Problem Identification

Problem Identification

There are countless problems with family planning and health programs. Finding a problem is not hard, but identifying one for the purpose of research is not always easy. One of the most important tasks of research is to identify and define clearly the problem you wish to study. If you are uncertain about the research problem, if you are not certain in your own mind about what you want to study, you may be sure that others who read your proposal will also be uncertain. A well-defined problem leads naturally to the statement of research objectives, to the hypotheses, to a definition of key variables, and to a selection of a methodology for measuring the variables. A poorly defined research problem leads to confusion.

All research is set in motion by the existence of a problem. A problem is a perceived difficulty, a feeling of discomfort with the way things are, a discrepancy between what someone believes **should be** and **what is.** While problems are the initiating force behind research, not all problems require research. A potential research situation arises when three conditions exist:

1 A perceived **discrepancy** between what is and what should be.
2 A **question** about why the discrepancy exists.
3 At least **two possible and plausible answers** to the question.

The last point is important. If there is only one possible and plausible answer to the question about the discrepancy, then a research situation does not exist. Consider the example given below.

1 Example of a Nonresearch Problem

Problem Situation: A recent survey in District A found that 1,000 women were continuous users of contraceptive pills. But last month's service statistics indicate that none of these women are using contraceptive pills.

Discrepancy: All 1,000 women **should be using** contraceptive pills, but all 1,000 women **are not using** contraceptive pills.

Problem Question: What factor or factors are responsible for 1,000 women discontinuing their use of contraceptive pills?

Answer: A monsoon flood has prevented all new supplies of pills reaching District A, and all old supplies have been exhausted.

In the above example, a problem situation exists, but the reason for the problem is already known. Therefore, assuming that all the facts are correct, there is no reason to conduct research on the factors associated with pill discontinuation among the 1,000 women. On the other hand, there may very well be a need to conduct research on the question of why the supply and logistics system is incapable of providing contraceptives to women during the monsoon. Study the next example.

2 Example of a Research Problem

Problem Situation: District A is always flooded during the monsoon season. Recognizing this problem, the national family planning program established a new supply logistics system for the district. Each pill user is given a four-month supply before the monsoon begins. During the monsoon, small motorboats are available to transport new supplies to selected distribution centers accessible to village-level family planning workers. Despite these new measures, this year service statistics indicated that there are no pill supplies in District A.

Discrepancy: The new logistics system **should be able** to assure a continuous supply of pills, but this year **there are no supplies.**

Problem Question: Why has the new supply logistics system been incapable of delivering contraceptive pills to users?

Possible Answers:

1 An order for new pill supplies was not placed in time before the monsoon rains.
2 The riverboats used to transport the supplies are out of order.
3 Field-workers were not told about the new system and failed to give users a four-month supply of pills before the monsoon.

In this example, there are several possible and plausible reasons for the problem situation. One or more of these reasons might be correct. Therefore, this is a potential research situation.

In some situations, it is relatively easy to identify the problem, to define it, to hypothesize the reasons for it, and to conduct research to determine which reason is correct or more nearly correct. The reasons for the supply and logistics problem in the above example could probably be determined fairly easily and certainly would not require an expensive research study. Other problems, such as the one in the next example, are not so easy to identify or to study.

3 Example of a Research Problem

Problem Situation: A recent family planning survey revealed great differences between villages in the rate of contraceptive prevalence. Despite the fact that all villages receive the same level of health and family planning services, some villages have a prevalence rate as high as 80 percent, while others have a rate as low as 6 percent.

Discrepancy: All villages **should have** approximately the same rate of contraceptive prevalence, but in fact **there is great variation** between villages.

Problem Question: What factors are responsible for the areal variation in contraceptive prevalence rates?

Possible Answers:

1 Villages differ in their socioeconomic environments. Some villages are agricultural; some are fishing communities. Some villages are Hindu; others are predominantly Muslim or Buddhist. Some villages have access to markets in towns; others do not. Some villages have schools, health clinics, electricity, and a good water supply; others do not have these facilities. These socioeconomic differences affect the level of contraceptive practice.
2 Villages differ in institutional support for contraceptive acceptance. In some villages, local influentials strongly support the national family planning program. In other villages, they do not support it. In some villages, there are active Mothers' Clubs that support family planning. In other villages, there are

no Mothers' Clubs. These differences in institutional support for family planning affect the level of contraceptive practice.

3 Village-level health and family planning workers differ in their effectiveness. Some workers are highly motivated and very active in their assigned areas. Other workers are less motivated and less active. These differences in worker effectiveness affect the level of contraceptive practice.

While the problem situation presented above is fairly clear, the reasons for the problem are complex. Three reasons have been given, but it is likely many more could be stated. In situations such as this, the researcher must devote considerable time and attention to identifying the problem situation. The aim is to focus the research on the most important aspects of the problem.

CHAPTER 1

An Introduction to Research Methodology

Meaning of Research

Research may be defined as systematic gathering of data and information and its analysis for advancement of knowledge in any subject. Research attempts to find answer of intellectual and practical questions through application of systematic methods. Webster's Collegiate Dictionary defines research as "studious inquiry or examination; esp: investigation or experimentation aimed for the discovery and interpretation of facts, revision of accepted theories or laws in the light of new facts, or practical application of such new or revised theories or laws". Some people consider research as a movement, a movement from the known to the unknown.

We all possess the vital instinct of inquisitiveness for, when the unknown confronts us, we wonder and our inquisitiveness makes us probe and attain full and fuller understanding of the unknown. This inquisitiveness is the mother of all knowledge and the method, which man employs for obtaining the knowledge of whatever the unknown, can be termed as research.

Research is an academic activity and as such the term should be used in a technical sense. According to Clifford Woody research comprises defining and redefining problems, formulating hypothesis or suggested solutions; collecting, organizing and evaluating data; making deductions and reaching conclusions; and at last carefully testing the conclusions to determine whether they fit the formulating hypothesis. D. Steiner and M. Stephenson in the Encyclopedia of Social Sciences define research as "the manipulation of things, concepts or symbols for the purpose of generalizing to extend, correct or verify knowledge, whether that knowledge aids in construction of theory or in the practice of an art."

Research is, thus, an original contribution to the existing stock of knowledge making for its advancement. It is the pursuit of truth with the help of study, observation, comparison and experiment. In short, the search for knowledge through objective and systematic method of finding solution to a problem is research. The systematic approach concerning generalization and the formulation of a theory is also research. As such the term 'research' refers to the systematic method consisting of enunciating the problem, formulating a hypothesis, collecting the facts or data, analyzing the facts and reaching certain conclusions either in the form of solutions(s) towards the concerned problem or in certain generalizations for some theoretical formulation.

Objectives of Research:

The purpose of research is to discover answers to questions through the application of scientific procedures. The main aim of research is to find out the truth which is hidden and which has not been discovered as yet. Though each research study has its own specific purpose, we may think of research objectives as falling into a number of following broad groupings:

1. To gain familiarity with a phenomenon or to achieve new insights into it (studies with this object in view are termed as exploratory or formulative research studies);
2. To portray accurately the characteristics of a particular individual, situation or a group(studies with this object in view are known as descriptive research studies);
3. To determine the frequency with which something occurs or with which it is associated with something else (studies with this object in view are known as diagnostic research studies);
4. To test a hypothesis of a causal relationship between variables (such studies are known as hypothesis-testing research studies).

Utility of Research

It has been observed that research is of extensive use for a manager in planning, forecasting, coordinating, motivating, controlling, decision- making, etc. While managerial research helps in managerial analysis, academic research helps in academic objectives. Utility of social research includes social prediction, social enlightenment social welfare, social growth, social cohesion, social control, improving and perfecting the tools of social research, etc..

Utility of research can be summed up as:

a) Research is an aid to decision-making.
b) Research facilitates the process of thinking, analysis, evaluation, and interpretation of the business environment; and of the various business situations.
c) Research provides a basis for innovation.
d) Research and development helps to develop new products and to modify the existing products.
e) Research identifies problem areas.
f) Research establishes the relationship not only between variables in each functional area, but also between the various functional areas.
g) Research is an aid to forecasting, which is an effective tool in the hands of managers.
h) Research helps all the managerial functions.
i) Research helps in the economic utilization of resources
j) Market and marketing analysis may be based on research.
k) Research is an aid to management information systems and
l) Research is helpful in the formulation of policy and strategy.

Research Methods

Research methods may be understood as all those methods/techniques that are used for conduction of research. Research methods or techniques, thus, refer to the methods the researchers use in performing research operations. In other words, all those methods

which are used by the researcher during the course of studying his research problem are termed as research methods. Since the object of research, particularly the applied research, it to arrive at a solution for a given problem, the available data and the unknown aspects of the problem have to be related to each other to make a solution possible. Keeping this in view, research methods can be put into the following three groups:

1. In the first group we include those methods which are concerned with the collection of data. These methods will be used where the data already available is not sufficient to arrive at the required solution;
2. The second group consists of those statistical techniques which are used for establishing relationships between the data and the unknowns;
3. The third group consists of those methods which are used to evaluate the accuracy of the results obtained.

Research methodology It is a way to systematically solve the research problem. It may be understood as a science of studying how research is done scientifically. In it we study the various steps that are generally adopted by a researcher in studying his research problem along with the logic behind them. It is necessary for the researcher to know not only the research methods / techniques but also the methodology. Researchers not only need to know how to develop certain indices or tests , how to calculate the mean , the mode , the median or the standard deviation or chi - square , how to apply particular research techniques , but they also need to know which of these methods or techniques , are relevant and which are not , and what would they mean and indicate. Researchers also need to understand the assumptions underlying various techniques and they need to know the criteria by which they can decide that certain techniques and procedures will be applicable to certain problems and others will not. All this means that it is necessary for the researcher to design a methodology for his problem as the same may differ from problem to problem. For example , an architect , who designs a building , has to consciously evaluate the basis of his decisions , i.e. , he has to evaluate why and on what basis he selects particular size , number and location of doors , windows and ventilators , uses particular materials and not others and the like. Similarly, in research the scientist has to expose the research decisions to evaluation before they are implemented. He has to specify very clearly and precisely what decisions he selects and why he selects them so that they can be evaluated by others also.

