sample size of the second sample

Example 8: In a college, there are two streams: science and commerce. The college management wants to find out whether there is a significant difference between the proportions of average students (students who are neither toppers or laggards with respect to study) of the two streams. Therefore, the management conducts a survey and finds out that 350 out of 500 students of the science stream are under the category of average students. In the case of the commerce stream, 550 students out of 600 students are under the category of average students. Use 5% as a level of significance.

Solution: The null hypothesis and the alternative hypothesis are as follows:

H_0: There is no difference between the proportions of average students of the science and commerce streams in the college.

H_1: There is a significant difference between the proportions of average students of the science and commerce streams in the college.

Or,

H_0: $p_1 = p_2$

H_1: $p_1 \neq p_2$

Where,

p_1 = Proportion of success in the science stream

p_2 = Proportion of success in the commerce stream

Proportion of success in the science stream, $p_1 = 350/500$

$p_1 = 0.7$

Proportion of failure in the science stream, $q_1 = 1 - p_1 = 1 - 0.7$

$q_1 = 0.3$

Proportion of success in the commerce stream, $p_2 = 300/600$

$p_2 = 0.5$

Proportion of failure in the commerce stream, $q_2 = 1 - p_1 = 1 - 0.5$

$q_2 = 0.5$

Sample size of science stream, $(n_1) = 500$

Sample size of commerce stream, $(n_2) = 600$

The test of significance used is:

$$z = \frac{p_1 - p_2}{\sqrt{\left(\frac{p_1 q_1}{n_1}\right) + \left(\frac{p_2 q_2}{n_2}\right)}}$$

$$z = \frac{0.7 - 0.5}{\sqrt{\frac{(0.7)(0.3)}{500} + \frac{(0.5)(0.5)}{600}}}$$

$z = 0.2/0.029$

$z = 6.9$

The z-value for the 5% level of significance for two-tailed test is ± 1.96.

Notes

The graphical representation of the preceding solution is shown in Figure 10:

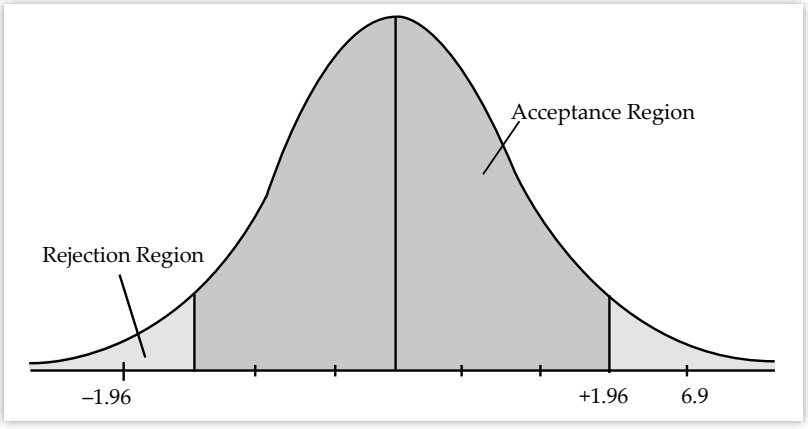

Figure 10: Rejection of Calculated z-Value in Case of Two-Sample Proportions

In Figure 10, it can be observed that the z-value lies in the rejection region; therefore, H_0 is rejected. This implies that there is a significant difference between the average students of the science and commerce streams in the college. It can be interpreted from the calculated z-value that the difference between the proportions of the two samples is statistically significant.

Example 9: In a sample of 700 engineering colleges from a state, littering by first year students was prevalent in 500 colleges. After the ban on littering in the same state, it was found that 500 colleges out of 800 colleges were involved in littering. The decrease in the proportion of the number of colleges involved in littering was significant or not? Test the hypothesis at the 1% level of significance.

Solution: The null hypothesis and the alternative hypothesis are as follows:

H_0: There is no difference between the proportion of the number of engineering colleges involved in littering before and after the ban on littering.

H_1: There is a significant difference between the proportion of the number of engineering colleges involved in littering before and after the ban on littering.

Or,

H_0: $p_1 = p_2$

H_1: $p_1 \neq p_2$

Where,

p_1 = Proportion of success in sample one

p_2 = Proportion of success in sample two

Proportion of success in sample one, $p_1 = 500/700$

$p_1 = 0.71$

Proportion of failure in sample one, $q_1 = 1 - p_1 = 1 - 0.71$

$q_1 = 0.29$

Proportion of success in sample two, $p_2 = 500/800$

$p_2 = 0.625$

Proportion of failure in sample two, $q_2 = 1 - p_1 = 1 - 0.625$

$q_2 = 0.375$

Size of sample one, $(n_1) = 700$

Size of sample two, $(n_2) = 800$

The two samples are taken from the same population; therefore, you can calculate the best estimate for proportion, which is the common value of proportion. The best estimate for proportion (p_0) for the two samples of colleges involved in ragging can be calculated as follows:

$p_0 = (n_1p_1 + n_2p_2)/(n_1 + n_2)$

$p_0 = (700 \times 0.71 + 800 \times 0.625)/700 + 800$

$p_0 = 0.66$

$q_0 = 1 - 0.66$

$q_0 = 0.34$

The test of significance used is as follows:

$$z = \frac{p_1 - p_2}{\sqrt{\left(\frac{p_1q_1}{n_1}\right) + \left(\frac{p_2q_2}{n_2}\right)}}$$

$z = 0.71 - 0.625/\sqrt{}\ (0.66 \times 0.34/700) + (0.66 \times 0.34/800)$

$z = 0.085/0.024$

$z = 3.54$

The z-value for the 1% level of significance for two-tailed test is ± 2.58. The graphical representation of the preceding solution is shown in Figure 11:

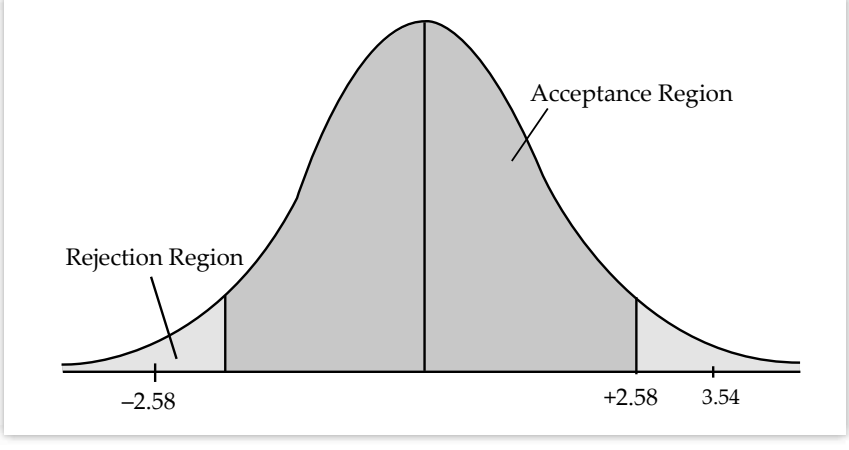

Figure 11: The z-Value Calculated with the Help of the Best Estimate of Proportion

Notes

In Figure 11, it can be observed that the z-value lies in the rejection region; therefore, H_0 is rejected. This implies that there is a significant difference between the number of engineering colleges involved in littering. It can be interpreted from the calculated z-value that the difference between the proportions of two samples is statistically significant.

10.5.3 COMPARING TWO RELATED SAMPLES

In this study, the researcher takes two related samples. The samples are related to each other in some way or the other. They are compared to find a relationship between them. The researcher has to test if there is any statistical difference between the means for the two groups. This type of study is done to find out the impact of certain policies on an entity, such as the impact made by introducing new human resource policies on an organisation. To study the impact of changes, data is collected before and after the occurrence of events. The difference between both the samples (datasets) is calculated to test whether the samples show a positive or negative impact of the changes.

If a researcher wants to compare two related samples, then he/she can use the following test statistic:

$$t = \frac{D}{\left(\frac{SD}{\sqrt{n}}\right)}$$

Where,

D = Mean difference between the two samples

SD = Standard Deviation of the sample

n = Sample size

SD of a sample can be calculated by using the following formula:

$$(SD) = \sqrt{\frac{\sum D^2 - \frac{\left(\sum D\right)^2}{n}}{(n-1)}}$$

10.5.4 STUDY OF EQUALITY OF VARIANCES OF TWO POPULATIONS

In this study, a researcher takes two samples from two populations and finds whether there is a significant difference between the two populations by comparing their variances. The sample variances are known to the researcher. The researcher uses the F-test to study the equality of variances of the two populations. If the researcher wants to compare the variances of two different populations, then he/ she would use the following test statistic:

$F = s_1^2/s_2^2$

Where, s_1 is larger of the two variances

s_1^2 = Variance of the first sample = $\frac{\sum(X_{1i} - \bar{X}_1)^2}{(n_1 - 1)}$

s_2^2 = Variance of the second sample = $\frac{\sum(X_{2i} - \bar{X}_2)^2}{(n_2 - 1)}$

n = Sample size

Variance of the two samples can be calculated using the following formula:

X_{1i} = Value of observation of the first sample

X_{2i} = Value of observation of the second sample

$\bar{X}_1$ = Mean of the first sample

$\bar{X}_2$ = Mean of the second sample

n_1 = Sample size

n_2 = Sample size

Degree of freedom for first sample 1, $v_1 = n_1 - 1$

Degree of freedom for second sample 2, $v_2 = n_2 - 1$

F-value is calculated by dividing the larger variance by smaller variance.

Let us learn to calculate the equality of variances from two different populations with the help of an example.

Example 10: A researcher studied two samples of a type of wheat produced from the north region and the south region of a state. He took two samples of wheat – type A (north region) and type B (south region). The sample size of type A wheat is 10 cities and the sample size of type B wheat is 13 cities. The variances for two samples with respect to gluten content are 5 and 4, respectively. The researcher wants to find out whether the two populations have the same variance. Test this at the 5% significance level.

Solution: The null hypothesis and the alternative hypothesis are as follows:

H_0: The variance of the two populations is the same.

H_1: The variance of the two populations is different.

Or,

$H_0 : \sigma_1^2 = \sigma_2^2$

$H_1 : \sigma_1^2 \# \sigma_2^2$

Where,

σ_1^2 = Population variance from sample A

σ_2^2 = Population variance from sample B

Notes

We are given that $\sigma_1^2 = 5$ and $\sigma_2^2 = 4$

Therefore,

The test of significance used is:

$$F : \frac{\sigma_1^2}{\sigma_2^2}$$

F = 5/4

F = 1.25

Degree of Freedom for sample A = $n_1 - 1$

= 10 – 1= 9

Degree of Freedom for sample B = $n_2 - 1$

= 13 – 1

= 12

The value of sample B is greater than the value of sample A; therefore, $v_1 = 12$ and $v_2 = 9$. In this case, the F-values for the two-tailed test are calculated as:

$F_{\alpha/2} = F(0.025,12,9) = 3.87$

$F_{1-\alpha/2} = F(0.975,12,9) = 0.291 = \frac{1}{F_{0.025,9,12}}$

The graphical representation of the preceding solution is shown in Figure 12:

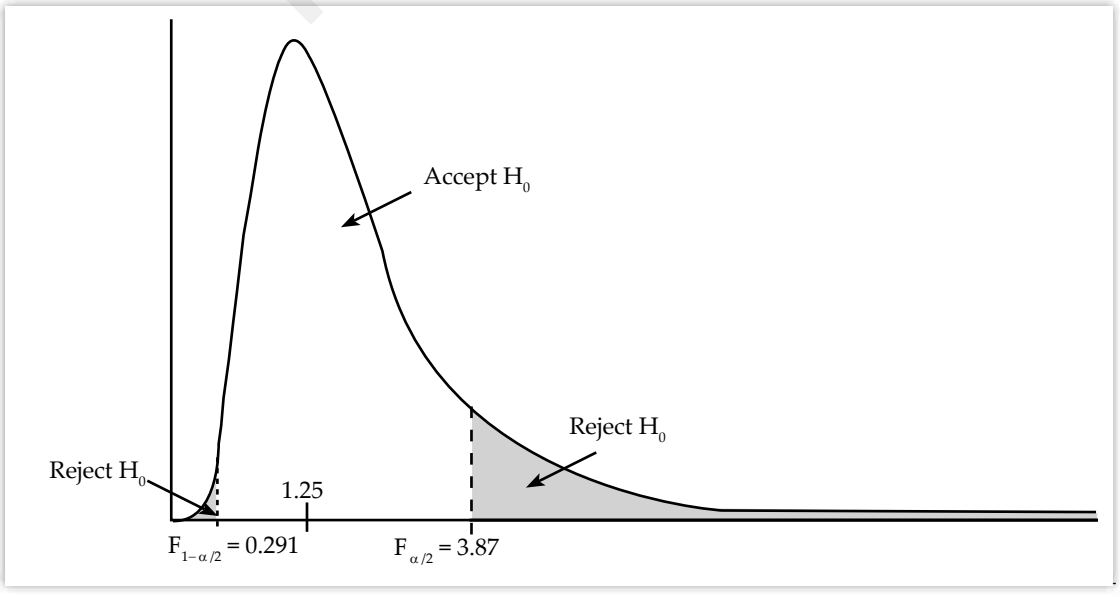

Figure 12: Position of Calculated F-Value

In Figure 12, it can be observed that the calculated F-value lies in the acceptance region; therefore, H_0 is accepted and H_1 is rejected. This implies that there is no

difference between the variances in gluten content of two populations. It can be interpreted from the calculated F-value that the samples are statistically insignificant, that is, the variances of the two populations are equal.