From what has been stated above, we can say that research methodology has many dimensions and research methods do constitute a part of the research methodology. The scope of research methodology is wider than that of research methods. *Thus, when we talk of research*

methodology we not only talk of the research methods but also consider the logic behind the methods we use in the context of our research study and explain why we are using a particular method or technique and why we are not using others so that research results are capable of being evaluated either by the researcher himself or by others. Why a research study has been undertaken, how the research problem has been defined, in what way and why the hypothesis has been formulated what data have been collected and what particular method has been adopted, why particular technique of analyzing data has been used and a host of similar other questions are usually answered when we talk about research methodology concerning a research problem or study.

Need of Research Methodology

It is necessary for a researcher to design a research methodology for the problem chosen. One should note that even if the research method considered for two problems are the same the research methodology may be different. It is important for the researcher to know not only the research methods necessary for the research undertaken but also the methodology. For example, a researcher not only needs to know how to calculate the mean, variance, and distribution function for a set of data, how to find a solution to a physical system described by a mathematical model, how to determine the roots of algebraic equations and how to apply a particular method but also need to know (i) which is a suitable method for the chosen problem?,
(ii) what is the order of accuracy of the result of a method?, (iii) what is the efficiency of the method? And so on. Considerations of these aspects constitute a research methodology. More precisely, research methods help us get a solution to a problem. On the other hand, the research methodology is concerned with the explanation of the following:

1. Why is a particular research study undertaken?
2. How did one formulate a research problem?
3. What types of data were collected?
4. What particular method has been used?
5. Why was a particular technique of analysis of data used?

The study of research methods gives the training to apply them to a problem. The study of research methodology provides us with the necessary training in choosing research methods, materials, scientific tools, and training in techniques relevant to the problem chosen.

Deduction: Testing Theory

Deduction is the research approach used to test a theory. It involves the development of a theory that is subjected to a rigorous test. The stages involved in such research are:

a) deducing a hypothesis from the theory ,
b) expressing the hypothesis in operational terms ,
c) testing the operational hypothesis ,
d) examining the specific outcomes of the enquiry , and
e) Modifying the theory in the light of the findings, if necessary.

An attempt is thus made to verify the revised theory by going back to the first step and repeating the whole cycle

Induction: Building Theory

In this approach, the researcher tries to understand the nature of the problem, gather the required quantitative and qualitative data, and analyze them to draw conclusions. Hence, developing an understanding about the problem and making proper analysis of its different dimensions are the strengths of inductive research. The result of this analysis would be the formulation of a theory. Thus, in an inductive approach, theory is built from the empirical evidences gathered through different sources. In deductive approach, data would follow a theory.

Characteristics of a Scientific Method:

The chief characteristic of a scientific method are:

1. Verifiability: The conclusion drawn through a scientific method is subjected to verification at any time. The preposition is that the phenomenon under investigation must be capable of being observed and measured. In case direct observation could not be done, other methods such as interview can be utilized for verification. For instance, two man's order of preference for various jobs, although incapable of being observed can still be verified by means of an interview.

2. Generality: Laws derived through scientific method are universal in their applications. They are not limited to individual objects or individual groups of objects. The individual groups or objects considered as specimen or instances, and there are relationships discovered through these individual groups should be applicable to whole group called Universe.

3. Predictability: Another characteristic of a Scientific method is that its results can be predicted with sufficient accuracy. For example, we can say with certainty that if water is heated to 100°C, it will vaporize, and if it is cooled to O'C, it will turn to ice. Also we can say that if an unbiased coin is tossed 500 times, head will turn about 250 times. Predictability is fixed on two factors i.e. fixing of relationship between the cause and the effect and the stability of causative factors.

4. Objectivity: The results obtained through a scientific method should be free from investigator's own views, wishes or prevalent notions i. e., they must be subjected to objective observations. The main criterion of objectivity is that all persons should arrive to the same conclusion about the phenomenon. For example, when we say Coal is black, it is objective statement because coal will appear black to all people. But when we say Coal is useful mineral, the statement may not be objective, for every one may not agree to the statement.

5. System: In every scientific study, there is an accepted mode of investigation. The result arrived true, at by means of a haphazard method, even true, cannot be called scientific because its accuracy is purely accidental.

Types of Research

Research can be divided into two broad types relative to its purposes; applied and fundamental

1. Applied Research

Applied research is conducted in response to a specific problem, which requires a solution. The major purpose of applied research is to answer practical and useful questions about policies programs, projects, procedures, or organizations. Business executives, therefore, take interest in applied research. They often hire outside researchers and consultants to study a problem of concern to them in order to find solutions that can be implemented to rectify the problem situation

As applied research is concerned with knowledge that has immediate applications, it is also called decisional research. The attempt to get a cure for Bird Flu is a case in point.

EXAMPLE: *The Dairy Development Corporation (DDC) has to improve its productivity in order to remain competitive in the market. There are two alternative strategies to improve its productivity. One is to pay attention to all of its existing brands and make continuous improvement; the other is to focus on new brand development. Each of these alternatives has some advantages and disadvantages. The Corporation will now have to research into each of these strategies and see which one would best be suitable to it, taking into account its capabilities, know-how, resources and so on.*

The above example indicates the need for an applied research to work out a strategy in view of the strengths and weaknesses of the DDC. Applied research is thus more concerned with knowledge that has immediate application and would be useful in making decisions and formulating policies.

The defining quality of applied research is that the researcher attempts to conduct a study whose

results can be applied directly to a specific situation. To accomplish this task, the researcher must choose a research strategy that maximizes the applicability of findings. Applied research often results in recommendations on decisions or actions.

2. ***Fundamental Research***

Fundamental research is undertaken to improve our understanding of certain problems that commonly occur in organizational setting, and how to solve them. It is undertaken for the sole purpose of adding to our knowledge that is fundamental and generalizable. It is conducted without any practical end-use in mind. It is also known as pure or basic research.

The purpose of fundamental research is not to apply the findings to solve an immediate problem at hand, but rather to generate more knowledge and understanding of the phenomena and problems that occur in several organizations, and to build theories based on the research results. Such theories subsequently become the foundation for further study of the phenomena.

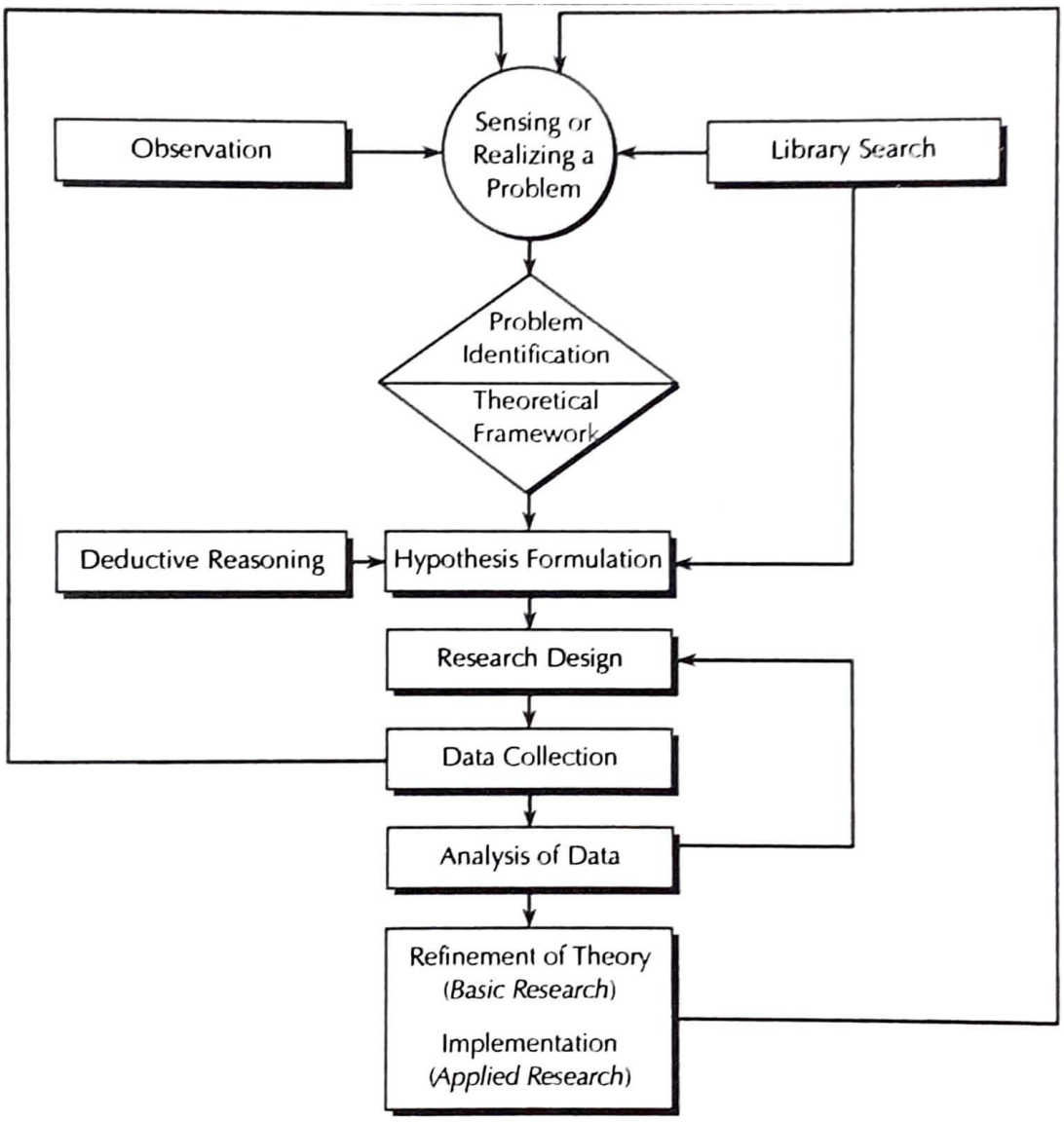
Fundamental research is also concerned with the development, examination, verification and refinement of research methods, procedures, techniques and tools that form the body of research methodology. Thus, fundamental research simply aims to advance knowledge and to identify and explain relationships between variables.

EXAMPLE: The HRD Managers' Conference recently held in Kathmandu focused on the issue of employee socialization, training and commitment. The participants in that HRD Conference commonly believed that socialization and training should have a great impact on the productivity and organizational commitment of employees However, through the years; it has been observed that the productivity of workers over forty years of age does not improve from Socialization and training. On the other hand, organizational commitment of employees over 40 years is relatively higher. Why is this so? The participating HRD managers were looking for answers to these phenomena. What factors might be responsible for these phenomena? What type of socialization and training should be given to employees to improve their productivity and organizational commitment?

To answer the questions raised by the HRD managers, one has to undertake a basic research. Our existing knowledge is not enough to answer these questions. The purpose of the research is thus to simply increase the amount of knowledge on the issue of employee commitment and training, not to actually come up with a practical solution to a problem. The researcher therefore, has to design an investigation and conduct a study observing socialization and training programs in different work settings and recording the effects of such programs on the productivity and commitment of younger and older employees.

Several of such experiments conducted in different work situations would give the research some idea about the relationship between socialization, training, commitment and productivity of employees belonging to different age groups. The main purpose of conducting fundamental research is thus to advance the level of scientific knowledge.

Scientific Research Process



Scientific research is systematic and follows the steps of the scientific method. From the inception of a research idea to the final report of results, the research process has several crucial steps. However, these steps do not provide a rigid pattern into which you must force your thinking. Thinking simply cannot be scheduled. An investigator does not tackle one step at a time, complete that process and then move on to the next step. Some steps can go simultaneously. Others need proper sequencing and logical arrangement.

There are eight steps in scientific method. These eight steps cover the total spectrum of a research endeavor, starting from problem formulation through to refinement of theory or practice. However, these steps may vary depending on the subject matter and the researcher, and also are interdependent with considerable back and forth interaction.

Sensing or Realizing Problem

The first step in any scientific inquiry is to identify an issue you want to study. There are many sources of research idea (observing the situation or sensing the problem). New problems keep on emerging in the environment. At this stage, you may not know exactly what is happening, but you can definitely sense that things are not going on as smoothly as they should be.

Problem Identification

Once you increase your level of awareness of what is happening in the environment, you would then focus on the problem and the associated factors through further search of information. In this step, you try to identify what exactly are the problems or issues in the situation. There is a saying in research that "a problem well defined is a problem half solved".

Theoretical Framework

In the third step of scientific research, you make an attempt to integrate the information logically so that the reason for the problem can be conceptualized. The critical variables are examined and the association among them is identified. Putting all the variables and their association together, a theoretical framework is developed.

Hypothesis Formulation

In the fourth step of scientific research, hypotheses are formulated. Hypotheses are logically conjectured relationship between two or more variables expressed in the form of testable statements. Hypotheses for the study arc drawn from the theoretical framework. Research hypotheses are even more focused. They provide the specific answers to questions that the research will examine often in an empirical way. Hypotheses are particularly useful in quantitative research, where there is statistical analysis.

Research Design

The fifth step is devising the plan for the research. Once you have narrowed your research hypothesis, you must next decide on a design or plan of attack for your research. The research design is thus a strategy for conducting research. It describes the general framework for analyzing and evaluating data after identifying:

a) What you want to know, and
b) What has to be dealt with in order to obtain required information?

The decision of which design to use can totally depend on the nature of the research project.

Collection of Data

Data collection, the sixth step in scientific research, is also known as fieldwork. At this stage, you have to administer the research instruments (questionnaire, interview schedules, observation schedules, etc.) to gather data.. However, the procedures used to obtain the data vary depending on the research design chosen and the source of the data. It is important to note that this step is the key part of the scientific research process and is crucial to the success of the research project.

Data Analysis

After you have collected data, you must summarize and analyze them. Data analysis is in fact the statistical analysis of data that have been edited, coded and tabulated. It is especially important in cases, where you have collected large amounts of information from many respondents. You can analyze data in several ways, and some types of data are better analyzed with one method than another. In most cases, you will probably calculate some descriptive statistics that provide a "nutshell" description of your data and inferential statistics that assess the reliability of our data. With the use of these different statistical techniques, the hypotheses are tested.

Refinement of Theory or Practice

The final step involves interpretation and generalization of the findings into the larger body of knowledge about the phenomenon. In the case of applied research, specific implementation strategy is proposed to solve the problem identified by the study. Through research existing theories or practices are refined and modified.

By carefully following the major steps outlined above, you can reduce the possibility of making major errors and increases the possibility that meaningful research results will be obtained. Scientific research helps you to state your findings more accurately and with confidence.

Consider the following case as an example, which shows the nature and process of scientific research:

EXAMPLE *A dealer of a car producing company was concerned with the complaints received from the car users that the cars it produces have some problems with rating sound at the dash board and the rear passenger seat after a few thousand kilometers of driving.*

- *He obtained information from the company workers to identify the various factors influencing the problem.*
- *He then formulated the problem and generated guesses (hypotheses).*
- *He constructed a checklist and obtained requisite information from a representative sample of cars.*
- *He analyzed the data thus collected, interpreted the results in the light of his hypotheses and reached conclusions.*

In this example, the dealer went through a sequence of steps which were in order and thus systematic. Secondly, the dealer did not just jump at the conclusions. He used a step-wise scientific method of inquiry in reaching at conclusions. This research study, thus, met the important characteristics of research: first, it was a systematic process, and secondly it followed a step-wise scientific method of enquiry to reach at the conclusion.

The most characteristic feature of the scientific research process is its cyclical nature. Research usually starts with a problem and ends in a tentative empirical generalization. The generalization at the end of one cycle is the beginning of the next cycle. The cyclical process continues indefinitely, reflecting the process of a scientific discipline and the ongoing accumulation of scientific knowledge. The research process is also self-correcting. Tentative generalizations to research problems are tested logically and empirically. If these generalizations are rejected, new ones are formulated and tested.

Lecture 5

Case study

THE CIO DILLEMA

Observation

The chief observation officer (CIO) of a firm observes that the newly installed Management Information System (MIS) is not being used by middle managers as much as was originally expected. The managers often approach the CIO or some other "computer expert" for help, or worse still, make decisions without facts. "There is surely a problem here," the CIO exclaims.

Information Gathering through Informal Interviews

Talking to some of the middle-level managers, the CIO finds that many of them have very little idea as to what MIS is all about, what kinds of information it could provide, and how to access it and utilize the information.

Obtaining More Information through Literature Survey

The CIO immediately uses the Internet to explore further information on the lack of use of MIS in organizations. The search indicates that many middle-level man- agers especially the old-timers are not familiar with operating personal computers and experience "computer anxiety." Lack of knowledge about what MIS offers is also found to be another main reason why some managers do not use it.

Formulating a Theory

Based on all this information, the CIO develops a theory incorporating all the relevant factors contributing to the lack of access to the MIS by managers in the organization.

Hypothesizing

From such a theory, the CIO generates various hypotheses for testing, one among them being: Knowledge of the usefulness of MIS would help managers to put it to greater use.

Data Collection

The CIO then develops a short questionnaire on the various factors theorized to influence the use of the MIS by managers, such as the extent of knowledge of what MIS is, what kinds of information MIS provides, how to gain access to the information, and the level of comfort felt by managers in using computers in general, and finally, how often managers have used the MIS in the preceding 3 months.

Data Analysis

The CIO then analyzes the data obtained through the questionnaire to see what factors prevent the managers from using the system.

Deduction

Based on the results, the manager deduces or concludes that managers do not use MIS owing to certain factors. These deductions help the CIO to take necessary action to rectify the situation, which might include, among other things, organizing seminars for training managers on the use of computers, and MIS and usefulness.

Research Language

- Theory
- Conceptualization
- Operationalization
- Variables
- Hypotheses
- Assumptions
- Population
-
- Sample
- Validity
- Reliability
- Data
- The research process
- Summary
- Methodological queries
- References

Concepts And Constructs

Constructs include happiness, recreation, love, hate, satisfaction, IQ, morality, etc. Scientist refer to these abstract concepts as constructs because they have been conceptually constructed to represent a name of something real that cannot be directly observed but may be useful to study or describe.

One can describe the difference between constructs and concepts in terms of set theory. Constructs extend over actual cases, whereas concepts extend over both actual and possible cases.

> The terms "concept" and "construct" have similar meanings. Yet there is an important distinction. A concept expresses an abstraction formed by generalization from particulars. "Weight" is a concept: it expresses numerous observations of things that are more or less "heavy" or "light."

Constructs can be conceptually defined in that they have meaning in theoretical terms. They can be abstract and do not necessarily need to be directly observable.

Examples of concepts include common demographic measures: Income, Age, Education Level, number of Siblings. We can measure concepts through direct and indirect observations: Direct Observation: We can measure someone's weight or height. And, we can record the color of their hair or eyes.

CHAPTER 2

Unit 2: Research Problem Identification and Formulation

Identification of Research Problem

Formulation of problem is the first and foremost step in a research work. The research problem can be formulated and selected rationally and then the whole research work can be conducted only if the identification of the problem is done precisely. To identify the problem a researcher should have some basic knowledge, which is then developed through discussion with experts or through the literature or by continuation of activities in the related field.

The research problem undertaken for the study must be carefully selected. This task is a difficult one, although it may not appear to be so.. Help may be taken from a supervisor in this connection. A research supervisor can at the most only help a researcher to choose a subject. Identifying the exact nature and dimensions of a problem is of major importance in research work. It is very essential that an investigator should learn how to recognize and define a problem.

The following steps are to be followed in identifying a research problem:

1. Determining the field of research in which a researcher is keen to do the research work.
2. Develop the mastery on the area or in field of specialization.
3. Review the recent research conducted in the selected area.
4. On the basis of review, select the priority field of the study.
5. Draw an analogy and insight in identifying a problem or employ the personal experience of the field in locating the problem. In this process researcher can take help of supervisor or expertise of the field.

6. Pin-point specific aspect of the problem which is to be investigated.

Ways of Understanding Research Problem

The selection of a suitable problem is not an easy task. It is a serious responsibility to commit oneself to a problem that will inevitably require much time and energy and which is so academically significant. Specifically, the concept for separating out the research problem from the diversified field can be made by the

i. Discussion among the colleagues
ii. Discussion with the research guide
iii. Discussion with some experts and
iv. Intensive reading all the available literature.