Self Assessment Questions

8. In the study of differences between two samples, researchers try to find out the relationship between two samples from different populations in terms of their _____.
9. A researcher takes two samples from the same population before and after a change and compares them to find the impact of the change. What test statistic will he use?
   a. $z = \overline{X}_1 - \overline{X}_2 / \sqrt{(\sigma_{s12}/n_1) + (\sigma_{s22}/n_1)}$
   b. $\overline{X}_1 - \overline{X}_2 / \sqrt{[(n_1 - 1)\sigma_1^2 s_1 + (n_2 - 1)\sigma_2^2 s_2 / n_1 + n_2 - 2]/\sqrt{(1/n_1) + (1/n_2)}}$
   c. $z = \overline{X}_1 - X_2/\sqrt{\sigma p_2 (1/n_1) + (1/n_2)}$
   d. $t = D/(SD/\sqrt{n})$
10. In the given formula $t = D/(SD/\sqrt{n})$, what does D stand for?
   a. Mean difference between two samples
   b. Standard deviation of sample
   c. Sample size
   d. Sample density

10.6 EXPLORING ANOVA

ANOVA is used to study and explain the amount of variation in more than two samples or data sets. In a data set, two main types of variations can occur. One type of variation occurs due to chance, while the other type of variation occurs due to specific reasons. These variations are studied separately in ANOVA to identify the actual cause of variation and help the researcher take effective decisions. There are two main types of ANOVA. Let us learn about these in detail.

10.6.1 ONE-WAY ANOVA

One-way Analysis of Variance (ANOVA) is used to test whether the means of two or more independent (unrelated) groups are statistically significantly different. A table of variation, ANOVA table is created in this test. This is shown in Table 6:

Table 6: General Table of ANOVA

Source of Variation	Sum of Squares (SS)	Degree of Freedom (d.f.)	Mean of Square (MS)	F-ratio
Between Sample	$n_1 (X_1 - X)^2 + n^2 (X_2 - X)^2 + n^3(X^3 - X)^2$ …… or SSB $\Sigma n_j (\overline{X}_j - \overline{X})^2$	(k – 1)	SS between/(k – 1)	MS between/ MS within

NOTES

Source of Variation	Sum of Squares (SS)	Degree of Freedom (d.f.)	Mean of Square (MS)	F-ratio
Within Sample	$\Sigma (X_{1i} - X_1)^2 + \Sigma (X_{2i} - X_2)^2 + \Sigma (X_{3i} - X3)^2$……. OR SSE= $\Sigma\Sigma (X - \overline{X}_j)^2$	(n – k)	SS within/(n – k)	
Total	SST = $\Sigma\Sigma (X - \overline{X}_j)^2$	(n – 1)		
X = Individual observation, $\overline{X}_j$ = Sample mean of the jth treatment (or group), $\overline{X}$ = Overall sample mean, k = The number of treatments OR independent comparison groups and N = Total number of observations or total sample size				

The process of carrying out one-way ANOVA is as follows:

1. Calculate the mean of each sample using the following formula: $X = X_1 + X_2 + \ldots\ldots + X_k/k$

   Where, k = number of samples

   Means of samples are termed as X_1, X_2, X_3,……

2. Calculate the mean of all sample means with the help of the following formula:

   $= X_1 + X_2 + \ldots\ldots + X_k/k$

   Where, k = number of samples

3. Calculate the variation between two samples, known as SS between, with the help of the following formula:

   SS between = $n (X_1 - X)^2 + n_2(X_2 - X)^2 + n_3 (X_3 - X)^2$

   Where, n_1, n_2 …..= sample size of sample 1, sample 2, and so on……

   SS between is the square of deviations of the sample means from the mean of the sample means value. It helps know variations between two samples.

4. Divide SS between with d.f. k – 1 to get mean of square between (MS between).

   MS between is the mean of variations in two samples. The following formula is used to calculate MS between:

   MS between = SS between/(k – 1)

5. Calculate variation within samples, known as SS within, with the help of following formula:

   SS within = $\sum (X_{1i} - X_1)^2 + \sum (X_{2i} - X_2)^2 + \sum (X_{3i} - X_3)^2$

   Where, X_{1i}, X_{2i}, X_{3i} = observed values in a sample

   X_1, X_2, X_3 = means of corresponding samples

SS within is the square of deviations of values of data series from the corresponding means of samples. It helps calculate variations within samples.

6. Divide SS within with d.f. n – k to get mean of square within (MS within).

   MS within is the mean of variations occurred within samples. The following formula is used to calculate the MS within:

   MS within = SS within/(n – k)

   Where, n = total of the sample size of all the samples, that is, $n_1 + n_2 + \ldots..$

7. Add the square of deviations to get the total variation in samples. The following formula is used to calculate the total variation:

   Total variation = SST = $\sum\sum(X - \overline{X})^2$

   To calculate total SS, first individual observations are subtracted from the mean of sample means. After that, the squares of individual observations are taken and summed up to obtain results. The d.f. used in this case is n – 1.

8. Calculate the F-ratio with the help of the following formula: F-ratio = MS between/ MS within.

   The calculated value of F-ratio is tested against the tabulated value of F-ratio (determined at a specified level of significance). If the value of F-ratio lies under the limits of acceptance region, the null hypothesis is accepted and the alternate hypothesis is rejected.

Let us understand the application of one-way ANOVA with the help of the following example.

Example 11: The researcher observed the sale of a product of a particular brand in six big retail houses in three cities. He/She wants to determine whether the mean sale is the same across cities. Use the data shown in Table 7 to calculate one-way ANOVA:

TABLE 7: Sales Data of the Product in Cities A, B and C

Retail Houses	City A (in Lakhs)	City B (in Lakhs)	City C (in Lakhs)
1	3	6	9
2	8	9	8
3	4	8	6
4	9	5	7
5	6	7	5
6	7	4	7

Solution: Null hypothesis and alternate hypothesis are as follows:

H_0: The sale in three cities is same

H_1: The mean sale of at least one city is different from the rest of the two cities

First, calculate the mean sale of three cities separately, as follows:

Mean for City A (X_1) = 3 + 8 + 4 + 9 + 6 + 7/6 = 6.17

Notes

Mean for City B (X_2) = 6 + 9 + 8 + 5 + 7 + 4/6 = 6.5

Mean for City C (X_3) = 9 + 8 + 6 + 7 + 5 + 7/6 = 7

Mean of the samples (X) = 6.17 + 6.5 + 7/3

$\overline{X}$ = 6.6

SS between = $n_1(X_1 - X)^2 + n_2 (X_2 - X)^2 + n_3 (X_3 - X)^2$

= $6(6.17 - 6.6)^2 + 6(6.5 - 6.6)^2 + 6(7 - 6.6)^2$

= 1.11 + 0.06 + 0.96

= 2.1

SS within = $\sum (X_{1i} - X_1)^2 + \sum (X_{2i} - X_2)^2 + \sum (X_{3i} - X_3)^2$

= $[(3 - 6.17)^2 + (8 - 6.17)^2 + (4 - 6.17)^2 + (9 - 6.17)^2 + (6 - 6.17)^2 + (7 - 6.17)^2 + (6 - 6.5)^2 + (9 - 6.5)^2 + (8 - 6.5)^2 + (5 - 6.5)^2 + (7 - 6.5)^2 + (4 - 6.5)^2 + (9 - 7)^2 + (8 - 7)^2 + (6 - 7)^2 + (7 - 7)^2 + (5 - 7)^2 + (7 - 7)^2]$

= (10.05 + 3.35 + 4.71 + 8.01 + 0.03 + 0.7 + 0.25 + 6.25 + 2.25 + 2.25 + 0.25 + 6.25 + 4 + 1 + 1 + 0 + 4 + 0) = 54.34

Total variance = $[(3 - 6.6)^2 + (8 - 6.6)^2 + (4 - 6.6)^2 + (9 - 6.6)^2 + (6 - 6.6)^2 + (7- 6.6)^2 + (6 - 6.6)^2 + (9 - 6.6)^2 + (8 - 6.6)^2 + (5 - 6.6)^2 + (7 - 6.6)^2 + (4 - 6.6)^2 + (9 - 6.6)^2 + (8 - 6.6)^2 + (6 - 6.6)^2 + (7 - 6.6)^2 + (5 - 6.6)^2 + (7 - 6.6)^2] = 56.48$

ANOVA table created after completing preceding calculation is shown in Table 8:

Table 8: Calculation of ANOVA

Source of Variation	SS	d.f.	MS	F-ratio	5% F limit
Between Sample	2.1	(3 – 1) = 2	2.1/2 = 1.06	1.06/6.04 = 0.29	3.68
Within Sample	54.34	(18 – 3) = 15	54.34/15 = 3.62		
Total	56.48	(18 – 1) = 17			

You can check the F-table for significance with the help of one-tailed test. The graphical representation of the preceding solution is shown in Figure 13:

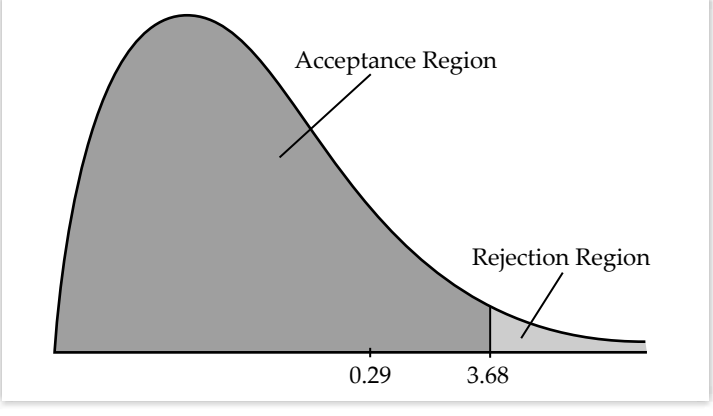

Figure 13: Graph Showing the Position of the Calculated F-Value

Figure 13 shows that the calculated F-value lies in the acceptance region; therefore, H_0 is accepted and H_1 is rejected. The value implies that the product's sale is almost same in the three cities. You can also use another method of ANOVA, which is performed with the help of correction factor. It is also termed as the shortcut method. It is more convenient in case of non-integer values. The steps involved in this method are mentioned as follows:

1. Calculate the correction factor with the help of the following formula: Correction Factor = $(T)^2/n$

   Where, T= Summation of all the observed values in the samples

   n = Total number of observations

2. Compute SS between by first taking the sum of observed values in each sample. Thereafter, obtain the square of the sum of the observed values and divide the number with the respective sizes of samples. Then, add the resultant values and take difference between the added value and correction factor to obtain variation between two samples. The following formula is used to calculate the variation:

   SS between = $\sum (T_j)^2/n_j - (T)^2/n$

   Where, T_i= Sum of the observed value of a sample = T_1, T_2, …….

   n_j = Sample size of a sample = n_1, n_2,……

   n = Sum of the sample size of different samples

3. Divide SS between with d.f. k – 1 to get MS between. The following formula is used to calculate MS between:

   MS between = SS between/(k – 1)

4. Calculate and add the squares of all individual values in samples. The sum of the square of individual values is subtracted from SS between and the value obtained is termed as SS within or variation within the samples. The following formula is used to calculate SS within:

   SS within = $\sum X_{ij}^2 - \sum (T_j)^2/n_j$

   Where, X_{ij}^2 = Squares of all individual values in samples

5. Divide SS within with d.f. n – k to get MS within. The following formula is used to calculate MS within:

   MS within = SS within/(n – k)

   Where, n = Total of the sample size of all the samples, that is, $n_1 + n_2$ + …..

6. Calculate total variation by taking the sum of squares of all individual values in the samples. After that, subtract each variation of individual values with its corresponding correction factor. The following formula is used to calculate the variation:

   Total SS = $\sum X_{ij}^2 - (T)^2/n$

7. Calculate the F-ratio with the help of the following formula:

   F-ratio = MS between/MS within

Notes

The calculated value of F-ratio is tested against the tabulated F-value that is determined at a specified level of significance. If the calculated value of F-ratio lies under the limits of acceptance region, the null hypothesis is accepted and the alternate hypothesis is rejected.

Let us learn the application of one-way ANOVA with the help of correction factor using Example 12.

Example 12: First calculate the correction factor and then various components of ANOVA table.

The correction factor can be calculated as follows: Correction factor = $(T)^2/n$.

Where, T= summation of all the observed values in the three cities collectively

n = sum of the sample size of different samples.

Correction factor = $(118)^2/18$

= 773.6

SS between = $\sum (T_j)^2/n - (T)^2/n$

= $(37 \times 37)/6 + (39 \times 39)/6 + (42 \times 42)/6 - 773.6$

= 228.17 + 253.5 + 294 – 773.6

= 2.1

SS within = $\sum X_{ij}^2 - \sum (T_j)^2/n_j$

= $(3)^2 + (8)^2 + (4)^2 + (9)^2 + (6)^2 + (7)^2 + (6)^2 + (9)^2 + (8)^2 + (5)^2 + (7)^2 + (4)^2 + (9)^2 + (8)^2 + (6)^2$ + (7)2 + (5)2 + (7)2 – 775.67

= 54.34

Total SS = 830 – 773.6

= 56.4

The values of total SS, SS between and SS within are same in both the cases used for the calculation of ANOVA. Therefore, the ANOVA table would also be the same.

10.6.2 TWO-WAY ANOVA

Two-way ANOVA is used when a researcher wants to test the differences between groups that have been split on the basis of two attributes or independent variables or factors. The steps involved in performing two-way ANOVA are as follows:

1. Calculate the correction factor of all attributes/factors separately with the help of the following formula:

   Correction factor = $(T)^2/n$

   Where, T= summation of all the observed values in the samples

   n = total number of observations

2. Compute SS between rows. To do so, first take the sum of observed values in each row. Thereafter, take the square of the sum of observed values and divide the number with the respective sample size of rows. Then, the resultant values are added and difference between the added value and correction factor is taken to obtain the variation between two rows. The following formula is used to calculate SS between rows:

   SS between rows = $\sum (T_j)^2/n_j - (T)^2/n$

   Where, T_j = Sum of the observed value of a row = T_1, T_2,…….

   n_j = Sample size of a row = n_1, n_2,……

   n = Sum of the sample size of different samples

   In two-way ANOVA, there are three possible null hypotheses. These are as follows:

   1. There is no difference in the means of the first factor.
   2. There is no difference in the means of the second factor.
   3. There is no interaction between first and second factors.

   For null hypotheses 1 and 2, the alternative hypothesis is: The means of first factor and second factor are not equal.

   For null hypothesis 3, the alternative hypothesis is: There is an interaction between first factor and second factor.

3. Divide SS between rows with d.f. k – 1 to get MS between rows, which is the mean of variations occurred in between row samples. Similarly, MS between rows for other attributes can also be calculated.