The following are the general ways for understanding problem to which one may proceed for a suitable research:

1. Personal experience of the investigator in any field is the main means for understanding a suitable problem.
2. The other ways of understanding of problem, most frequently used by the investigator as suggested by the supervisors, is the extensive study of available literature-research abstracts, journals, hand-books of research international abstracts etc
3. In the choice of a suitable problem, the researcher has to decide his field of investigation. He should study the field intensively in the specific area; this may enable him to identify a problem from the specific field.
4. The new innovations, technological changes and curricular developments are constantly bringing new problems and new-opportunities for social research.
5. The most practical ways of understanding problem is to consult supervisor, experts of the field and most experienced person of the field
6. It is a general practice that researchers suggest some problems in their research reports. The researcher can understand a suitable problem for his own study.

Steps in Research Problem Formulation

. In a scientific inquiry, the formulation of general topic into a specific problem is the formulation of research problem. The researcher must try to understood the whole problem thoroughly and then rephrasing the same into meaningful terms from an analytical point of view. The following points are suggested as the steps for the formulation of research problem.

• Statement of problem in general way

• Understanding the nature of the problem

• Surveying the available literature

• Developing the ideas through discussion

• Rephrasing the research problem.

Criteria of a Good Problem

Fred. N. Kerlinger has defined a good problem as an inquisitive sentence statement that asks what relation exists between two or more variables. The research questions, research objectives and the hypotheses of the research lie on the problem statement of the research work. So for selecting research questions, setting research objectives and the hypothesis of the research selected problem should be an ideal one. An ideal research problem must have the following three main criteria:

1. *The problem should express a relation between two or more variables.* The topic of the research work reflects the research problem and it would be inquisitive and interesting if stated in terms of relation between variables.

2. *The problem should be stated rigidly and unambiguously.* If a research problem has ambiguity and haziness in its interpretation consequently it affects research design and the whole research process and hence the result of the study.

3. *The problem statement should be such as to imply possibilities of empirical testing.* In case, when problem statement expresses the relationship between two variables and is stated rigidly but if the testing the relationship in the circumstances of adopted research design and within the available facility is impossible then the selected problem cannot be good problem. Thus, a good research problem should always be linked with the research design and it must consider the available facility and capability of the study.

Problem Statement

Developing a problem statement includes some combination of the interrelated tasks like generation of an issue, exploration of an issue, and from that exploration determining worthwhile research questions. The problem statement has thus the following three characteristics:

- It should raise a question about a relationship between variables.
- The relationship between the variables should be stated and explained clearly.
- The problem statement should suggest a method of researching the question.

A statement of problem could be stated either in declarative or in interrogative form.

EXAMPLES

Declarative: Factors contributing to the excessive absenteeism among Nepalese workers.

Interrogative: Why is absenteeism so high among workers in Nepalese organizations?

The following are some examples of well-defined research problems. These are stated in interrogative form:

EXAMPLES

- To what extent do age, education, length of service, level of earning, and place of residence of employees predict occupational aspirations?
- Do long work hours, lack of development opportunities, and discrimination account for the lack of inward mobility of women in civil service?
- Can cultural differences account for the differences in the nature of hierarchical relationships between supervisors and subordinates?

Problem statement that appeared in a research report is given here as an example:

EXAMPLES A review of research studies on leadership and age (Kabacoff & Stoffey, 2001) reveals the controversy and recent interest in examining the relationship between the variables. These studies explain some reasons for the importance of the association between age and leadership. In the first place, they explain that older workers remain in employment for longer years and they work side by side with younger members in various work and leadership roles. It

is no secret that today's workers, as a result of several reasons; live much longer than their counterparts in the last generation.

As older and younger employees abound in organizations there is the need to manage both of them effectively in order to realize organizational goals more fully. Both age groups have something to offer: technology has driven the rapid promotion of younger workers while experience has made the older worker very relevant. In addition, today's flatter organizations give greater interaction between younger and older workers and the practice of leadership is no longer an exclusive domain of the older people, as it used to be. In several organizations, therefore, top management team will comprise of multigenerational members. It is argued that the ability to understand, learn, and effectively leverage multigenerational diversity will be necessary for organizations now and in the future to build and maintain high performance systems (Kabacoff & Stoffey, 2001, p.2).

Another reason that underscores the importance of the study of the relationship between leadership and age is the finding by kakabedse. et al. (1998) that age, along with other time-related dimensions, has a powerful effect in shaping the attitudes and hence the behaviors of senior leaders within organizations. In a study undertaken in Australia, three leader profiles emerged - the radicals, the Bureaucrats and the team players. The radicals were the youngest (between 26- 35years), the team players were the oldest (56 years and over), while the bureaucrats were in between (45-55 years). Older workers were mature, saw challenges and had longer-term perspectives in managing people and systems. On the other hand, younger employees were competitive, result oriented, energetic and adopted an open style management.

Research Questions

Research is intended to help us learn something new. The research process encloses the research questions, the most important element of any research, for the effective execution of research activity. We often define our research goals in terms of questions and hence research questions describe the ideas contained in the research objectives. Research questions are the interrogative form of research objectives. Research questions are such questions that can help the researcher learn something new- fruitfully Formulation of research questions is the real starting point in preparation of a research process. The data required to be collected for the study are determined by the help of the research questions. The research design is necessarily based on the research questions; the research method to be adopted for the study of specific problem is also set on these questions. The data analysis tools and methods, result interpretation procedures and writing phases of the reports are also determined by the research questions. The questions have to be related to three aspects: What, Why and How? What question seeks descriptions, why question seek explanation and understanding and how question seek interventions to bring about change. If the researcher does not have clear formulated research questions at the starting point of the research in his practical field, then He (she) may face different challenges to precede the direction of research.

Types of Research Questions

Generally there are three types of research questions, they are: What questions (concerned with description), Why questions (concerned with explaining causes) and how questions (concerned with bringing about change). 'What questions' pertain to describing the characteristic of trend and pattern in the given situation? For example: What are the types of community involved in transformation of skills?, What are the socio economic characteristics of community?, what are the needs of the community ? etc. Why question relate to the cause or reasons for the characteristics of the particular phenomenon and the behavior of the individual involved. They also explain the relationship between events and activities. For example: Why do drug abusers commit thefts? , Why does stressful living result in heart attacks?, Why do some people use a product while other do not? How questions are concerned with bringing about change and the outcomes of change. For example: How has caste system changed in Nepal in last century?, How does technology create unemployment?, How do MC health service affect infant mortality?

Besides these three types of question different authors have proposed different types of research questions. Lin (1993) has proposed four more types of research questions they are Who, Where, How many and How much.

Identification of Research Question

The main purpose of formulating research question is to define the scope of the research. It is used to determine what is to be studied and the extent to which it will be studied. Neuman _ (1997) offered some techniques of developing research questions, which are:

- Record all questions that occur in mind after reading literature or after discussions with other or after thinking on various aspects of study.
- Review all these questions whether each question is necessary and delete those which are beyond the scope of the study. This will also remove overlapping between questions.
- Classify questions on the basis of their nature, i.e. What, Why and How questions
- Examine the scope of the questions for availability of time and money; chose these which can be answered within manageable time and resources.
- Separate major or key questions (which for the core of the research) from subsidiary questions.

Hypothesis

Definition

A hypothesis proposes relationship between two or more variables. In common usage, a hypothesis refers to a provisional idea whose merit requires evaluation. For example: political participation increases with education. This simple assertion can be seen as a hypothesis. It has a subject (the variable, political participation), a connective verb (a relationship, increases), and an object (the variable, education). This hypothesis takes two basic ideas "political participation" and "education" and suggests that they are connected to the extent that as one increases then the other increases as well. This can be stated in more mathematical terms as one variable being directly proportionate to the other.

Fred N. Kerlinger and H. B. Lee (2000): "A hypothesis is a conjectured statement that implies or states a relationship between two or more variables".

John W. Creswell (2014): "A hypothesis is a formal statement that presents the expected relationship between independent and dependent variables". A hypothesis is thus a statement about the relationship between two or more variables which needs to be investigated for its truth. It is basically a working assumption. If the relationship between two variables is found as the hypothesis predicts, then the hypothesis is supported and a new theory has been suggested. A good hypothesis states as clearly as possible the expected relationship (or difference) between two variables and defines these variables in operational and measurable terms**.**

Functions of Hypothesis

Specifically, a hypothesis serves the following functions (Kumar, 2011):

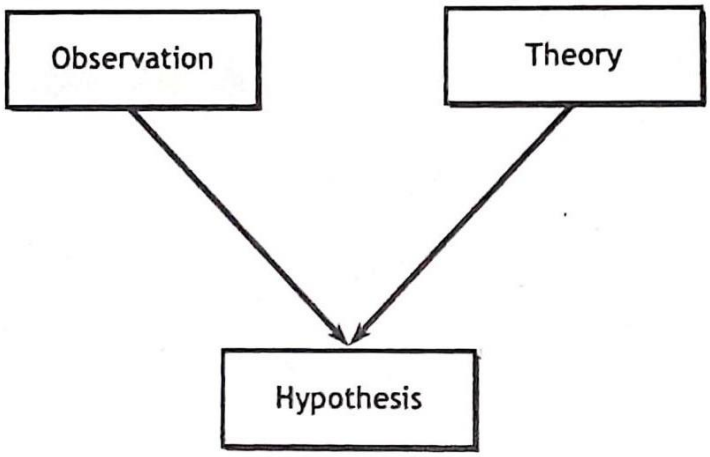
- The formulation of a hypothesis provides a study the focus. It tells you what specific aspects of a research problem to investigate.
- A hypothesis tells you what data to collect and what not to collect, thereby providing focus to the study.
- As it provides a focus, the construction of a hypothesis enhances objectivity in a study.
- A hypothesis may enable you to add to the formulation of theory. It enables you to specifically conclude what is true or what is false**.**

Hypothesis Formulation

Hypothesis can be derived in a variety of ways i.e. general culture, past research/scientific theory, personal experience, discussion and conversations and intuition. A researcher observes a social situation and come to a conclusion about some of the variables which are operating within it. You could then develop some hypotheses which connect two or more of these variables. Generally there are two grounds on which a hypothesis may be justified: logical and empirical.

Logical justification is developed from arguments based on concepts and theories relating directly to the research problem. Empirical justification is based on reference to other research found in the literature. Hence, in order to formulate a useful hypothesis, you need to have good knowledge of the background to the subject and the nature of the problem or issue which is being addressed. A hypothesis statement is derived directly from the statement of the problem. Hypothesis can be stated rather easily once the research problem is known. The hypothesis is thus more operational than the problem statement.

A diagrammatic presentation of the process of hypothesis formulation is given in figure.



Hypothesis generation and testing require an understanding of the deductive and inductive reasoning. A simple definition of deductive reasoning is "taking a known idea or theory and applying it to a situation with the intention of testing whether it is true". Deduction is thus the process of arriving at conclusion by interpreting the meaning of the results of the data analysis. In this form of reasoning, one goes from general knowledge to specific knowledge. For example, consider the following two arguments**:**

Argument 1

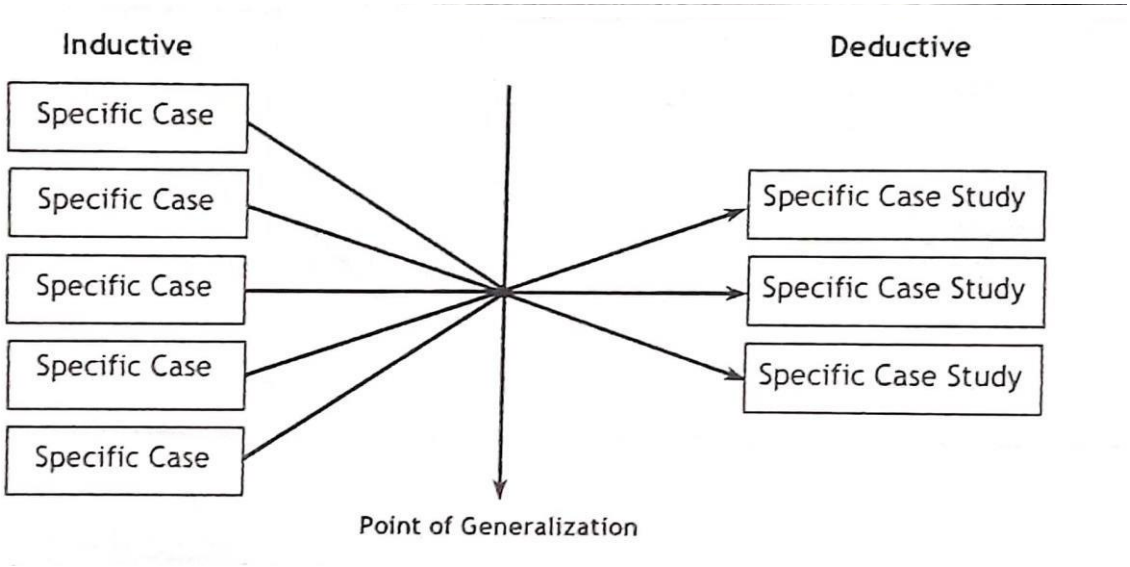
- All books have pages (theory or generalization).
- This is a book (empirical observation - fact).
- Therefore, this book has pages (logical conclusion).

Argument 2

- Lung cancer is caused by smoking (theory or generalization).
- John has lung-cancer (empirical observation-fact).
- John was a cigarette smoker (logical conclusion).

Deduction starts from a generalization and goes to a specific case. Inductive reasoning is the opposite. A simple definition of inductive reasoning is "using observation to formulate an idea or theory". Induction is thus the process of examining many cases and then generalizing from them. In this form of reasoning, one goes from a specific knowledge to the general knowledge. Looking at the cigarette-cancer example, the researcher would investigate whether the people who have long-cancer had previously smoked before they received cancer. Both induction and

deduction are used by the researchers to organize facts, describe results, develop new relationship, and suggest new research.



Deductive logic, as stated above, is useful for going from a general problem to a specific hypothesis. This statement can be understood by an example:

■ **Problem:** Nepal's population is increasing so rapidly that if it continues at its present rate, in 30 years, it will not be possible to feed all of its citizens.

■ **Theory:** Population growth can be controlled through family planning clinics.

■ **Hypothesis:** Family planning can reduce the growth of population in Nepal.

The above example is stated in very general terms and later will be made specific so that it can be tested, but it is a good example of the deductive logic used in a thesis. The problem statement has been created from the facts of Nepal's present population and from the prediction of its growth in the future. The prediction is made from examining past facts of population growth in Nepal. The theory is a very general theory, which has been true in other parts of the world; it has almost become a principle for population control. The hypothesis is the result of deductive logic from the first two statements.

It is now possible to examine the stating of problems and hypotheses. The problem asks about the relation between several facts or observations. Accordingly, the hypothesis suggests that the relationship exists. It is important to realize that the hypothesis has to be stated in a very specific terms so that the means of investigating the hypothesis are included in the statement. A problemis formulated in the form of a question; it serves as the basis or the origin from which a hypothesis is derived. A hypothesis is a suggested solution to a problem. A problem (question) cannot be directly tested, whereas a hypothesis can be tested and verified. Hence, a problem cannot be scientifically solved unless it is reduced to hypothesis form.

EXAMPLE

Research Problem: What is the relationship between population growth in Kathmandu before the introduction of family planning and after the introduction of family planning?

Research Hypothesis: There is a significant difference in the population growth in Kathmandu between when family planning was first introduced and five years later.

Hypothesis statements should be clear if the definition of a variable is understood as some characteristic, which changes. The above hypothesis is simply stating that two groups exist in relation to some characteristic. If there is a significant difference between the two groups then the hypothesis is supported. The theory that family planning can reduce the growth of population in Nepal is supported and becomes tentative. Hence, there appears to be a solution to the population problem in Nepal.

One-sided Vs Two-sided Hypothesis

During the planning of our research, we need to specify whether we plan to use a one-sided or two-sided hypothesis. A one-sided hypothesis states a specific direction (e.g. increase or decrease). If a change in the unexpected direction is equivalent in practice to no change, then we should use a one-sided hypothesis. A two-sided hypothesis states that there is a difference between the dependent and independent variable, but does not specify the direction. If we expect that a change in either direction is possible and that changes in either direction are interested, then we should use a two-sided hypothesis.

Formats of Stating Hypothesis

The different formats of hypothesis construction based on association and correlation between variables are as follows:

Correlation There is a significant relationship between Variable A and Variable B for Group 1,

Difference between Means

There is a significant difference between mean levels of Variable A for Group 1 and Group 2.

Difference between Frequencies

There is a significant relationship between Group 1 and Group 2 for Variable A. There is a significant difference between Group 1, 2 and 3 for the following variables:

Variable A Variable B etc.

Types of Hypothesis

1. Descriptive and Relational Hypothesis

Research hypothesis can be classified as: descriptive and relational. Descriptive hypotheses are in the form of propositions that only state the existence, size, form, or distribution of some variable (Cooper & Schindler, 2011).

EXAMPLES

- Tribhuvan University (case) is experiencing budget difficulties (variable).
- The Hetauda- Narayangadh sector of the East-West Highway (case) has a higher-than- average accident rates (variable).
- The average stockholders of Nepal Development Bank (case) favor returns in the form of bonus dividends (variable).

These descriptive statements contain only one variable. Hence, the relationship between variable cannot be studied and explored. These statements do not fulfill the criteria of research hypotheses. It is, therefore, advisable to use research questions rather than descriptive hypotheses. The research questions for the above three statements could be stated as follows:

EXAMPLES

■ What is the extent of budget difficulties in Tribhuvan University?

■ Why is the accident rate higher in Hetauda-Narayangadh sector of the East-West Highway?

■ Why do the stockholders of commercial banks favor returns in the form of bond dividends?

A relational hypothesis, on the other hand, describes the relationship between two or more variables with respect to some case. Relational hypotheses are of two types: correlational hypothesis and explanatory (causal) hypothesis. When a statement describes the relationship between two variables, it is called a correlational hypothesis.

EXAMPLES

■ Families with higher incomes spend more for recreation.

■ With education people's political participation will increase.

2. Explanatory Hypotheses

In an explanatory hypothesis, the implications of one variable on the other are stated. How one variable would cause or lead to a change in the other variable? Such causal relations can be unidirectional, in which variable A influences variable B, but not vice versa. They can also be bidirectional, in which each variable influences the other. The following are the examples of unidirectional and bidirectional relations:

EXAMPLES

- The increase in age would lead to decrease in organizational commitment.
- The productivity of skilled workers will increase if the workers are given added pay for production in access of the standard.

3. Directional and Non-directional Hypotheses

The directional hypothesis indicates the particular direction of the expected relationship between two variables. These relationships could be stated in positive or negative form. In stating the relationship between the two variables, the terms such as "positive", "negative", "more than' "less than" and the like are used. The directional hypothesis requires a one-tailed test. The following are the examples of directional hypotheses.

EXAMPLES

- Younger workers are less motivated than older workers.
- The greater the workload, the lower the job satisfaction of the workers..

The non-directional hypotheses are formulated when there are no clues available about the positive or negative relationship between two variables. Hence, these hypotheses do not indicate any direction of the relationship or difference and require a two-tailed test. Non-directional hypotheses are formulated in cases where previous studies do not exist or indicate conflicting findings (Sekaran & Bougie, 2013). The following are some examples of non-directional hypothesis:

EXAMPLES

■ There is a difference between work attitudes of industrial and agricultural workers.

■ There is no relationship between educated and uneducated employees in their occupational commitments.

4. Null and Alternative Hypotheses

There are the two methods of stating the hypothesis: null and alternative: A null hypothesis is

a statistical hypothesis that is tested for possible rejection under the assumption that it is true. The hypothesis contrary to null hypothesis is known as alternative hypothesis. In other words, a null hypothesis is a hypothesis set up to be nullified or refuted in order to support an alternative hypothesis.The null hypothesis is called null because it usually reflects the "no-difference" or "no-effect' situation.

The following example would clarify the concepts of null and alternative hypothesis. Suppose you are interested in a study to determine whether production would increase if the skilled workers are given a bonus or incentive pay for production in excess of a standard. For this investigation, you can formulate a research hypothesis in the following way:

EXAMPLE

The productivity of skilled workers will increase if they are given added pay for production in access of the standard.

This is a positive statement whose validity you would attempt to test through your research However, many researchers would object to the use of a positive hypothesis like this. A positive hypothesis like this may indicate a built-in prejudice on the part of the researcher toward a result favoring the hypothesis. To them, a null hypothesis is more desirable. The null hypothesis takes the form of a statement indicating no prejudice toward an answer. How can then this hypothesis be stated in a null form? The following is an example:

EXAMPLE No significant difference will exit between productivity of skilled workers on an incentives plan and productivity of skilled workers on a regular wage plan.