   The following formula is used to calculate MS between rows: MS between rows = SS between rows/(r – 1)

   Where, r = number of rows

4. Calculate SS between columns. To do so, first take the sum of observed values in each column. Thereafter, take the square of sum of observed values and divide the number with the respective sample size of columns. Then, the resultant values are added and difference between the added value and correction factor is taken to obtain the variation between columns. Similarly, SS between columns for other attributes can also be calculated. The following formula is used to calculate SS between columns:

   SS between columns = $\sum (T_j)^2/n_j - (T)^2/n$

   Where, T_j = Sum of the observed value of a column = T_1, T_2,…….

   n_j = Sample size of a columns = n_1, n_2,……

5. Divide SS between columns with d.f. n – k to get MS between columns, which is the mean of variations occurred within samples. Similarly, MS within for other attributes can also be calculated. The following formula is used to calculate MS within columns:

   MS between columns = SS between columns/(c – 1)

   Where, c = Total of the sample size of all the columns

6. Calculate total variation by first taking the sum of squares of all individual values in the samples. After that, subtract the sum of squares from correction factor. Similarly, total variation for other attributes can also be calculated. The following formula is used to calculate variation:

   Total SS = $\sum X_{ij}^{2} - (T)^2/n$

7. Compute residual variation by first adding SS between and SS within, and then subtracting the difference between total SS and the value obtained by adding up SS between and SS within. Similarly, residual variation for other attributes can also be calculated. The following formula is used to calculate residual variation:

   Residual variation = Total SS – (SS between + SS within)

8. Calculate the F-ratio with the help of the following formula: F-ratio = MS between/ MS within

   The calculated value of F-ratio is tested against the tabulated F-value that is determined at a specified level of significance. If the calculated value of F-ratio lies under the limits of acceptance region, the null hypothesis is accepted and the alternate hypothesis is rejected.

Let us understand the application of two-way ANOVA with the help of an example.

Example 13: Three respondents have rated three small cars of different brands on a five-point scale (5 being the highest) with respect to their features. The ratings and features are provided in Table 9:

Table 9: Ratings Given by Customers to Different Brands of Cars with Respect to their Features

Respondents		Mileage	Durability	Maintenance Cost	Technology	Price
1	Zen	3	2	4	3	5
	i10	4	4	4	5	4
	Alto	4	3	5	2	4
2	Zen	2	4	3	1	4
	i10	4	5	3	4	4
	Alto	3	1	2	5	3
3	Zen	4	5	3	2	4
	i10	3	2	4	5	3
	Alto	4	5	4	5	5

The researcher wants to know the difference between the brands in terms of features.

Solution: Null hypothesis and alternate hypothesis are as follows:

H_0: There is no difference in the means of the five features of the cars.

H_1: The means of the five features are not equal.

Correction factor = $(T)^2/n$

= (162 × 162)/45

= 583.2

SS between columns (i.e., between variables) = (31 × 31)/9 + (31 × 31)/9 + (32 × 32)/9 + (32 × 32)/9 + (36 × 36)/9 – 583.2

= 106.8 + 106.8 + 113.8 + 113.8 + 144 – 583.2

= 585.2 – 583.2

= 2

SS between rows (i.e., between cars) = (56 × 56)/15 + (48 × 48)/15 + (58 × 58)/15 –583.2

= 209.1 + 153.6 + 224.3 – 583.2

= 587– 583.2

= 3.8

Total SS = $(3)^2 + (4)^2 + (4)^2 + (2)^2 + (4)^2 + (3)^2 + (4)^2 + (4)^2 + (5)^2 + (3)^2 + (5)^2 + (2)^2 + (5)^2 + (4)^2 + (4)^2 + (2)^2 + (4)^2 + (3)^2 + (4)^2 + (5)^2 + (1)^2 + (3)^2 + (3)^2 + (2)^2 + (1)^2 + (4)^2 + (5)^2 + (4)^2 + (4)^2 + (3)^2 + (4)^2 + (3)^2 + (4)^2 + (5)^2 + (2)^2 + (5)^2 + (3)^2 + (4)^2 + (4)^2 + (2)^2 + (5)^2 + (5)^2 + (4)^2 + (3)^2 + (5)^2 – 583.2$

= 638 – 583.2

= 54.8

SS residual = Total SS – (SS between columns + SS between rows)

= 54. 8 – (2 + 3.8)

= 49

ANOVA table created after preceding calculation is shown in Table 10:

Table 10: Calculation of ANOVA for the Three Brands of Cars

Source of Variation	SS	d.f.	MS	F-ratio	5% F limit
Between columns	2	(5 – 1) = 4	2/4 = 0.5	0.5/6.125 = 0.08	F(4,8) = 3.84
Between rows	3.8	(3 – 1) = 2	3.8/2 = 1.9	1.9/6.125 = 0.31	F(2,8) = 4.46
Residual	49	(5 – 1) × (3 – 1) = 8	49/8 = 6.125		
Total	56.48	(45 – 1) = 44			

Notes

You can check the F-value for significance with the help of one-tailed test. The graphical representation of the preceding solution for F-value at 4 v_1 and 8 v_2 is shown in Figure 14:

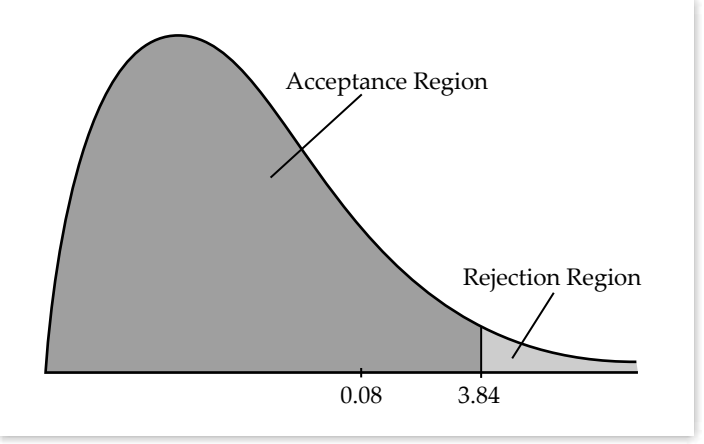

Figure 14: Rejecting the Calculated F-Value

The graphical representation of the preceding solution for F-value at 2 v_1 and 8 v_2 is shown in Figure 15:

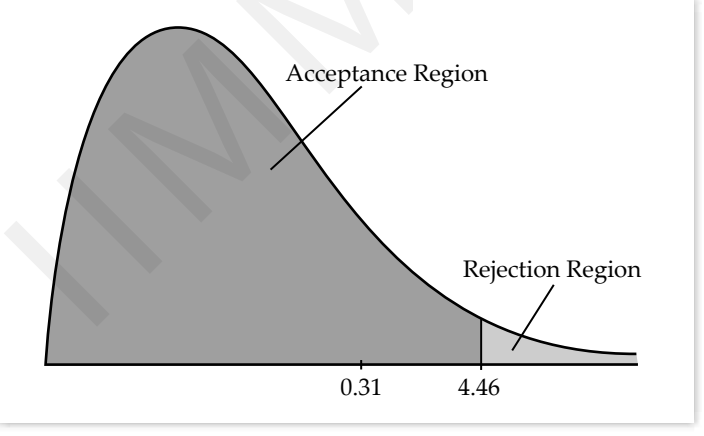

Figure 15: Accepting the Calculated F-Value

Figures 14 and 15 show that the calculated F-value lies in the acceptance region. Therefore, H_0 is accepted and H_1 is rejected. The value implies that the cars have the same features.

Self Assessment Questions

11. _____ is a non-parametric test that is used to study more than two samples or data sets.
12. One-way ANOVA determines whether all samples have the same type of variations. (True/False)
13. _____ ANOVA is used when you need to determine the relation between two attributes.

Activity

Search on the Internet more about the parametric tests and prepare a note of 1,000 words on parametric tests.

10.7 SUMMARY

- A hypothesis can be tested by using a large number of tests and these tests are connected with each other in one way or another.
- In parametric tests, researchers make some assumptions about some properties of the parent population from which samples are drawn. In non-parametric tests, no assumptions are made.
- The different types of parametric tests are z-test, t-test, Chi-square test and F-test.
- In a one-sample test, you study the relationship between a sample and the population.
- In a two-sample test, you study the relationship between two samples drawn from two different or same populations.
- ANOVA is used to study and explain more than two samples or data sets. It helps in explaining the amount of variation in two data sets.

10.8 KEY WORDS

- **Distribution pattern:** A probability distribution pattern that is similar to normal distribution and is used for testing hypothesis.
- **F-test:** A test that is used to compare the significant difference between the variances of two samples under study.
- **Non-parametric tests:** The tests which do not make assumptions about the parameters of the population from which a sample is derived.
- **Parametric tests:** The tests which make assumptions about the parameters of the population from which a sample is derived.
- **t-distribution:** A type of probability distribution that is appropriate for estimating the mean of a normally distributed population where the sample size is small and population variance is unknown.
- **t-test:** A test that is used to study the means of samples having a sample size below 30 and unknown population variance.
- **z-test:** A test that is used to study the means and proportion of samples whose size is more than 30.

10.9 CASE STUDY: NATIONAL MOTORS INC.

National Motors Inc. is a manufacturer of motor scooters. As a part of its operating policy, the executives want to determine whether the customers' and dealers' satisfaction depends on warranty cards or not. To test this, the company has withdrawn its warranty cards from the market. The marketing research department

Notes

of the company develops a questionnaire in a summated scale form to collect data about customer satisfaction with and without the warranty card. The department mails the questionnaire to a random sample of customers after they have received warranty cards. The same questionnaire is then sent to the same set of customers after their warranty cards are expired. The company also sends the questionnaire to dealers who have provided their customers with warranty cards.

The customers and dealers have provided marks out of 100 for their satisfaction level. The data collected by the marketing research department for customer satisfaction and dealer satisfaction is given in Table A as follows:

Table A: Data Collected for Customer and Dealer Satisfaction

No. of Observations	Customers' Satisfaction When They Have Warranty Cards	Customers' Satisfaction When They Do not Have Warranty Cards	Dealers
1	74	43	92
2	81	23	42
3	35	88	54
4	59	55	59
5	90	67	83
6	33	53	30
7	82	85	34
8	68	70	54
9	56	30	39
10	46	75	65

After conducting the research, the company comes to the conclusion that warranty cards do not have much impact on the customers' and dealers' satisfaction. A reason behind this can be that the same type of warranty is given by the competitors of National Motors Inc.

QUESTIONS

1. Find out the effect of warranty cards on the satisfaction of customers with the help of data provided in the case study. Use 5% as the level of significance to test the hypothesis.

   (**Hint:** H_0: The customer satisfaction before and after returning the warranty card is the same.)

2. What should National Motors do to overcome this problem?

   (**Hint:** The company can conduct a survey regarding the available warranty cards in the entire motor scooters industry.)

3. Why did the marketing research department of National Motors Inc. develop a questionnaire?

   (**Hint:** In order to determine whether the customers' and dealers' satisfaction depends on warranty cards or not.)

4. What was the base of providing marks to the questionnaire?

   (**Hint:** Satisfaction level)

5. Was the questionnaire mailed to all customers and dealers?

   (**Hint:** The department mailed the questionnaire to a random sample of customers and to dealers who have provided their customers with warranty cards.)

10.10 EXERCISE

1. What are the two types of hypotheses tests?
2. Explain the different types of parametric tests.
3. Explore the following cases of one-sample tests:
   a. Normal and infinite population, large sample size, known population variance and two-tailed test or one-tailed test.
   b. Normal and infinite population, small sample size, unknown population variance and two-tailed test or one-tailed test.
4. Explain any two-sample tests along with examples.
5. Explain the concept of ANOVA in detail.

10.11 ANSWERS FOR SELF ASSESSMENT QUESTIONS

Topic	Q. No.	Answer
Types of Hypothesis Testing	1.	b. Parametric tests
Parametric Tests	2.	d. z-test
	3.	t-test
	4.	d. F-test
	5.	one observation, number of observations
One-Sample Test – Different Situations in Which One-Sample Test is Used	6.	means; variance; proportion
	7.	b. Population mean
Two-Sample Tests	8.	means
	9.	d $t = D/(SD/\sqrt{n})$
	10.	a. Mean difference between two samples
Exploring ANOVA	11.	ANOVA
	12.	True
	13.	Two-way

Notes

10.12 SUGGESTED BOOKS AND E-REFERENCES

SUGGESTED BOOKS

- Biddle, J., & Emmett, R. *Research in the History of Economic Thought and Methodology*.
- Panneerselvam, R. (2014). *Research Methodology*. Delhi: PHI Learning.

E-REFERENCES

- IMPORTANT PARAMETRIC TESTS in Research Methodology Tutorial 09 April 2020 - Learn IMPORTANT PARAMETRIC TESTS in Research Methodology Tutorial (11529) | Wisdom Jobs India. (2020). Retrieved 9 April 2020, from https://www.wisdomjobs.com/e-university/research-methodology-tutorial-355/important-parametric-tests-11529.html
- ANOVA Test: Definition, Types, Examples - Statistics How To. (2020). Retrieved 9 April 2020, from https://www.statisticshowto.com/probability-and-statistics/hypothesis-testing/anova/

CHAPTER 11

Non-Parametric Tests

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LEARNING OBJECTIVES

After studying this chapter, you will be able to:

- Explain the concept of non-parametric test
- Discuss the sign tests
- Explain the concept of rank correlation
- Discuss the rank sum tests
- Elaborate the Wilcoxon matched pairs test
- Explain the concept of Chi-square test

11.1 INTRODUCTION

In the previous chapter on Parametric Tests, you have learned about different types of parametric tests used to check the validity of a hypothesis. You have also studied that parametric tests can only be applied if you know population type and population parameters, such as mean and variance. However, if this information is unavailable, you cannot use parametric tests. In such a situation, you need non-parametric tests to check the validity of a hypothesis and draw inferences.

Non-parametric tests are used when you do not have adequate information about population type and parameters. These tests are widely used to study data given in the form of ranks. Examples of non-parametric tests are sign tests, rank correlation, rank sum test, Wilcoxon matched pairs and chi-square test. The selection of the test depends on problem type, sample size and data. For example, rank correlation is used to establish correlation between two ranked data sets. Researchers should observe caution while selecting a non-parametric test to ensure accurate and precise results.