This null hypothesis thus indicates a definitive, exact relationship between two variables. That is, it states that the population correlation between two variables is equal to zero, or that the difference in the means of two groups in the population is equal to zero. In statistics, the only way of supporting your hypothesis is to refute your null hypothesis. Rather than trying to prove your idea (the alternative hypothesis) right, you must show that the null hypothesis is likely to be wrong. You have to refute or nullify the null hypothesis. You have to assume that your alternative hypothesis is wrong until you find evidence to the contrary. The following is another example of null hypothesis:

H_0: There is no difference between male and female statistically in their productivity.

Statistically expressed: H_o: $\mu_l = \mu_2$

Where, H_0= the null hypothesis

μ_1 = the productivity of male workers

μ_2 = the productivity of female workers

The alternate form of the above null hypothesis can be formulated as follows:

H_A : Male workers will have more productivity than female workers, or female workers will have less productivity than male workers.

Statistically expressed: $H_A : \mu_1 >$

μ_2 where, H_A = the alternate

hypothesis μ_1 = the productivity

of male workers

μ_2 = the productivity of female workers

From the above example, it is clear that an alternative hypothesis, which is the opposite of the null, is a statement expressing a relationship between two variables or indicating differences between groups. The following are some other examples of null and alternative hypotheses:

• H_0: There is no relationship between working conditions and job satisfaction of employees.

H_A: If the working conditions are improved, then the job satisfaction of employees will

improve. H_0: There is no difference between male and female workers in their organizational

commitment. H_A: Male workers will have greater organizational commitment than female

workers.

■ H_0: There is no relationship between pay and

productivity. H_A: Pay and productivity are positively

related.

■ H_0: Working condition, pay and fringe benefits have no influence on job satisfaction of workers.

H_A: Working conditions, pay and fringe benefits all have positive influence on job satisfaction of workers.

Stating the Null Hypothesis

■ There is no difference between the means of the two populations from which the two samples were drawn at random.

■ The two means in the two populations from which the samples were respectively

drawn at random are equal.

Criteria of Good Hypothesis Statement

The main requirement of hypothesis formulation is that it should fulfill certain basic criteria. Many different criteria can be found in the literature over what are the desirable qualities of a "good" hypothesis. Mason and Bramble (1997) outline the important features (criteria) of good hypothesis statement as follows: •

- Hypothesis should be stated in declarative form.
- Hypothesis should state the expected (articulated) describe a relationship between two or more variables.
- Hypothesis should be testable empirically.
- Hypothesis should be limited in scope.
- Hypothesis should be clearly and precisely stated. There should be no ambiguity in the variables or the relationships proposed.
- Hypothesis should state the conditions and circumstances under which it is supposed to apply.
- Hypothesis should reflect a guess at a solution or outcome to a problem based upon some knowledge, previous research, or identified needs .It should be consistent with most known facts.

Linkage between Research Hypothesis and Statistical Hypothesis

A research hypothesis is a specific and focused hypothesis that guides a research project or study. It is derived from a broader research question or problem, and it reflects the objectives and expectations of the researcher. For example, a research question could be: "How does gender affect the academic performance of students?". A research hypothesis could be: "Female students have higher grades than male students".

A statistical hypothesis is a hypothesis that can be formally tested with statistical methods and techniques. It is usually expressed in terms of parameters or distributions of a population or a sample. For example, a statistical hypothesis could be: "The mean height of men is equal to 175 cm".

In statistical hypothesis there are two types, null and alternative. Null is default hypothesis as statistical tests are designed to test homogeneity only. Almost Statistical tests can't test heterogeneity. This restriction is important as research question may go along with Null or

Alternative hypothesis. It is also useful to avoid further confusion as whatever research question default hypothesis will be null.

CHAPTER 3

Literature Review

Introduction

In terms of a literature review, "the literature" means the works you consulted in order to understand and investigate your research problem. Re-view (or look again) is a process of systematic, meticulous, and critical summary of the published literature in your field of research. How others have dealt with topics in your research subject and of what knowledge they have acquired?

The following are some definitions which explain the meaning, purposes and functions of literature review:

F. Cardesco and E.M. Gatner (1986): "A literature review is a self-contained unit in a study which analyzes critically a segment of a published body of knowledge through summary, classification, and comparison of prior research studies and theoretical articles."

P. Haywood and E.C. Wragg (1996): "A literature review is the process of locating, obtaining, reading and evaluating the research literature in the area of your interest."

N. Walliman (2010): "A literature review (or overview) is a summary and analysis of current knowledge about a particular topic or area of enquiry."

Review of literature is, thus, an essential part of all research studies. It is a way to discover what other research in the area of your problem has uncovered. A critical review of the literature helps you to develop a thorough understanding and insight into previous research works that relates to your study. It is also a way to avoid investigating problems that have already been definitely answered.

Example: A social scientist is interested to study the impact of social mobilization program on poverty alleviation. From his or her knowledge and experience in the field, he or she knows that a body of knowledge exists about the methods and policies of social mobilization, but he or she also knows that the boundaries of this body of knowledge are constantly expanding. Other social scientists have worked in the same area and have, no doubt, contributed new information to the field. Therefore, he or she seeks to identify these new contributions and add them to the established body of knowledge before he or she conducts his or her own investigation.

Purpose of Literature Review

Scientific research must be based on past knowledge. The previous studies cannot be ignored because they provide the foundation to the present study and provide you with a handy guide to a particular topic. The primary purposes of literature review are: to learn how others have defined and measured key concepts; to identify data sources that other researchers have used; to identify potential relationships between concepts; and to identify researchable hypotheses. The literature review enables you to know:

- What research has been done in the subject?
- What others have written about the topic?
- What theories have been advanced?
- What approaches were taken by other researchers?
- What were the areas of agreement or disagreement?
- Whether there are gaps that can fill through the proposed research?

The purpose of literature review is, thus, to find out what research studies have been conducted in your chosen field of study, and what remains to be done. No matter what topic you choose, chances are that someone has already done research on it. If so, then conducting your research as originally planned would be a waste of time and resource. The purposes of literature survey are as follows:

- To give continuity in research.
- To place the research in a historical context to show familiarity with state-of-the-art developments.
- To synthesize and gain new perspective, get more insight into the topic and know about the knowledge status of the proposed subject.
- To draw a theoretical framework and define the research parameters.
- To discover important variables relevant to the topic.
- To generate hypotheses.
- To identify the methodology and techniques of research.

The literature survey provides the foundation for developing a comprehensive theoretical framework from which hypothesis can be developed for testing.. Another advantage of reviewing the literature applies to the design phase of your project. Designing a study involves several decisions as to what variables to include and how to measure them, what techniques to use, what procedures to follow, and so on. A literature review provides you with a rich source for addressing these important design questions.

Need of literature review:

- It demonstrates that you know the field. This means more than reporting what you have read and understood. Instead, you need to read it critically and to write in such a way that shows you have a feel for the area; you know what the most important issues are and their relevance to your work; you know the controversies and things that are neglected.
- It justifies the reason for research. This is closely connected with demonstrating that you know the field. It is the knowledge of your field which allows you to identify the gap which your research could fill.
- It allows you to establish your theoretical framework and methodological focus. Even if you are proposing a new theory or a new method, you are doing so in relation to what has been done.

Types of Literature Review

There are different types of literature review that can be undertaken, depending on the purpose of the research. The main kinds of literature review are as follows:

- **Historical review:** This type of literature review traces the issues, concepts or events over time.
- **Methodological review**: This kind of review assesses and evaluates methodological techniques used and the strengths of different studies.
- **Theoretical review:** This type of review focuses on the theories or concepts related to the research issue under study.
- **Integrative review:** This type of review summarizes and integrates the current state of knowledge on the topic under study.

  These kinds of literature reviews are not mutually exclusive. These are often mixed together. In the case of academic research, all these types of literature review need to be undertaken.

Functions of Literature Review

The review of literature accomplishes the following functions:

- Ensures that you are not "reinventing the wheel".
- Gives credit to those who have laid the groundwork for your research.
- Demonstrates your knowledge of the research problem.

- Demonstrates your understanding of the theoretical and research issues related to your research.
- Shows your ability to critically evaluate relevant literature information.
- Indicates your ability to integrate and synthesize the existing literature.
- Convinces your readers that your proposed research will make a significant and substantial contribution to the literature.

Encyclopedias

■ ***Encyclopedia Britannica***: It is an excellent introduction to almost any field. It includes features and relatively long articles, which may be relied upon for authenticity and scholarly quality. The original British version of the encyclopedia is sometimes reflected in the fuller treatment given certain English topics. If an American orientation is desired, the Encyclopedia Americana should be consulted. Both these encyclopedias offer extensive bibliographies.

■ ***Britannica Online:*** This is an online version of Encyclopedia Britannica. Now with the online version, the task of locating materials, events and bibliographies has become much quicker and simpler.

■ ***Encyclopedia of the Social Sciences:*** It is the first comprehensive encyclopedia covering all fields of social sciences. Though it is international in scope, its emphasis is on English-speaking and Western European nations. It includes signed articles by specialists with adequate bibliographies. This encyclopedia is a good source for biographical articles.

■ ***International Encyclopedia of the Social Sciences***: International Encyclopedia of the Social Sciences is not meant to replace the earlier Encyclopedia of the Social Sciences. Instead, they should be used together with the International Encyclopedia emphasizing recent developments and an analytic comparative approach to a subject (e.g. "Comparative Politics"). Once again, articles are written by specialists and contain up-to-date bibliographies.

■ ***Encyclopedia of Education:*** Authoritative articles are included covering the history and theory of education, structure of education, structure of educational systems in various countries, research in education, important people and educational institutions, etc. This encyclopedia should be used in conjunction with the detailed index (Vol. 10). Its orientation is based primarily on education in the US; however, a number of articles treat international or comparative topics.

• ***McGraw-Hill Encyclopedia of Science and Technology:*** Clearly written articles, intelligible to the non-specialist, treat the basic subject matter of natural sciences, including their major technological applications in engineering, agriculture, forestry, etc. Articles are profusely illustrated and have short bibliographies.