This chapter covers non-parametric tests and their types. It provides information about one and two sample sign tests. It also elaborates on rank correlation and rank sum tests, including the Mann-Whitney and Kruskal-Wallis tests. In addition, it explains the Wilcoxon matched pairs test/signed rank test. Finally, the chapter also sheds light on chi-square test for goodness of fit and chi-square test for independence.

11.2 CONCEPT OF NON-PARAMETRIC TESTS

As already discussed earlier, non-parametric tests are not based on assumptions about a population and its parameters. A researcher can use these tests without taking into consideration population distribution and sample type. Non-parametric tests are also known as distribution-free tests because they do not assume that the given data follows a specific distribution. These tests are mainly used when the test model does not specify any stringent conditions regarding the population parameters from which a sample is drawn.

Let us understand the reason behind choosing a non-parametric test over a parametric test with the help of a simple example. Suppose, a researcher wants to find out the preference of customers about the different brands of toothpaste available in the

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market. He/she would ask customers to rank different brands according to their preferences. The data collected would be in the rank form on which parametric tests cannot be performed. This is because a parametric test requires numeric values, such as mean and variance, to test a hypothesis. Therefore, in this case, the researcher would use a non-parametric test.

The different types of non-parametric tests are shown in Figure 1:

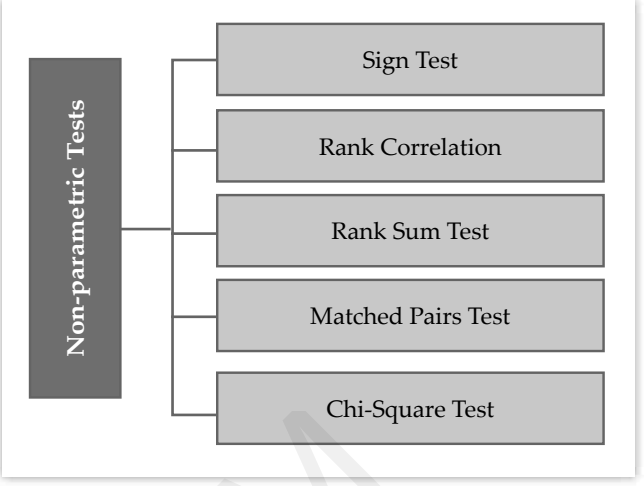

Figure 1: Non-Parametric Tests

Self Assessment Questions

1. Non-parametric tests are also known as _____ tests.
2. A researcher can use non-parametric tests without taking into consideration population distribution and sample type. (True/False)

11.3 SIGN TEST

Sign test is considered one of the easiest non-parametric tests because it takes into account only the plus and minus signs of observations in a sample. It does not consider the magnitude of observations while analysing the data present in a sample. Sign test can be used in place of some parametric tests, such as one-sample t-test and paired t-test. It uses binomial distribution to test the validity of a hypothesis. There are two types of sign tests, which are shown in Figure 2:

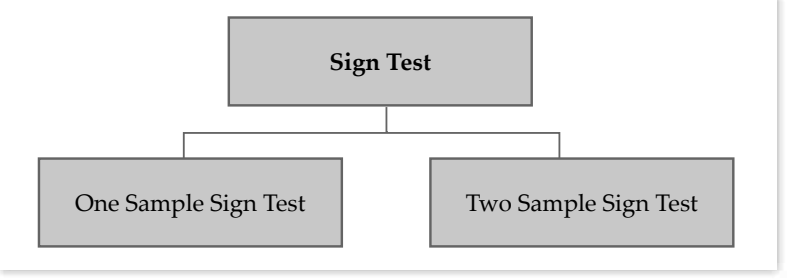

Figure 2: Types of Sign Tests

Let us now discuss the types of sign tests in detail.

11.3.1 ONE SAMPLE SIGN TEST

One sample sign test is applied on a sample where the researcher does not assume that the data is normally distributed. In this test, the probability of getting a sample value of less or greater than median value is equal. This implies that the proportion of success (p) and failure (q) is equal, which means that p = q = 0.50. Therefore, it is called binomial sign test. In one sample sign test, the researcher provides sample values with positive (+) and negative (–) signs to test the hypothesis.

Here, the researcher usually tests the null hypothesis: $M = M_0$ against an appropriate alternate hypothesis.

Sign test is a hypothesis test for population median and not for population mean.

Here, three types of tests are possible as shown in Table 1:

Table 1: Three Types of Sign Tests for Population Median

Null Hypothesis	Alternate Hypothesis	Type of Test
$H_0: M = M_0$	$H_1: M > M_0$	Right-tailed test
$H_0: M = M_0$	$H_1: M < M_0$	Left-tailed test
$H_0: M = M_0$	$H_1: M \neq M_0$	Two-tailed test

In any given sign test, each data value or observation is converted into a plus sign or a minus sign. The allocation of + and – signs is done by assuming a median value of the sample. Values that are greater than the median value are replaced by a plus sign and the values that are less than the median value are replaced by minus sign. The values that are equal to the given median value are discarded or not considered. After assigning the signs, the researcher may test the null hypothesis that the probability of getting plus and minus signs is 0.5.

The sign test can be performed by using two methods as follows:

- When the sample size is small, the test is carried out by calculating the binomial probabilities using the binomial probabilities table.
- When $np \geq 5$ and $nq \geq 5$, normal distribution can be used as an approximation of binomial distribution.

When n is large and when p is sufficiently large (i.e., $p > 0.10$), normal distribution is used as an approximation of binomial distribution.

The mean and standard deviation of normal distribution are given as follows:

Mean $\mu = np$

SD = $\sigma = \sqrt{npq}$

Let us understand the application of one sample sign test with the help of an example.

Example 1: The scores of 15 students in a class test of 20 marks are as follows: 09, 10, 16, 18, 17, 19, 20, 16, 14, 12, 11, 13, 14, 09 and 13.

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Test the hypothesis that the median score of all the students is equal to 15 against the hypothesis that the median score of 15 students is greater than 15. Use 5% level of significance.

Solution: Null and alternate hypotheses are as follows:

H_0: Median score of 15 students is 15

H_1: Median score of 15 students is greater than 15 OR

H_0: p = 0.5 H_1: p > 0.5

The researcher assigns minus (–) sign to values of less than 15 and plus (+) sign to values of greater than 15.

Observation	19	17	16	18	17	19	20	16	16	18	11	13	14	09	13
Sign	+	+	+	+	+	+	+	+	+	+	–	–	–	–	–

The following result is obtained:

No. of + signs = 10

No. of – signs = 5

Number of observations = 15

It must be remembered that the test statistics is larger of the number of + signs and the number of – signs.

Now, we need to check whether 10 plus signs observed in the given 15 trials support the null hypothesis that p = 0.5 or p > 0.5.

Now, we use binomial probability table to find the probability of 10 or more successes as follows:

$\Rightarrow$ P (10 or more successes (X ≥ 10) | n = 15, p = 0.5) = P(X = 10) + P(X = 11) + …….. + P(X = 15)

$\Rightarrow$ P(X = 10) + P(X = 11) + + P(X = 15)

$\Rightarrow$ 0.092 + 0.042 + 0.014 + 0.003 + 0.000 + 0.000

$\Rightarrow$ P (10 or more successes (X ≥ 10) | n = 15, p = 0.5) = 0.151

Since the value of one-tailed p is greater than α = 0.05, null hypothesis is accepted. Note that here np = 15 (0.5) = 7.5.

Therefore, we can also use normal approximation to binomial distribution.

Z-statistic is calculated as:

$$Z = \frac{X - np}{\sqrt{npq}}$$

$$= \frac{10 - 7.5}{\sqrt{\frac{15}{4}}} = \frac{2.5}{1.93} = 1.295$$

The value of Z at 0.05 level of significance is +1.645. Since Z = 1.295 lies in the acceptance region, the null hypothesis is accepted.

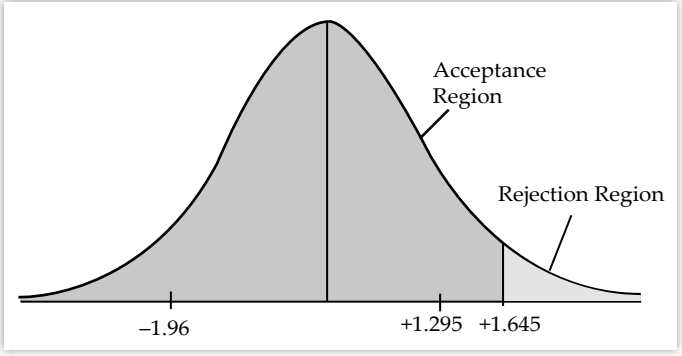

Figure 3: Graph Showing the Position of the Calculated Binomial Value

Figure 3 shows that the calculated binomial value lies in the acceptance region. Therefore, H_0 is accepted. This implies that the median marks scored by 15 students are 15.

11.3.2 TWO SAMPLE SIGN TEST

In two sample sign test, the researcher tests two related samples. This test is equivalent to paired t test. Researchers use sign test when data is given as pairs. In this test, the researcher provides positive (+) and negative (–) signs to values. These signs are allocated on the basis of the difference between the values of first sample and second sample. If the difference is positive, the difference value gets a plus (+) sign and if the difference is negative, the difference value gets a minus (–) sign. If the values of two samples are equal, these values are discarded.

Thereafter, the researcher calculates the total plus and minus signs and divides the number by the sample size. Then, standard error is calculated and limits are determined. Finally, the hypothesis is tested against the calculated value of limit.

Let us understand the application of the two sample sign test with the help of an example.

Example 2: Sales target achieved by two employees in a year is shown in Table 2:

Table 2: Data Showing Sales Done by Employees

Month	Employee 1 (in Lakhs)	Employee 2 (in Lakhs)
1	2	1.5
2	2	2.5
3	4	3
4	1	1
5	1	1.5
6	2.5	2.75
7	3	2.5
8	3.5	1
9	4	3

Notes

Month	Employee 1 (in Lakhs)	Employee 2 (in Lakhs)
10	1.5	1.4
11	2	4
12	3	3

The researcher wants to find out whether the first employee is the better performer. Use 5% as the level of significance.

Solution: Null hypothesis (H_0) and alternate hypothesis (H_1) are as follows:

H_0: p = 1/2

H_1: p > 1/2

Or

H_0: Sales done by two employees is the same.

H_1: Sales done by the first employee is more than that of the second employee.

The researcher assigns the plus (+) and minus (–) signs to the data shown in Table 3:

Table 3: Signs Allocated to the Data

Month	Employee 1 (in Lakhs) X	Employee 2 (in Lakhs) Y	Sign (X–Y)
1	2	1.5	+
2	2	2.5	–
3	4	3	+
4	1	1	0
5	1	1.5	–
6	2.5	2.75	–
7	3	2.5	+
8	3.5	1	+
9	4	3	+
10	1.5	1.4	+
11	2	4	–
12	3	3	0

According to Table 3, the number of + signs = 6

No. of – signs = 4

Number of observations = 10 (2 of the observations are 0; therefore, the researcher does not consider them)

Now, we use binomial probability table to find the probability of 6 or more successes as follows:

$\Rightarrow$ P (6 or more successes (X ≥ 6) | n = 10, p = 0.5) = P(X = 6) + P(X = 7) +.....+ P(X = 10)

$\Rightarrow$ P(X = 6) + P(X =7) +.....+ P(X = 10)

$\Rightarrow$ 0.205 + 0.117 + 0.044 + 0.010 = 0.376

Note that here np = 10 (0.5) = 5

Therefore, we can also use normal approximation to binomial distribution. Z-statistic is calculated as:

$$Z = \frac{X - np}{\sqrt{npq}}$$

$$Z = \frac{6 - 5}{\sqrt{\frac{10}{4}}}$$

$$Z = \frac{1}{1.581} = 0.632$$

The value of Z at 0.05 level of significance is +1.645. Since Z = 0.632 and it lies in the acceptance region, null hypothesis is accepted. This implies that the median sale done by two employees is equal.

11.3.3 WILCOXON MATCHED PAIRS TEST/SIGNED RANK TEST

The Wilcoxon matched pairs test/Signed rank test is a combination of sign and rank tests and is used to compare a paired sample. It is used in place of paired t-test when the distribution is not normal. The Wilcoxon matched pairs test is used when the researcher wants to determine the direction and magnitude of difference in the matched values. Steps to perform the test are mentioned below:

1. Determine the difference (d_i) among observed values.
2. Rank the difference $|d_i|$ in the ascending order (lowest to highest). If the difference between two values is zero, the researcher needs to ignore those values.
3. Segregate the ranks according to the positive and negative signs of d_i values.
4. Add the ranks with negative and positive signs separately.
5. Determine the T-value by comparing the sums of ranks with negative sign and positive sign. If the sum of ranks with positive sign is more than the sum of ranks with a negative sign, the T-value would be equal to the sum of ranks of negative sign or vice versa.

Mean is calculated using the following formula:

Mean, $\mu_T = n (n + 1)/4$

SD is calculated using the following formula:

Standard deviation, $\sigma_T = \sqrt{n (n + 1) (2n + 1)/24}$

Where, n = number of observations – number of ignored observations

Notes

The test statistic z can be calculated as follows:

$$Z = \frac{T - \mu_T}{\sigma_T}$$

If the calculated z-value lies under the limits of acceptance region, the null hypothesis is accepted and the alternate hypothesis is rejected.

Let us understand the application of the Wilcoxon matched pairs test/signed rank test with the help an example.

Example 3: Two brands are ranked on a five-point scale (five being the highest). The researcher wants to determine the difference between the satisfaction levels of customers for two brands. The data for Brand A and Brand B and their difference is provided in Table 4:

Table 4: Rating Given by Customers to Brand A and Brand B

No. of Respondents	Brand A	Brand B	Difference (d_i)
1	2	2	0
2	3	4	–1
3	4	3	1
4	1	2	–1
5	2	5	–3
6	5	4	1
7	4	2	2
8	3	4	–1
9	4	3	1
10	5	4	1
11	2	4	–2
12	4	3	1

Use the Wilcoxon matched pairs test with 5% level of significance.

Solution: Null hypothesis and alternate hypothesis are as follows:

H_0: Customer satisfaction for the two brands is same.

H_1: Customer satisfaction for the two brands is different.