■ ***Business Encyclopedia and Legal Adviser.*** This encyclopedia includes articles written by professionals in accounting, banking, journalism, commerce and industry and explains the concepts significant to business, including the legalities invol***ved.***

- ***Internet***

Today Internet is a very easy and quick source of Review of Literature. Internet sites are very useful for providing easy access to original writings by important researchers. They also provide such an updated information on the topic that ordinarily is not available in the library. Internet sites also provide for useful bibliographies related to a particular researcher. Search on Internet also reveals some relevant professional societies and academic associations which can provide a lot of support to the studies in the concerned area. Sometimes, the Internet sites include articles extracted from encyclopedias which can also be very useful and informative as background reading. However, they are not normally suitable for citing in a report.

Difference between Reference and Bibliography

While writing an assignment, article or book, the writer often looks for the sources to generate an idea or data. In this context, students usually misinterpret bibliography for reference, but they are different, in the sense that you give **reference** to the sources, that you have quoted in-text, in the research report or assignment. But on the other hand, in the **bibliography**, you create a list of all the sources you have gone through to conceive the idea.

Reference Vs Bibliography Comparison Chart

BASIS FOR COMPARISON	REFERENCE	BIBLIOGRAPHY
Meaning	Reference implies the list of sources, that has been referred in the research work.	Bibliography is about listing out all the materials which has been consulted during the research work.
Based on	Primary Sources	Both Primary and Secondary Sources
Arrangement	Alphabetically and numerically	Numerically
Includes	Only in-text citations, that have been used in the assignment or project.	Both in-text citations and other sources, that are used to generate the idea.
Supporting argument	A reference can be used to support an argument.	A bibliography cannot be used to support an argument.
Used for	Thesis and Dissertation	Journal Papers and Research work

Definition of Reference

Reference can be understood as the act of giving credit to or mentioning the name of, someone or something. In research methodology, it denotes the items which you have reviewed and referred to, in the text, in your research work. It is nothing but a way to acknowledge or indirectly showing gratitude, towards the sources from where the information is gathered.

Definition of Bibliography

At the end of the research report, bibliography is added, which contains a list of books, magazines, journals, websites or other publications which are in some way relevant to the topic under study, that has been consulted by the researcher during the research. In finer terms, it comprises of all the references cited in the form of footnotes and other important works that the author has studied.

Key Differences Between Reference and Bibliography

The difference between reference and bibliography can be drawn clearly on the following grounds:

1. Reference implies referring to someone or something, that means it provides the list of sources, whose text is used in the assignment or research work. Conversely, bibliography represents the list of all the sources, from which the research has gained some information about the topic, irrespective of the work cited or not.
2. References are based on primary sources, whereas bibliography is created on the basis of primary and secondary sources.
3. References used in the assignment can be arranged alphabetically or numerically. On the contrary, list of sources used in the bibliography is arranged numerically.
4. The bibliography is used to list out everything you go through to obtain the information relating to the assignment, no matter if you specifically cite it in your assignment or not. Now coming to references, it only takes into account those sources which have been cited in the assignment.
5. The main objective of adding a reference at the end of the document is to improve credence or support an idea or argument. As against, the bibliography is not used for supporting an argument.
6. While reference is used in thesis and dissertation. On the other hand, bibliography is used in case of journal paper and research work.

Research Design

Introduction

. A research design is the plan of attack: What approach to the problem will be taken? What methods will be used? What strategies will be most effective?

Definition

Fred N. Kerlinger (1986): "Research design is the plan, structure, and strategy of investigation conceived so as to obtain answers to research question. The plan is the overall scheme or program of the research. It includes an outline of what the investigator will do from writing the hypotheses and their operational implications to the final analysis of data".

John W. Creswell (2011): "Research designs are plans and the procedures for research that span the decision from broad assumptions to detailed methods of data collection and analysis."

William Zikmund (2013): "Research design is a master plan specifying the methods and procedures for collecting and analyzing the needed information".

Essential elements of a research design

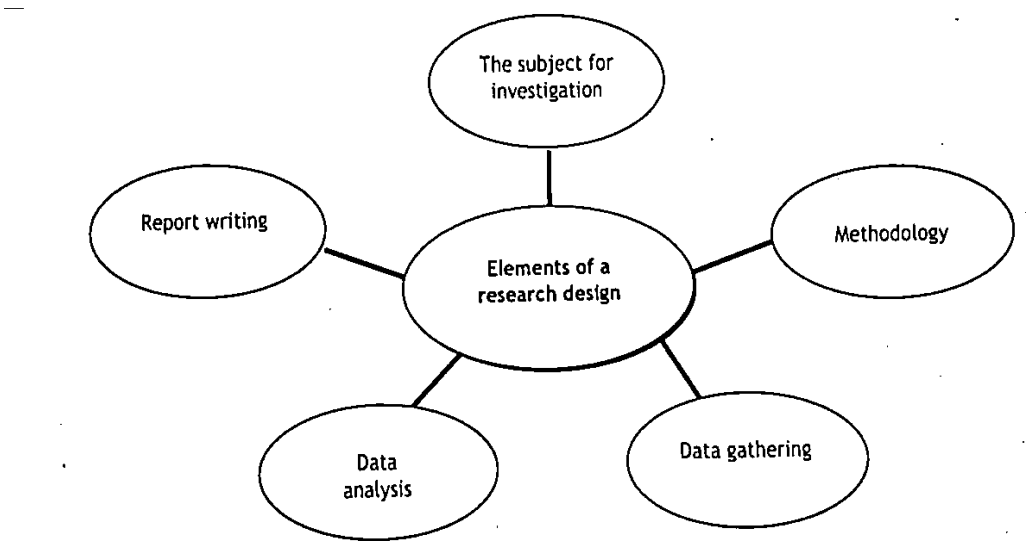
- A research design is an *overall plan* for the activities to be undertaken during the course of a research study.
- The research design serves as a *framework for the study*, guiding the collection and analysis of the data, the research instruments to be utilized, and the sampling plan to be followed.
- It is an *organized and integrated system* that guides the researcher in formulating, implementing, and controlling the study.
- The research design is a *blueprint* specifying the method to be adopted for gathering and analyzing data.

- The research design is a *strategy* of obtaining information for the purpose of conducting a study and making generalizations about the population.

In planning a research investigation, choices have to be made about research strategy (experimental vs non-experimental), research setting (laboratory vs natural setting), measures (questionnaires, observations, interviews), the data analysis strategies (descriptive vs inferential statistics), and a host of other factors. A research design thus includes all these essential factors of an investigation.

Elements of a Research Design

The basic elements of a research design are (a) the problem, (b) the methodology, (c) data gathering, (d) data analysis, and (e) report writing. These elements of research design have been shown in figure. A good research design considers all these elements. The first element of a research design is to answer the research question or test research hypothesis.



Every research work usually requires an explanation of the methodology and the sample description. What methods were used to choose the sample? Why these methods were chosen and how they were applied? Next, there should be an explanation of what the variables are in the hypothesis and how they were measured. Furthermore, the details of the data collection must he explained and a discussion on the reliability and validity of the measurements included. Finally, it is necessary to explain how the data were analyzed.

Preparation of the Research Design

A research design is a clearly planned procedure for carrying out the research. Many things need to be planned in advance. The design generally incorporates answers to the following kinds of questions (Oliver, 2011):

- What sort of data do I need to collect in order to test the hypothesis and/or achieve research aims?
- Where will I collect the data?
- How will I collect the data?
- What type of data-collection instruments and procedures will I use?
- Who will provide me the data?
- Do I need to ask permission before trying to collect data?
- When will I collect the data?
- How will the data be analyzed?
- Will I use a particular theoretical frame in order to interpret the data?

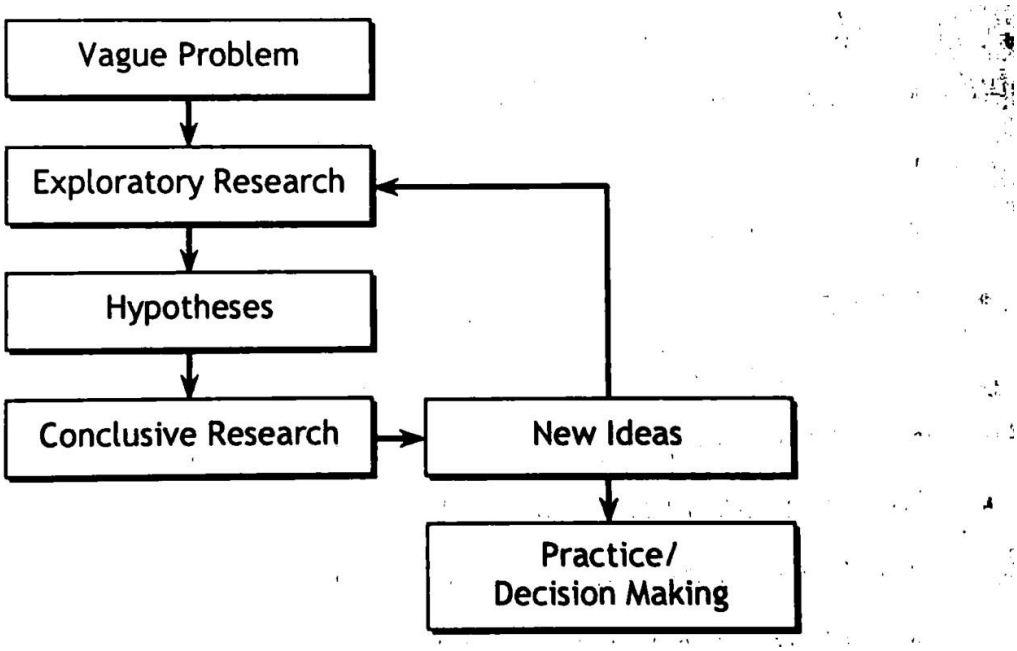
Exploratory Research Design

When searching for hypotheses, exploratory designs are appropriate. When hypotheses have been established and are to be tested, conclusive research designs are needed. Figure given below, highlights the sequence of research activities, from vague problem to new idea generation. First, let us define exploratory research.

An exploratory research is defined as "a study undertaken in areas where very little prior knowledge or information is available on the subject under investigation". It is thus the initial research conducted to study and define the nature of a problem. An exploratory study is undertaken when we do not know much about the situation at hand. In such cases, extensive preliminary work needs to be done to gain familiarity with the phenomenon in the situation.