The researcher calculates the T statistic, as shown in Table 5:

Table 5: Calculation of Wilcoxon Matched Pairs Test

No. of Respondents	Brand A	Brand B	Difference (d_i)	$\lvert d_i \rvert$	Sign	Rank $\lvert d_i \rvert$	Rank with Signs
1	2	2	0	0	0	–	–
2	3	4	–1	1	–	4.5	– 4.5
3	4	3	1	1	+	4.5	+ 4.5
4	1	2	–1	1	–	4.5	– 4.5
5	2	5	–3	3	–	11	– 11

No. of Respondents	Brand A	Brand B	Difference (d_i)	$\lvert d_i \rvert$	Sign	Rank $\lvert d_i \rvert$	Rank with Signs
6	5	4	1	1	+	4.5	+ 4.5
7	4	2	2	2	+	9.5	+ 9.5
8	3	4	–1	1	–	4.5	– 4.5
9	4	3	1	1	+	4.5	+ 4.5
10	5	4	1	1	+	4.5	+ 4.5
11	2	4	–2	2	–	9.5	– 9.5
12	4	3	1	1	+	4.5	+ 4.5
						Total	Sum of Positive Ranks (W^+) = 32 Sum of Negative Ranks (W^-) = 34
							T (smaller of W^+ and W^-) = 32

In this case, the researcher has neglected the first observation, as it is 0. The ranking of difference is done from a smaller to a larger value. If there is a tie between the ranks, the mean of ranks is taken and assigned to identical values. The T statistic is equal to 32, which is the smallest value between the ranks with positive signs and negative signs. The T-value, with 5% level of significance and two-tailed test, is ± 1.96.

Value of z-statistic is calculated as:

$$Z = \frac{T - \mu T}{\sigma T}$$

$$Z = \frac{32 - [(11(11+1))/4]}{\sqrt{\frac{11(11+1)[2(11)+1]}{24}}} = \frac{32 - 33}{\sqrt{\frac{11 \times 12 \times 23}{24}}} = \frac{-1}{11.25} = -0.088$$

The graphical representation of the preceding solution is shown in Figure 4:

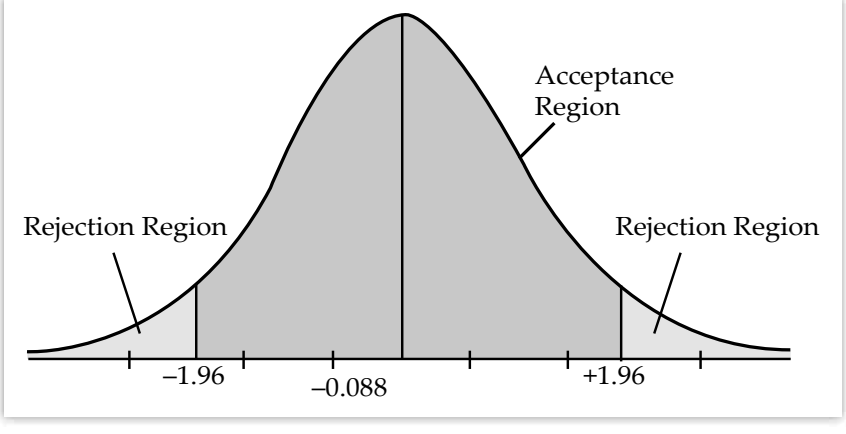

Figure 4: Position of the Calculated Value

Notes

Figure 4 shows that the calculated Z-value lies in the acceptance region; therefore, H_0 is accepted. This implies that customer satisfaction for two brands is the same.

Self Assessment Questions

3. _____ is considered as one of the easiest non-parametric tests because it takes into account only the plus (+) and minus (–) signs of observations in a sample.
4. In one sample sign test, the probability of getting a sample value less than or greater than mean is equal. (True/False)
5. Which of the following tests is also known as paired sign test?
   a. Sign test
   b. One sample sign test
   c. Two sample sign test
   d. None of these

11.4 RANK CORRELATION

Rank correlation, also known as Spearman's rank correlation coefficient, is used to establish correlation between two data sets that can be ranked. Steps to calculate rank correlation are mentioned below.

1. Assign ranks to all observations present in two data sets in the descending order. If two or more values in the data sets are identical, calculate mean rank and allocate it to all identical values. For example, if third, fourth and fifth ranks have the same value, take out their mean (3 + 4 + 5)/3 = 4 and allocate it as rank to those values.
2. Calculate the difference between ranks by subtracting the rank of one data set from that of second data set. The difference is denoted as d_i.
3. Calculate the square of d_i.
4. Find the sum of square of d_i.
5. Calculate Spearman's rank correlation coefficient by using the following formula:

$$\rho = 1 - \frac{6\sum d_i^2}{n\left(n^2 - 1\right)}$$

Where, d_i= Difference between ranks

n = Sample size

The value of Spearman's rank correlation coefficient lies between +1 and –1, where +1 indicates perfect positive correlation and –1 indicates perfect negative correlation. The values that lie between +1 and –1 show different degrees of correlation. The researcher can assess the value of rank correlation coefficient by performing a hypothesis test. If the sample size is less than 30, the researcher needs to use the tabulated value of Spearman's rank correlation coefficient to test the value of coefficient. Suppose, the sample size (n) = 15 and σ_r = 0.6364, which shows a reasonably high degree of correlation between two data sets. The researcher wants to check the value of σ_r (rank correlation coefficient) to judge whether the correlation is actually

present or not. He/She forms a null hypothesis that there is no correlation between the two data sets and tests it at 5% level of significance using two-tailed test. The researcher checks the critical value for ρ in the table showing values of Spearman's rank correlation coefficient. The critical value of ρ is –0.5179 (lower limit) and +0.5179 (upper limit). The given value of ρ = 0.6364 is outside the acceptance region; therefore, the researcher rejects the null hypothesis and concludes that there is a correlation between two data sets.

Let us understand the application of Spearman's rank correlation coefficient with the help of an example.

Example 4: A researcher wants to test correlation between the IQ level and hours spent in studying newspaper per week. The data is provided in Table 6:

Table 6: Data Showing IQ Level and Hours Spent on Reading Newspaper

No. of Observations	IQ (X)	Hours Spent in Studying Newspaper (Y) Per Week
1	105	6
2	91	7
3	99	24
4	100	56
5	99	29
6	103	30
7	97	20
8	113	12
9	112	10
10	110	17
11	94	16
12	110	8
13	112	9

Use rank correlation to find out correlation between the IQ level and hours spent on reading a newspaper, with 5% level of significance.

Solution: Null hypothesis and alternate hypothesis are as follows:

H_0: There is no correlation between the IQ level and hours spent on reading the newspaper every week.

H_1: There is correlation between the IQ level and hours spent on reading a newspaper every week.

Or

H_0: $\rho = 0$

H_1: $\rho \neq 0$

Notes

Table 7 shows the calculation of rank correlation test:

Table 7: Calculation of Rank Correlation Test

No. of Observations	IQ (X)	Hours Spent in Reading Newspaper (Y)	Rank X	Rank Y	Difference ($d_i = X - Y$)	d_i^2
1	105	6	6	13	– 7	49
2	91	7	13	12	1	1
3	99	24	9.5	4	5.5	30.25
4	100	56	8	1	7	49
5	99	29	9.5	3	6.5	42.25
6	103	30	7	2	5	25
7	97	20	11	5	6	36
8	113	12	1	8	–7	49
9	112	10	2.5	9	– 6.5	42.25
10	110	17	4.5	6	– 1.5	2.25
11	94	16	12	7	5	25
12	110	8	4.5	11	– 6.5	42.25
13	112	9	2.5	10	– 7.5	56.25
Total						$\sum d_i^2 = 449.5$

The calculation of rank correlation is shown below:

$$\rho = 1 - \frac{6\sum d_i^2}{n\left(n^2 - 1\right)}$$

$\rho = 1 - \{6 \times 449.5/[13(13 \times 13 - 1)]\}$

$\rho = 1 - [2697/2184]$

$\rho = 1 - 1.235 = -0.235$

The rank correlation value at 5% level of significance with a degree of freedom (d.f.) 13 and two-tailed test is ± 0.484. The researcher can check the rank correlation value for significance with the help of two-tailed test.

The calculated rank correlation value lies in the acceptance region; therefore, H_0 is accepted. This implies that there is no correlation between the IQ level and number of hours spent on reading newspaper in a week. It can be interpreted that reading a newspaper cannot increase your IQ level unless you analyse news.

Self Assessment Questions

6. _____, also known as Spearman's rank correlation coefficient, is used to establish correlation between two data sets that can be ranked.

11.5 RANK SUM TEST

Rank sum test is used to analyse ordinal data (data in the rank form) and calculate the value of rank sum. First, observations of different samples are arranged in the

ascending order of value. Thereafter, these observations are ranked and the sum of ranked observations is calculated. Finally, the sum is tested against the specified test statistic value to test the hypothesis. There are two types of rank sum tests, as shown in Figure 5:

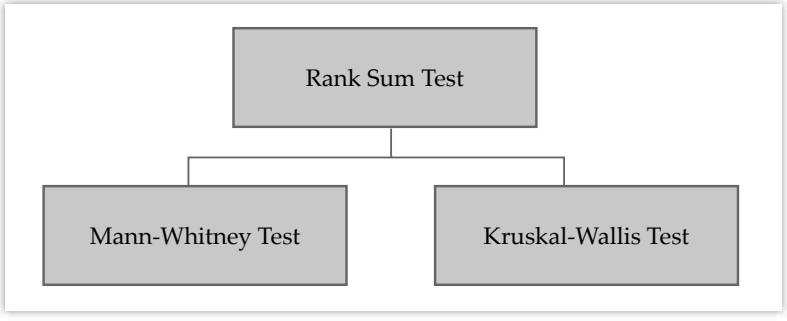

Figure 5: Types of Rank Sum Tests

Let us learn about these in detail.

11.5.1 MANN-WHITNEY TEST OR U TEST

Mann-Whitney test (or U test) is used to determine whether two independent samples are drawn from the same population. The test is applied in general conditions and does not have any specific requirement. The only requirement of the test is that population should be continuous. However, failure to fulfil this requirement does not have a huge impact on the result. In the Mann-Whitney test, first two samples are merged in increasing or decreasing order. After that, the data in the merged sample is ranked from lowest to highest. After rank allocation, the ranks are classified as R_1 for sample 1 and R_2 for sample 2. After that, the total of ranks in R_1 and R_2 is determined. Finally, the U test is applied in the following manner:

$$U_1 = R_1 - \frac{n_1(n_1+1)}{2}$$

$$U_2 = R_2 - \frac{n_2(n_2+1)}{2}$$

Where, U = Smaller of U_1 and U_2 and

n_1= Sample size of sample 1 and

n_2 = Sample size of sample 2

R_1= Sum of the ranks of sample 1 and

R_2= Sum of the ranks of sample 2

The mean and SD are determined to calculate the limits of acceptance region. The mean could be calculated with the help of the following formula:

$\mu_U = n_1 n_2/2$

Where, n_1= Sample size of sample 1

n_2 = Sample size of sample 2

Notes

The formula for standard deviation is as follows:

$$\sigma_U = \sqrt{\frac{n_1 n_2 n_1 + n_2 + 1}{12}}$$

If the value of U test lies under the limits of the acceptance region, the null hypothesis is accepted. However, if the calculated U value lies outside the limits of the acceptance region, the null hypothesis is rejected and the alternate hypothesis is accepted. Let us take an example to understand the application of the Mann- Whitney test.

Example 5: The production of Product A and Product B in a year is shown in Table 8:

Table 8: Production of Product A and Product B

No. of Respondents	Product A	Product B
1	40	28
2	35	30
3	20	35
4	36	40
5	22	45
6	26	21
7	45	26
8	50	28
9	44	30
10	47	44
11	48	50
12	25	49

The researcher wants to find out that the two products are from the same production house. Use the Mann-Whitney test (or U test) with 10% significance level.

Solution: Null hypothesis and alternate hypothesis are as follows:

H_0: $Med_A = Med_B$

H_1: $Med_A \neq Med_B$

The researcher merges the data of two products and arranges it in the increasing order. Thereafter, he/she calculates R_1 and R_2 for Products A and B, respectively, as shown in Table 9:

Table 9: Calculation for Mann-Whitney Test

S. No.	Product A Rank	Product B Rank
1	14.5	7.5
2	11.5	9.5
3	1	11.5
4	13	14.5
5	3	18.5

S. No.	Product A Rank	Product B Rank
6	5.5	2
7	18.5	5.5
8	23.5	7.5
9	16.5	9.5
10	20	16.5
11	21	23.5
12	4	22
	$R_1 = 152$	$R_2 = 148$

The calculation of U statistic is as follows:

$$U_1 = 152 - \frac{12(13)}{2} = 74$$

$$U_2 = 148 - \frac{12(13)}{2} = 70$$

Therefore, U = 70

$$\mu U = \frac{n_1 n_2}{2} = \frac{12 \times 12}{2} = 72$$

$$SD = \sigma U = \sqrt{\frac{n_1 n_2 (n_1 + n_2 + 1)}{12}} = \sqrt{\frac{12 \times 12(12 + 12 + 1)}{12}}$$

$$SD = 5\sqrt{12} = 17.3$$

The U-value at 10% level of significance and two-tailed test is 42.

$$U_\alpha = 42$$

Since U is greater than U_α, the researcher rejects H_0. This implies that Products A and B are from different production houses.

11.5.2 KRUSKAL-WALLIS TEST

The Kruskal-Wallis test is equivalent to one-way ANOVA (explained later in this chapter) with only one difference that the former is based on ranks while the latter is based on numerical values. The test is an extension of the Mann-Whitney U-test. In the Kruskal-Wallis test, the samples must be more than two, whereas, samples are two in the Mann-Whitney U-test. The Kruskal-Wallis test is used to determine whether samples in a study are taken from the same population. In the test, the data from different samples is merged and values are ranked in any order (low to high or high to low). Ranks are classified as $R_1, R_2 \ldots$ and R_n, according to the samples to which they belong. The test is performed in the following manner:

$H = 12/n\,(n + 1) \sum (R_i^2/n_i) - 3(n + 1)$

Where,

n = Sample size

Notes

R_i= Sum of the ranks of all the samples separately, that is, R_1, R_2, and….., n_i

= n_1, n_2, n_3,……

Chi-square value is determined at d.f. k–1 and the specified level of significance and the calculated H value is tested against it. If the H value lies under the limits of acceptance region, the researcher accepts the null hypothesis and rejects the alternate hypothesis. However, if the H value lies outside the limits of acceptance region, the researcher rejects the null hypothesis and accepts the alternate hypothesis.

Let us understand the application of the Kruskal-Wallis test with the help of an example.

Example 6: An organisation wants to purchase hundreds of different milling machines. As these machines cost a lot, the organisation wants to check whether it should purchase machines or not. Initially, it borrows four machines and randomly assigns them to 20 technicians with similar skill sets. Each machine was put through a series of tasks and rated using a standardised test. The high score indicates better performance. The scores given by technicians to four machines are shown in Table 10:

Table 10: Scores Given by Technicians to Four Machines

Machine 1	Machine 2	Machine 3	Machine 4
24	28	26	33
23	34	28	37
26	29	31	36
27	32	25	35
29	30	21	38

Perform the Kruskal-Wallis test to establish whether all four machines are equally good. Use 5% level of significance.

Solution: Null hypothesis and alternate hypothesis are as follows:

H_0: All four machines are equally good. (This implies that $Median_1$ = $Median_2$ = $Median_3$ = $Median_4$)

H_1: At least two machines are different.

First, the researcher merges performance data for the four machines and arranges it in an increasing order. Thereafter, he/she ranks the data and classifies ranks as R_1, R_2, R_3 and R_4 for machines 1, 2, 3 and 4, respectively. Finally, the researcher takes out the total of ranks in R_1, R_2, R_3 and R_4. The calculation is shown in Table 11:

Table 11: Allocation of Ranks to Scores Provided to Four Machines

No. of Observations	Machine Data	Ranks
1	21	1
2	23	2
3	24	3
4	25	4

No. of Observations	Machine Data	Ranks
5	26	5.5
6	26	5.5
7	27	7
8	28	8.5
9	28	8.5
10	29	10.5
11	29	10.5
12	30	12
13	31	13
14	32	14
15	33	15
16	34	16
17	35	17
18	36	18
19	37	19
20	38	20

After that, ranks are classified as R_1, R_2, R_3 and R_4 for machines 1, 2, 3 and 4, respectively, as shown in Table 12:

Table 12: Calculation of Kruskal-Wallis Test

Machine 1	R_1	Machine 2	R_2	Machine 3	R_3	Machine 4	R4
24	3	28	8.5	26	5.5	33	15
23	2	34	16	28	8.5	37	19
26	5.5	29	10.5	31	13	36	18
27	7	32	14	25	4	35	17
29	10.5	30	12	21	1	38	20
Total	28		61		32		89

The calculation of the Kruskal-Wallis test is as follows:

$H = 12/n\,(n + 1) \sum (R_1^2/n_1 + R_2^2/n_2 + R_3^2/n_3 + R_4^2/n_4) - 3(n + 1)$

Where, n = 20

$R_1 = 28$ $R_2 = 61$ $R_3 = 32$ $R_4 = 89$

$n_1 = n_2 = n_3 = n_4 = 5$

$H = 12/20(20 + 1)\,(28 \times 28/5 + 61 \times 61/5 + 32 \times 32/5 + 89 \times 89/5) - 3(20 + 1)$

$= (0.02857)\,(156.8 + 744.2 + 204.8 + 1584.2) - 63$

$= 13.85$

d.f. = k – 1

Notes

= 4 – 1

= 3

Chi-square value at 5% level of significance and 3 d.f. is 7.815. You can check the value for significance with the help of one-tailed test. The graphical representation of the preceding solution is given in Figure 6:

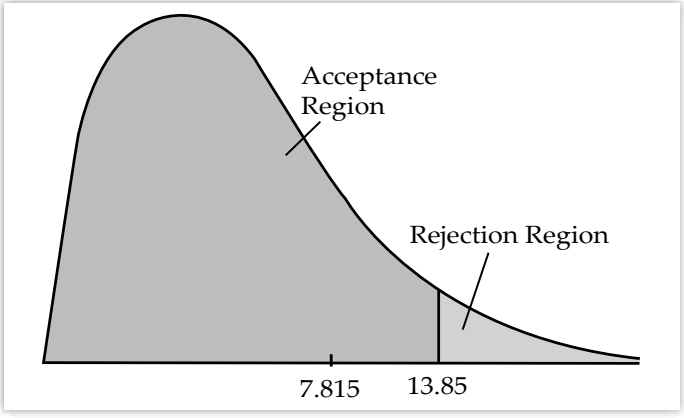

Figure 6: Showing the Rejection of the Calculated Chi-square Value

Figure 6 shows that the calculated chi-square value lies in the rejection region; therefore, H_0 is rejected and H_1 is accepted. This implies that all four machines are not equally good. It can be interpreted that all four machines have different capabilities and machine number 4 is the best, as its score (89) is the highest.

Self Assessment Questions

7. _____ is used to determine whether two independent samples are drawn from the same population.
8. _____ test is used to determine whether the samples in the study are taken from the same population.
9. Chi-square value is determined at d.f. k–1 and the specified level of significance and the H value is tested against it. (True/False)

11.6 CHI-SQUARE TEST

Chi-square test is used to find out dependency between two attributes. It can also be used to make comparisons between theoretical population (expected data) and actual data (observed data). The formula used in chi-square test is as follows:

$$\chi^2 = \sum_{i=1}^{k} \frac{(O_i - E_i)^2}{E_i}$$

Where, O_i = Observed frequency

E_i = Expected frequency

Expected frequency can be calculated with the help of the following formula:

E_i = Row total*Column total/Grand total (For test of independence)

If the value of chi-square is greater than critical value of c_2, null hypothesis is rejected.

Figure 7 shows two types of chi-square tests that are mainly used to find out the association between variables:

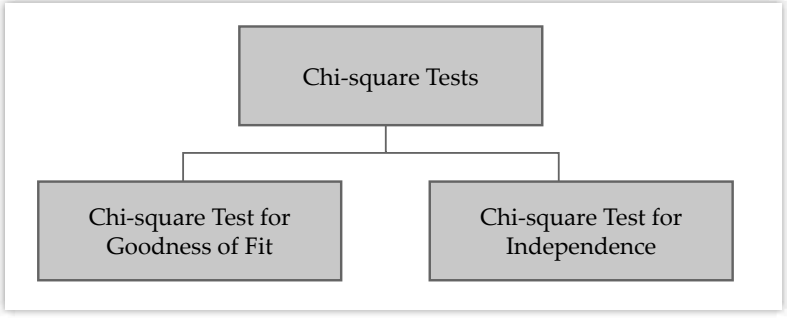

Figure 7: Types of Chi-square Tests

Let us discuss Chi-square test for goodness of fit and chi-square test for independence in detail.

11.6.1 CHI-SQUARE TEST FOR GOODNESS OF FIT

The test helps the researcher know whether the theoretical distribution (distribution of expected frequency) is fitted to the observed data and to what extent. In chi-square test, first the researcher finds out expected frequency on the basis of distribution.

Thereafter, he/she calculates chi-square value with the formula used to calculate chi-square. In chi-square test, d.f. used is n–1. Chi-square value is determined at the specified level of significance and d.f. If the calculated chi-square value lies under the limits of acceptance region, the researcher accepts the null hypothesis and rejects the alternate hypothesis.

Let us understand the application of chi-square test with the help of an example.

Example 7: An FMCG company produces various products. Currently, this company wants to launch four more products, namely A, B, C and D belonging to the same category. However, before launching the products, the company wants to evaluate the customer preferences for each product. For this, the company carries out a survey of 1,000 customers and records their responses as shown in Table 13:

Table 13: Customers' Responses

Product	Number of Customers the Product is Preferred by
Product A	300
Product B	280
Product C	220
Product D	200

Test the hypothesis that the customers have no preference for any particular product. Use 5% level of significance.

Solution: For H_0: Customers have no preference for any particular product.

Notes

The expected frequency and observed frequency of customers' responses are shown in Table 14 as follows:

Table 14: Expected Frequency and Observed Frequency of Customers' Responses

Product	Expected Frequency (E_i)	Observed Frequency (O_i)
Product A	250	300
Product B	250	280
Product C	250	220
Product D	250	200

$$\chi^2 = \sum_{i=1}^{k} \frac{(O_i - E_i)^2}{E_i}$$

$$\chi^2 = \frac{(300-250)^2}{250} + \frac{(280-250)^2}{250} + \frac{(220-250)^2}{250} + \frac{(200-250)^2}{250}$$

$$\chi^2 = \frac{50^2 + 30^2 + 30^2 + 50^2}{250}$$

$$\chi^2 = \frac{6800}{250} = 27.2$$

Critical value of χ^2 at 5% level of significance with 3 degrees of freedom (k–1 = 3) is 7.81. Since our χ^2 is greater than the critical value, we reject H_0.

11.6.2 CHI-SQUARE TEST FOR INDEPENDENCE

In chi-square test for independence, two attributes are tested to find out whether they are associated with each other. For example, the researcher wants to know that the introduction of better/unique services helps increase sales of an organisation or not. In this case, the researcher is trying to establish a relation between two attributes–better services and sales. In chi-square test, first expected frequency is calculated and then the value of chi-square is ascertained. The d.f. used in this case is (r–1) (c–1), where r equals the number of levels for one category of variable and c equals the number of levels for the second category of variable. The chi-square value is determined at the specified level of significance and d.f. If the calculated chi-square value lies under the limits of acceptance region, the null hypothesis is accepted and the alternate hypothesis is rejected.

Let us understand the application of chi-square test with the help of an example.

Example 8: The researcher has the data for the preferences of men and women regarding the joint and nuclear families, as shown in Table 15:

Table 15: Data for Preferences of Men and Women for Joint and Nuclear Families

	Joint Family	Nuclear Family	Total
Men	96	35	131
Women	170	360	530
Total	266	395	661

The researcher wants to find out whether the opinion of men and women about the type of family is the same. Use 5% level of significance.

Solution: Null hypothesis and alternate hypothesis are as follows:

H_0: The opinion of men and women about the type of family is indifferent.

H_1: The opinion of men and women about the type of family is different.

The test statistic used for this data is chi-square test for independence. The following equation is used for calculation:

$$\chi^2 = \sum_{i=1}^{k} \frac{(O_i - E_i)^2}{E_i}$$

Where, O_i = Observed frequency

E_i = Expected frequency

Expected frequency can be calculated with the help of the following equation:

E_i = Row total*Column total/Grand total

In the current scenario, expected frequency can be calculated using the following method:

$E_{1i} = \times 266/661 = 52.72$

$E_{2i} = 131 \times 395/661 = 78.28$

$E_{3i} = 530 \times 266/661 = 213.28$

$E_{4i} = 530 \times 395/661 = 316.72$

After calculating the expected frequency and the square of differences between the observed and expected frequency, Table 16 is created:

Table 16: Calculation of Chi-Square Test for Independence

No. of Observations	Observed Frequency (O_i)	Expected Frequency (E_i)	$O_i - E_i$	$(O_i - E_i)^2$	$(O_i - E_i)^2/E_1$
Men					
Joint Family	96	52.72	43.28	1873.158	35.53032
Nuclear Family	35	78.28	– 43.28	1873.158	23.92895
Women					
Joint Family	170	213.28	– 43.28	1873.158	8.782626
Nuclear Family	360	316.72	43.28	1873.158	5.914241
Total					74.15614

Calculated value of chi-square = 74.16

d.f. = (r – 1) (c – 1)

= (2 – 1) (2 – 1) = 1

Notes

Chi-square value at 5% level of significance with one-tailed test and 1 d.f. is 3.841. You can check the chi-square value for significance with the help of one-tailed test. The graphical representation of the preceding solution is shown in Figure 8:

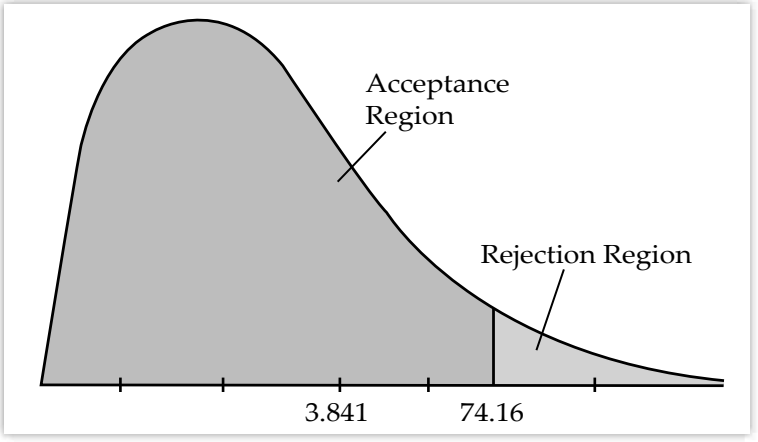

Figure 8: Rejecting Chi-square Value

Figure 8 shows that the value lies in the rejection region; therefore, H_0 is rejected. The value implies that there is a vast difference between the opinions of men and women about the type of family.

Self Assessment Questions

10. Expected frequency can be calculated using the formula _____.
11. Chi-square test for independence refers to a test in which two attributes are tested to find out whether they are associated with each other. (True/False)

Activity

Prepare a PowerPoint presentation on 'Non-Parametric Test'.

11.7 SUMMARY

- A researcher can use non-parametric tests without taking into consideration population distribution and sample type. Non-parametric tests are also known as distribution-free tests.
- Sign test is considered as one of the easiest non-parametric tests because it takes into account only the plus and minus signs of observations in a sample.
- One sample sign test is applied on a single sample taken from a symmetrical population.
- Two sample sign test is used to check whether two samples are related to each other. It is also known as paired sign test.
- Rank correlation, also known as Spearman's rank correlation coefficient, is used to establish correlation between two data sets that can be ranked.
- Rank sum test is used to analyse ordinal data (in the rank form) and calculate the value of rank sum statistics. To conduct this test, observations need to be arranged in the ascending order.

- The Mann-Whitney test (or U test) is used to determine whether two independent samples are drawn from the same population. It is applied in general conditions and does not have any specific requirement.
- The Kruskal-Wallis test is similar to one-way ANOVA with only one difference that the former is based on ranks, while the latter is based on numerical values.
- The Wilcoxon matched pairs test/signed rank test is a combination of sign and rank tests. It is used to compare two paired samples.
- Chi-square test is used to find out dependency between two types of data. It can also be used to make comparisons between theoretical population (expected data) and actual data (observed data).

11.8 KEY WORDS

- **Non-parametric tests:** These tests do not require any information about the parameters of a population from which a sample is derived.
- **Sign tests:** These are based on signs, not on the magnitude of observed values.
- **Rank correlation coefficient:** This test is used to study correlation among the ranks of different data sets.
- **Signed rank test:** It is used to study both the direction and magnitude of samples.
- **Chi-square test of goodness of fit:** It is used to analyse nominal data (in the yes/no format) and find out the best solution to the problem under consideration.
- **Chi-square test of independence:** It is used to find out whether two attributes are associated with each other.
- **Correction factor**: It refers to the adjustment made in a calculation to control deviations in a sample or a method of measurement.

11.9 CASE STUDY: PROBLEM FACED BY PORTABLE GENERATOR INDUSTRY

History of Portable Generators

The economic liberation policy of 1985 increased foreign industrial collaborations in India. There was a spurt in industrial tie-ups and consequently in industrial output. Foreign companies have collaborated with several Indian companies. Portable generator was one such industrial segment where foreign companies have collaborated with India companies to manufacture generators in India. For example, Sri Ram Group entered into Joint Venture (JV) with Honda of Japan to form Sri Ram Honda. The JV had a capacity to build 500 portable generators a day. In addition, the Birla group has partnered with Yamaha of Japan to form Birla Yamaha, which manufactures portable generators. However, some Indian companies independently entered in the portable generator industry with their local brands. For example, Greaves Cotton produced portable generators under the brand name 'Lombardini'. Kirloskare Group introduced a 1.5 KVA portable generator and Enfield India launched its generator under the brand name 'Gee'. There were 50–60 local brands with the capacity to produce 100 portable generators a day. By 1986, the total output

Notes

of the portable generator industry was 2.5 lakh units a month due to huge demand from customers. However, this demand was short-lived and, by 1987, many units closed down the production of generators. For example, Kirloskare Group has withdrawn its 0.5 KVA portable generator from the market. Lombardini has also disappeared from the market. Two major competitors, Sri Ram Honda and Birla Yamaha, were indulged in a price war.

Scenario of the Portable Generator Industry

In the portable generator industry, the rural market is emerging and requires generators mainly to run pump sets in farms. The market has been totally ignored by two market leaders (Sri Ram Honda and Birla Yamaha). The leaders produce expensive, good quality generators. These generators are light and fragile; therefore, these cannot be used in farms. Local brands so far have satisfied the requirement of the rural market. The market leaders have finally realised the importance of the rural market. For example, until now, portable generators were marketed on factors, such as low noise, fuel efficiency and reliable machine. However, market requirements have changed over time. So, leaders are conducting market research to know the changed requirements. Sri Ram Honda and Birla Yamaha hired researchers to study the changing market scenario. The researchers divided the problem into two research topics. The first research topic is to study the requirements of rural market in terms of technical feasibility and consumer preferences. The second topic is to compare the two types of generators on the basis of their efficiency with respect to the rural market. To study the first research topic, researchers collected two samples: one from a market leader and another from a local marketer. Rural technicians have assigned scores to two types of generators according to efficiency. The collected data is as follows:

Scores given by Rural Technicians to Generators		
	Generators	
No. of Technicians	Top Competitors (A)	Local Marketers (B)
1	33	45
2	35	30
3	24	35
4	36	40
5	22	45
6	26	41
7	45	46
8	50	52
9	44	49
10	47	44
11	48	50
12	25	42

Following table shows the preferences of rural and urban customers for two types (branded and local) of generators:

Preferences of Rural and Urban People for Local and Branded Generators			
	Top Competitors	**Local Marketers**	**Total**
Rural Market	100	150	250
Urban Market	120	99	219
Total	220	249	469

The researchers concluded that the rural market is widely different from the urban market. In addition, the efficiency of generators produced by top competitors is almost same as those produced by local companies. Therefore, the generators produced by top competitors to fulfil demand from urban marketers, can also be introduced in the rural market. The two market leaders should market their products very effectively in the rural market to capture the market share. Local marketers have the first mover advantage in the rural market. The market leaders can make slight changes in their generators to improve their capacity and promote their products as specifically designed for the rural market.

QUESTIONS

1. What are the two research topics identified by researchers?

   (**Hint:** Studying the requirements of rural market in terms of technical feasibility and consumer preferences.)

2. What is the conclusion given by researchers in the case study?

   (**Hint:** The researchers concluded that the rural market is widely different from the urban market.)

3. How did the two market leaders (Sri Ram Honda and Birla Yamaha) conduct the market research?

   (**Hint:** Sri Ram Honda and Birla Yamaha hired researchers to study the changing market scenario.)

4. What strategy was followed by researchers to conduct research?

   (**Hint:** The researchers divided the problem into two research topics.)

5. How was the study of the first research topic conducted by researchers?

   (**Hint:** Researchers collected two samples: one from a market leader and another from a local marketer. Rural technicians have assigned scores to two types of generators according to efficiency.)

11.10 EXERCISE

1. Explain the concept of non-parametric test.
2. Describe rank correlation with the help of an example.
3. Explain the types of sign tests.

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4. Discuss the concept of U test with the help of a diagram.
5. Write short notes on:
   a. Chi-square test
   b. Wilcoxon matched pairs/Signed rank test

11.11 ANSWERS FOR SELF ASSESSMENT QUESTIONS

Topic	Q. No.	Answer
Concept of Non-Parametric Tests	1.	distribution-free
	2.	True
Sign Test	3.	Sign test
	4.	True
	5.	c. Two sample sign test
Rank Correlation	6.	Rank correlation
Rank Sum Test	7.	Mann-Whitney test (or U test)
	8.	Kruskal-Wallis
	9.	True
Chi-Square Test	10.	E_i = Row total × Column total/Grand total
	11.	True

11.12 SUGGESTED BOOKS AND E-REFERENCES

SUGGESTED BOOKS

- Biddle, J., & Emmett, R. *Research in the History of Economic Thought and Methodology*
- National Academies Press. (2009). *Partnerships for Emerging Research Institutions*. Washington, D.C.

E-REFERENCES

- Nonparametric Tests - Overview, Reasons to Use, Types. (2020). Retrieved 9 April 2020, from https://corporatefinanceinstitute.com/resources/knowledge/other/nonparametric-tests/
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CHAPTER 12

Report Writing

Table of Contents

LEARNING OBJECTIVES

After studying this chapter, you will be able to:

- Explain the concept of report proposal
- Describe the research report
- Outline the importance of written reports
- Explain the concept of oral presentation
- Discuss the integral parts of a report

12.1 INTRODUCTION

In the previous chapter, you studied the non-parametric tests. The chapter discussed the sign test and its types. The latter sections of the chapter described rank correlation and rank sum test. The chapter concluded with the explanation of chi-square test.

Report writing is a process to document each and every step involved in the research process. These steps are Introduction, Literature Review, Methodology, Data Analysis and Interpretation, Conclusion and Recommendations. It helps the researcher in checking whether the research is progressing in the right direction or not. A research report serves as a reference for findings and recommendations of a research in future. The research report consists of a written report and an oral presentation. The written report states objectives, data, research methodology and findings. The oral presentation helps the target audience in judging whether research recommendations are feasible to address the research problem or not.

An organisation takes several crucial decisions on the basis of a research report related to its functioning. If the report is not clear and concise, then the organisation may misinterpret the research findings and take wrong decisions, which may prove disastrous for the organisation. Therefore, the researcher should observe utmost care and adopt a predetermined structure while writing a report to prevent the creeping in of ambiguities in the report.

The chapter begins by explaining the concept of research proposal. Next, it provides in-depth information about research report. Then the following topics are explained: written report, audience of a report, types of reports and steps in writing a report. The integral parts of a report are also discussed. Towards the end, the concept of oral presentations is discussed.

12.2 RESEARCH PROPOSAL

A research proposal is a clearly outlined plan submitted by one party for acceptance or rejection by another party. The first party wants the research to be conducted and the second party actually conducts the research. The first party can be an organisation, government body, or any other entity that has a problem, which can be solved only through research. The second party can be a research agency, research institution, or an independent researcher. The research proposal is a detailed description of the research prepared by the second party to explain the first party how the research would be conducted and what the requirements of the research are.

The research proposal includes the following information:

- **Purpose:** This is the objective for which the research is to be conducted. It also provides information about the needs and significance of the research.
- **Population:** It refers to the universe from which the researcher takes samples.
- **Research design:** It is the layout of the research giving details of procedures required for conducting research. Research design defines the information needed, deigns exploratory or descriptive phases of research, specifies measurement and scaling procedures, defines an appropriate data collection method, specifies sampling process and sample size, develops data analysis plan, etc.
- **Methods of data collection:** These are the techniques of collecting data for the research. Examples of data collection methods are questionnaires, observations and interviews.
- **Tests of significance:** These tests help in analysing the collected data. The researcher can use z-test, t-test or F-test depending on the sample size, the type of data and the research methodology.
- **Time frame:** It is the duration within which the research would be completed. The research proposal includes the tentative schedule to start and complete each activity in the research.
- **Budget:** It is the estimated cost to conduct the research. The research proposal should clearly indicate funds required for the research work.

An example of the research proposal is as follows:

RESEARCH PROPOSAL

Submitted to
Sales Manager: Vikas Kumar

Submitted by
Manali Batra, Senior Researcher
MSD Research Institute

Name: Manali Batra

Designation: Senior Researcher

Location of the Work: Max New York Life, Elegance Tower, Jasola Vihar

Working Days: Monday to Saturday

Working Hours: 9:30 am to 5:00 pm

Contact Number: +919XXXXX69

Time Frame for the Project: 2 months

Expected Cost of the Project: ₹ XXX thousand

(This includes the cost of project designing, travelling, administration and reporting.)

Name of the Reporting Officer: Mr. Vikas Kumar

NOTES

Designation: Sales Manager

Contact Number: +919XXXXX66

Title of the Project

Comparative Analysis of Max New York Life (MNYL) and HDFC Life Insurance: A Detailed Study on MNYL

Objectives:

- To study and compare the sales process of MNYL and HDFC
- To study the policies and products of MNYL and HDFC
- To compare the customer satisfaction of both the companies
- To study the impact of advertisement on the sale of both the companies

Methodology

The research methodology of this project consists of:

1. Research design
   - Descriptive research design
   - Hypothesis testing
2. Data collection
   - Primary data – Questionnaire, in-depth interviews
   - Secondary data – the Internet, articles in different sources (print media), MNYL
3. Sample
   - Sampling – Purposive and convenient sampling
   - Sample size – 200
   - ™ Sample population – Customers of MNYL and HDFC
4. Tools
   - Excel
   - SPSS

Importance of the Research Work

This study will help us in determining the sales process, products and policies of MNYL and HDFC. It will also shed light on the impact of advertisement on the sale of insurance companies.

In addition, the study will help us in comparing MNYL and HDFC to know which one is doing well in the market and satisfying its customers.

Expected Outcomes

The study aims to obtain information about:

- The sales process of MNYL and HDFC
- Products and policies of two companies

- The effect of advertisement on sales
- The trend of sales in both the companies
- Comparison of customer satisfaction and expectations from respective companies

Limitations of Study

This study covers data analysis of MNYL and HDFC for only a limited period of time from the financial years 2014–15 to 2018–19. Hence, the results are comparable and representative for this period only.

Self Assessment Questions

1. A _____ is an agreement between two parties. The first party wants the research to be conducted and the second party actually conducts the research.

12.3 RESEARCH REPORT

A research report is a crucial part of a research as it includes solutions and actionable recommendations of the research problem. A research report is prepared by an analyst or researcher who is a part of the research team. If the report is not made properly, all efforts of the researcher would become useless. The research report can be divided into two types, as shown in Figure 1:

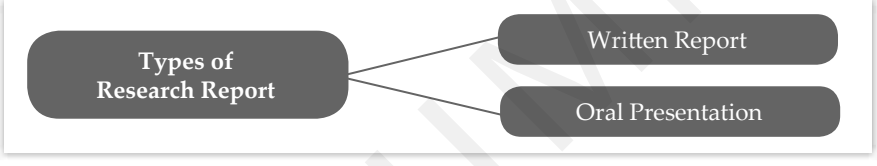

Figure 1: Parts of the Research Report

The written report is an official document giving the facts and information to the interested readers in a presentable manner. The facts must be accurate, complete and interpreted. The oral report, on the other hand, is a piece of face-to-face communication presenting one's research work in a seminar, workshop, etc. It helps the researcher present his/her views more clearly in front of research stakeholders. Since the reporter has to interact directly with the audience, any faltering during oral presentation can leave a negative impact on the audience. However, an oral report helps the researcher gather valuable suggestions and feedback from the research stakeholders. As compared to an oral report, a written report is a permanent record that can be used for reference again and again. Let us discuss the written reports and the oral presentations in detail.

12.3.1 WRITTEN REPORT

A research report refers to the systematic and orderly presentation of a research activity in a written form. While writing a report, the researcher should take into consideration various aspects, such as specific objectives of the study, description of the methods or techniques used, review of the data on which the study is based, assumptions made in the course of study and presentation of the findings including their limitations and supporting data.

A written report provides information about a subject or topic. In other words, it provides readers with an insight into topic on which the research work is carried,

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time duration, the methodology adopted for research, and so on. In addition, a written report helps in identifying alternative solutions to address a problem by presenting the present and past findings and recommendations.

Audience of a Report

As already discussed, there are two parties involved in a research – the first party wants the research to be conducted and the second party conducts the research. The first party is called audience. The researcher should tailor the writing of research report towards the specific requirements of the target audience. The length and composition of a research report and the details provided in it vary as per the target audience. This happens because organisations differ from one another in significant ways.

The researcher should adapt his writing successfully to three types of audiences that requires different techniques:

- **High-tech peers:** The research report should make use of the most professional/ complex resources, along with writing of jargon and technical terms, keeping in mind the expert-level knowledge of the audience.
- **Low-tech peers:** The research report should provide proper definitions for all the abbreviations/acronyms/technical terms used throughout the writing. This would enhance understanding where it is a mixture of laymen and professionals.
- **Lay readers:** The research report should use simple terms that are a lot easier to understand and interpret. There should be no use of abbreviations/acronyms.

Other Types of Reports

As already discussed, different types of audiences prefer different types of reports. Broadly, reports are classified into two types – technical report and popular report. The two types of reports are described as follows:

- **Technical report:** It lays emphasis on the method employed in conducting research, assumptions made during the research, details about the research topic, and the research findings and recommendations. Technical reports are full-fledged reports that are generally lengthy. These reports involve a detailed description of the research work. The target audience of technical reports are students, government bodies, special commissions and other organisations that need an in-depth analysis of the topic.
- **Popular report:** This report is non-technical in nature and is less comprehensive as the audience of this report is interested in knowing the results of the research, not the entire analysis. Therefore, the popular report focusses on the findings and recommendations of the research. It lays emphasis on simplicity and attractiveness in information presentation. The content of the popular report should be simple, clear and less technical in nature. Information should be explained with the help of simple charts and graphs instead of mathematical equations. The popular report should be attractive in terms of layout, fonts, figures, print and use of subheadings.

Steps in Writing a Report

The research report should be written in such a format that it is easily comprehensible by the target audience. The report writing process involves sequential steps that are described as follows:

1. **Analysing the subject matter:** It involves determining the kind of development pattern to be adopted for writing the report for a particular research. Two kinds

of development patterns are mostly used in research reports: logical development and chronological development. In logical development, the researcher makes logical decisions by using mental thoughts and links between one topic and the other. Logical thinking is mostly based on the study that the researcher has done during the research work. In logical development, the subject matter moves from simple to complex. In chronological development, the subject matter is sequentially structured.

2. **Drawing the outline of the report:** At this stage of report writing, the researcher makes a structure or outline of the report. It consists of a brief description of the topic to be covered in the report. This helps the researcher not to miss out any topic to be studied in the report. The outline is also considered as the framework of the report.
3. **Preparing the rough draft:** At this stage, the researcher starts writing the report. The researcher organises his/her thoughts and mentions methods to be used for data collection, analysis techniques, major findings of the research and limitations faced by him/her during the study. The recommendations of the study are also described in the rough draft.
4. **Reviewing the rough draft:** The researcher checks whether the report conveys the intent of the research work to be carried out. In addition, at this stage, the researcher also checks whether the report is apt for the target audience.
5. **Preparing bibliography:** Bibliography is a section of the report that contains sources of secondary data collection. It includes names of books, journals, magazines and other sources of print media from where the data is collected. It also contains the Internet links used in the preparation of the research report. There is a proper pattern to write the name of the source from where the data is collected.

   Multiple styles of referencing can be used, such as APA citation, Harvard referencing and MLA format, each having its unique rules for the structure of references with respect to author name, book title, date, publisher name, etc. Let us understand the pattern of mentioning data sources in bibliography with the help of the following examples:

   For books and pamphlets, the order of writing in APA referencing is as follows:

   Last name of the author, initials of the first name (year). Title of the book (edition). Place. Publisher name.

   For example,

   Sekaran, U., & Bougie, R. (2016). Research Methods FOR Business (4th ed.). New York: Wiley.

   For websites, the order of writing in APA referencing is as follows: Article title. (year). Retrieved from: URL.

   For example,

   4 Types of Research Methods For Start-Ups. (2019). Retrieved from https:// www.bl.uk/business-and-ip-centre/articles/4-basic-research-methods-for-business-start-ups.
6. **Making the final draft:** At this stage of report writing, the researcher gives a final touch to his/her report. The final report is prepared keeping in mind the objective of the research. It should be simple, concise and convincing. At this stage, it is checked whether all the portions of the research are covered or not.

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12.3.2 ORAL PRESENTATIONS

Most of the time, oral presentations are given with the help of PowerPoint software, which facilitate data presentation in the form of graphs and charts. These presentations are preferred by most organisations, as these are less time-consuming and economical. Oral presentations can be given to a large number of audiences in a single instance, whereas written reports can be read by only one person in a single instance.

The duration of an oral presentation is maximum 30 minutes. The researcher should be able to explain his/her entire research work in the given time. He/she should have convincing skills and presentable enough to gain the attention of the target audience. The researcher should also handle the queries of the audience patiently and should be well-prepared for the presentation to minimise the chances of errors. He/she should not get irritated and frustrated while answering the queries.

Self Assessment Questions

2. Which of the following are the most common purposes of writing a report?
   a. Providing information
   b. Generating ideas
   c. Finding solution
   d. All of these
3. Which of the following types of audience needs only one- or two-page report?
   a. Mathematicians
   b. Business firms
   c. Students of literature
   d. Chemists
4. Oral presentations can be given to a large number of audiences in a single instance, whereas written reports can be read by only one person in a single instance. (True/False)
5. What is the duration of an oral presentation?
   a. 10 mins
   b. 25 mins
   c. 30 mins
   d. 40 mins

12.4 INTEGRAL PARTS OF A REPORT

A research report contains many sections that provide segregated research information. Every part of the report is written and described in a different format. The length, data, objective and style of every part are different. The following points explain different parts of a report:

- **Title page:** It includes the heading of the report. The report should have a descriptive title that gives an overview of the research. The title page contains the name of the sponsor of the study, the name of the researcher, and duration of the research. Some examples of research titles are as follows:
  - Study of the types of investors in the present scenario
  - Factors affecting consumer preferences during shopping
  - Impact of retail display and store design on customer-buying behaviour
- **Preliminary pages:** These pages include acknowledgement or preface of the report which includes topic of the research and the person who authorises the

researcher to conduct the research. It also contains the name of the people who have contributed to the research. Preface talks about the subject matter of the report.

- **Executive summary:** It contains a brief account of the introduction, body and conclusion of the research. It gives an idea of every segment in the report. The summary can come at the start or end of the report. It depends on the type of report and the way of report-writing.
- **Introduction and objective:** It contains the detailed background of the research topic and the purpose of conducting the research. For example, if the research is carried on an organisation's product, the introduction would include product features and the background, profile, market and future plans of the organisation. It can also involve the industry background, which includes information regarding main players and the level of competition in the market.
- **Body of the report:** This part contains a detailed description of the research topic. It also contains methodology used in the research and analysis of the collected data.
- **Findings, conclusion and recommendations:** This part contains major findings of the research.
- **Bibliography and appendices:** This part lists sources from where the research data is collected. Bibliography contains sources of secondary data while appendices contain the sources of primary data or some extra information about the research topic. Appendices also contain the questionnaire or other sources of acquiring data.

Self Assessment Questions

6. The _____ contains the name of the sponsor of the research, the name of the researcher and duration of the research.
7. Bibliography contains the sources of secondary data while appendices contain the sources of primary data or some extra information about the research topic. (True/False)
8. _____ contain the questionnaire or other sources of acquiring data.

Activity

Prepare a PowerPoint presentation on research report-writing techniques.

12.5 SUMMARY

- A research proposal is an agreement between two parties. The first party wants the research to be conducted and the second party actually conducts the research.
- The research proposal includes purpose, population, research design, methods of data collection, tests of significance, time frame and budget.
- A research report is a crucial part of a research as it includes solutions and actionable recommendations of the research problem.
- A research report can be of two types, namely written report and oral presentation.

Notes

- Broadly, reports are classified into two types – technical report and popular report.
- Technical report lays emphasis on the method employed in conducting research, assumptions made during the research, details about the research topic and the research findings and recommendations.
- Popular report is non-technical in nature and is less comprehensive as the audience of this report is interested in knowing the results of the research, not the entire analysis.
- The report writing process involves sequential steps, which are analysing the subject matter, drawing the outline of the report, preparing the rough draft, reviewing the rough draft and preparing bibliography.
- Oral presentations are given with the help of PowerPoint software, which facilitate data presentation in the form of graphs and charts.
- A research report contains many sections that provide segregated research information, which are title page, preliminary pages, executive summary, introduction and objective, body of the report, findings, conclusion, recommendations and bibliography and appendices.

12.6 KEY WORDS

- **Final outline:** The stage of the report writing in which the researcher makes a structure or outline of the report.
- **Population:** The universe from which the researcher takes samples for the research.
- **Review of the rough draft:** The stage in which the researcher reviews his/her report.
- **Rough draft:** The stage in which the researcher starts writing a report.

12.7 CASE STUDY: A NEW PRODUCT

ABC Company wants to launch a new product, PR Paints, in a new market. Therefore, it hires a research agency to conduct a research and present a short report of 1–2 pages. Through the research, the manager wants to know about the market and the ways to enter the new market. The researchers prepare the following report proposal to be submitted to the company:

RESEARCH PROPOSAL

Submitted to
Manager S.R. Dicosta

Submitted by
Veera Malhotra
Senior Researcher
RPS Research Institute

Name: Veera Malhotra

Designation: Senior Researcher

Location of the Work: New Delhi

Working Days: Monday to Saturday

Working Hours: 9:30 am to 5:00 pm

Contact Number: +919XXXXX69

Time Frame for the Project: One month

Name of the Reporting Officer: Mr. S.R. Dicosta

Designation: Sales Manager

Contact Number: +919XXXXX66

Title of the Project: Study of Paint Industry in Delhi

Objectives

The objectives of the study are as follows:

- To study the paint industry in Delhi
- To determine the prospective customers of PR Paint
- To compare the paint industry and the present industry of ABC Company

To give recommendations about the launch of PR Paint

Methodology

The research methodology of this project consists of:

1. Research Design
   - Descriptive research design
   - Hypothesis testing
2. Data collection
   - Primary data: Questionnaire and in-depth interviews
   - Secondary data: The Internet and articles in different sources (print media)
3. Sample
   - Sampling: Purposive and convenient sampling
   - Sample size: 200
   - Sample population: Customers of similar product in the market
4. Tools
   - Excel
   - SPSS
   - TABLEAU

Importance of the Work

This study will help in knowing the competition level in the new market and how the company will beat this competition and enter the market.

Expected Outcomes

From this project, we will come to know about the following:

- What is size of the paint industry in Delhi?

Notes

- What are the products in this industry at present?
- What is the level of competition in the market?
- How to enter the market?
- What product development strategy will meet customers' requirements?

After sending the report proposal, the researcher starts researching and writes a report after the completion of the research. The report is as follows:

Research Report
Study of Paint Industry in Delhi
Findings of the Study

The major findings of the research are as follows:

- The paint industry in Delhi is very large.
- The paint market is highly competitive because a huge variety of paints with new colour combinations are available. However, there is a scope to enter in the paint market with new and innovative ideas.
- Customers always want to use new colours for their offices and houses.

Recommendations of the Study

Some recommendations made to ABC Company are as follows:

- Introduction of a new product, PR Paint, in the new market could be a good decision.
- Consider the requirements of consumers while introducing a new product in the paint market. The consumers want that the paint should give a smooth touch, different shades and innovative colour combinations.
- Provide customers a different range of colours, which help in keeping the product price higher.

Objectives of the Study

The objectives of the research are as follows:

- To study the paint industry in Delhi
- To study the market of PR Paint
- To compare the paint industry and the present industry of ABC Company
- To give recommendations about the launch of PR Paint

Data Collection

The data is collected from the following sources:

- **Primary data**: Includes the data collected by conducting interviews with shopkeepers and customers. The shopkeepers were asked which company was providing them better discounts and which products were preferred by customers. The customers were asked about how and why they selected a

particular paint. Also, customers' requirements in terms of expected product design or features were analysed.

- **Secondary data**: Includes the data collected from the Internet, books and articles on the paint industry in Delhi. The researcher also used documents of the company to know about its background.

Results

The researcher tries to explain the results of the research with the help of SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis, which is presented in the following table:

Strengths	**Weaknesses**
• Strong brand image • Dedicated sales team • Value-added services	• Centralised structure • Rigid department heads
Opportunities	**Threats**
• Large untapped market • Distinguishable product (such as PR Paint) • Unsatisfied customer • New area of expansion	• Presence of very strong competitors • Aggressive marketing by competitors • Various paints of good quality

Table: SWOT Analysis

QUESTIONS

1. Which type of report is used in the case study?

   (**Hint:** Popular report is used in the case study.)

2. What is the conclusion given by the researcher in the case study?

   (**Hint:** The researcher concluded that the competition is very high in the paint industry.)

3. How did the researcher explain the results of the research?

   (**Hint:** With the help of SWOT analysis)

4. What did the researcher do prior to writing research report?

   (**Hint:** Prepared research proposal and started the research)

5. What recommendations were given by ABC Company in the research report?

   (**Hint:** The recommendations given were:

   - Introduction of a new product, PR Paint, in the new market could be a good decision.
   - Consider the requirements of consumers while introducing a new product in the paint market. The consumers want that the paint should give a smooth touch, different shades and innovative colour combinations.
   - Provide customers a different range of colours, which help in keeping the product price higher.)

Notes

12.8 EXERCISE

1. Explain the research proposal.
2. What do you meant by research report?
3. Explain the concept of written report in detail.
4. Discuss the integral parts of a report.

12.9 ANSWERS FOR SELF ASSESSMENT QUESTIONS

Topic	Q. No.	Answer
Research Proposal	1.	research proposal
Research Report	2.	d. All of these
	3.	b. Business firms
	4.	True
	5.	c. 30 mins
Integral Parts of a Report	6.	title page
	7.	True
	8.	Appendices

12.10 SUGGESTED BOOKS AND E-REFERENCES

SUGGESTED BOOKS

- Biddle, J. & Emmett, R. *Reserach in the History of Economic Thought and Methodology*.
- Chandra, S. & Sharma, M. *Research Methodology*.
- National Academies Press. (2009). *Partnerships for Emerging Research Institutions*. Washington, D.C.

E-REFERENCES

- How to Write a Research Proposal | Guide and Template. (2020). Retrieved 10 April 2020, from https://www.scribbr.com/research-process/research-proposal/
- Research Reports: Definition and How to Write Them | QuestionPro. (2020). Retrieved 10 April 2020, from https://www.questionpro.com/blog/research-reports/

About IIMM

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