. There are three purposes for exploratory research:

- Diagnosing a situation
- Screening alternatives
- Discovering new ideas



An exploratory study is undertaken to orient the researcher and the study. It is, therefore' a important method of finding out what is happening, to see new insights, to ask questions, and assess phenomena in a new light. It is particularly useful if you wish to clarify your understanding of a problem. In such study, the focus is initially broad and becomes progressively narrower in the research progresses.

Characteristics of Exploratory Research Design

■ There is no set method of conducting exploratory research. The key requirements for this research are: imagination and flexibility. It is less structured and more flexible.

■ Exploratory research studies are not characterized by formal research design. Hence, they are not very scientific in nature.

■ The researcher may utilize any number of informal approaches in attempting to define the problem and gather the data.

■ Exploratory research provides low-risk form of research that may result in good outcomes. A clear picture of the situation can emerge leading to hypothesis formulation.

■ Exploratory research provides direction for a more formal research effort.

Descriptive Research Designs

Descriptive research describes phenomena as they exist. Such studies involve the systematic collection and presentation of data to give a clear picture of a particular situation. These studies attempt to obtain a complete and accurate description of a situation. These studies can be classified in the following five categories:

(a) Historical

(b) Descriptive

(c) Developmental

(d) Survey

(e) Case Study.

These five types of descriptive research designs are not mutually exclusive. A combination of all these could also be used in some research projects.

(a) Historical Research

History is a meaningful and an organized record of past events. It is not merely a list of events arranged chronologically, but a valid integrated account of social, cultural, economic, and political forces that had operated to produce a historical event.

Historical research is concerned with past phenomena. It can be defined as "the systematic and objective location, evaluation, and synthesis of evidence in order to establish facts and draw conclusions about past events."

Historical research is thus a process of collecting, evaluating, verifying, and synthesizing past evidence systematically and objectively to reach a conclusion. Historical research may also attempt to discern trends in the past and reconstruct the origin and development of those events. The main purpose of conducting historical research is to show the relevance of past events to the present. In other words, the purpose is to arrive at an accurate account of the past so as to gain a clearer perspective of the present.

Accuracy of gathered information is the main ingredient of success in historical research. There are two main sources from where past evidences can be found. One is the primary source, where you were a direct observer of the recorded event and the other is the secondary source, where you are reporting the observations of others. In most cases, you have to depend upon the data observed by others rather than by yourself. At the same time, you must also be aware that inappropriate and biased information results in faulty conclusions and findings.

Characteristics of Historical research

- Good historical data result from painstaking detective work which analyzes the authenticity, accuracy, and significance of source material.
- Historical research must be rigorous, systematic and exhaustive.
- Historical research depends upon two kinds of data: primary sources where the author was a direct observer of the recorded event and secondary sources where the author is reporting the observations of others and is one or more times removed from the original event. Of the two primary sources carry the authority of firsthand evidence and have priority in data collection.
- This critical evaluation of the data is what makes true historical research so rigorous - in many ways, more demanding than experimental methods.
- While historical research is similar to the, "reviews of the literature" which precede other forms of research, the historical approach is more exhaustive, seeking out information from a larger array of sources.

(b) Descriptive Research

It is a type of study, which is generally conducted to assess the opinions, behaviors, or characteristics of a given population and to describe the situation and events occurring at present. Descriptive research is a process of accumulating facts. It does not necessarily seek to explain relationships, test hypotheses, make predictions or get at meanings and implications of a study. Hence, a descriptive research is an extension of an exploratory research.

Descriptive research can be either quantitative or qualitative. This research involves gathering data that describes events and then organizes, tabulates, depicts, and describes the data collection. Descriptive statistics is used to reduce the data to manageable form. Descriptive

research is unique in the number of variables employed:

- Descriptive research, like other types of research, can include multiple variables for analysis.
- Descriptive research might simply report the percentage summary on a single variable.

Descriptive studies thus simply portray an accurate profile of organizations, events, or situation. Investigators collect, classify, and correlate data to describe what exists. However, they do not fully analyze and explain why phenomena behave as they do. They do not put the relationships they describe to crucial experimental tests. Although descriptive research cannot predict and control conditions and events, it contributes to science primarily by building a foundation of facts upon which exploratory hypotheses may be constructed, by checking the validity of existing theories, and by directing attention toward alternative hypotheses which better fit the facts (Van Dalen, 1973). In a descriptive research, it is necessary to have a clear picture of the phenomena on which you wish to collect data prior to the collection of data. Isaac (1978) identifies the characteristics and steps in a descriptive research as follows:

Characteristics

- Descriptive research is used in the literal sense of describing situation or events.
- It is accumulation of a database that is solely descriptive - it does not necessarily seek or explain relationship, test hypotheses, make predictions, or get at meanings and implications, although research aimed at these more powerful purposes may incorporate descriptive methods.

Purposes of Descriptive Studies

- To collect detailed factual information that describes existing phenomena.
- To identify problems or justify current conditions and practices.
- To make comparisons and evaluations.
- To determine what others are doing with similar problems or situations and benefit from their experience in making future plans and decisions.

(c) Developmental Research

Developmental research is conducted for the purpose of predicting future trends. It concentrates on the study of variables, their rates of change, directions, sequences and other inter-related factors over a period of time. There are several methods of developmental research.

(1) **Longitudinal Study**

It is a research where phenomena are studied over time either continuously or repeatedly. This type of study measures the nature and rate of change in a sample at different stages of development. This occurs when the data are collected at two or more points in time from the same group of individuals. Because data are gathered at two different points in time, it is not a cross-sectional or a one-shot study, but it is a study carried longitudinally across a period of time. Longitudinal studies are mostly quantitative.

(1.i)**Trend Study**

The trend study is probably the most common longitudinal study among others. When the data are collected at intervals spread over a period of time, it is called a trend study. It is designed to establish patterns of change in the past in order to predict future patterns or conditions. A trend study thus provides information about net changes at an aggregate level. It can establish a pattern over time to detect shifts and changes in some event. Marketing firms, for example, compile trend studies that chart fluctuations in consumption level for a certain product.

This type of study is particularly used to obtain and analyze social, economic, and political data to identify trends and to predict what is likely to take place in the future. Frequently regression analysis is used for trend studies.

(1.ii)Cohort Study

A cohort is a group of people who share a common characteristic or experience within a defined period. Thus, cohort study is a study of a specific group, such as those born on a day or in the particular period, say in the year 2003. This group then forms a birth cohort or a kindergarten cohort. Similarly, a group of students graduating from college in a year form a student cohort. There are many other kinds of cohorts, including disease, education, employment, housing, family formation, and the like.

A sample of the selected cohort group is then studied at different points of time. A cohort study s thus a systematic follow-up of a group of people for a defined period of time or until a specified event. To form cohort studies, data are compiled for the same population over time. Such studies are therefore rare because of the difficulty of maintaining contact with members of the cohort from year to year.

(1.iii) Panel Study

A panel is a group of individuals that have agreed to provide information to a researcher over period of time. In panel study we take the same people and study their attitudes towards particular phenomenon over time. Panel studies are most useful when studying change. These studies allow the researcher to find out why changes in the population are occurring. They measure the same sample of respondents at different points in time. For example, if we were interested in finding out the general attitude towards single parenthood, we would take a group of people and interview them at periodic intervals on the same subject and over a number of years.

(2.0) **Cross-sectional Study**

This type of study is also known as cross-sectional analysis. It involves observation of some items of the population all at the same time. This study basically measures the rates of changes by drawing samples from a cross-section of society. It focuses on comparing and describing groups.

In this study, data are gathered just once, perhaps over a period of time, in order to answer a research question. Such studies are also known as one-shot studies. Cross-sectional studies often employ the survey strategy. The fundamental difference between a cross-sectional study and longitudinal study is that a cross-sectional study takes place at a single point of time and that a longitudinal study Involves a series of measurements taken over a period of time

Characteristics of developmental Research

- Developmental research focuses on the study of variables and their development over a period of months or years. It asks, "What are the patterns of growth, their rates, their directions, their sequences, and the interrelated factors affecting these characteristics?"
- The sampling problem in the longitudinal method is complicated by the limited number of subjects it can follow over the years; any selected factor affecting attrition biases the longitudinal study.
- Once underway, the longitudinal method does not lend itself to improvements in techniques without losing the continuity of staff and financial support over an extended period of time and typically is confined to university or foundation centers that can maintain such an effort.
- Cross-sectional studies usually include more subjects, but describe fewer growth factors than longitudinal studies. While the latter is the only direct method of studying human development, the cross-sectional approach is less expensive and faster since the actual passage of time is eliminated by sampling different subjects across age ranges.
- Sampling in the cross-sectional method is complicated because the same children are not involved at each age level and may not be comparable.

(d) Survey Research

A survey is a means of gathering information about the characteristics, actions, or opinions of a large group of people, referred to as a population. A survey research is thus defined as "the Systematic gathering of information from respondents for the purpose of understanding and/or predicting some aspect of the behavior of the population of interest". If conducted scientifically this type of research can contribute to the advance of knowledge.

A Survey study may be done in the field - an example would be a survey of employee attitudes toward a new compensation policy- or it may take in a library, where a survey of secondary literature is conducted. In survey research, the researcher selects a sample of respondents from a population and administers a standardized questionnaire to them. Hence, using surveys it is possible to collect data from large or small populations.

Types of Survey Research

- Exploratory survey research. This type of survey research takes place during the early stages of research. It provides the basis for more in-depth surveys. Sometimes, this kind of survey is carried out using data collected in previous studies.
- Confirmatory (theory-testing or explanatory) survey research. In this type of survey, data collection is done with specific aim of testing the theory or hypothesis.
- Descriptive survey research. This type of survey research describes the distribution of the phenomenon in a population. Through facts described, it can provide useful hints both for theory building and for theory refinement.

The aim of survey research is to measure certain attitudes or behavior of a population or a sample. The attitudes might be opinions about the services provided by a business firm or feelings about certain issues or practices. Most often respondents are asked for information. Surveys come in a wide range of forms and can be distributed using a variety of media: written surveys, oral surveys, or electronic surveys. The questionnaire, or survey, can be a written document that is completed by the person being surveyed, on online questionnaire, a face-to-face interview, a mail survey, or a telephone interview. Some forms of survey research by telephone or Internet may be completely automated. Using surveys, it is possible to collect data from large or small population.

(e) Case Study Research

Case studies are written summaries or synthesis of real-life cases based upon data and research. A case study is thus defined as *"a strategy for doing research which involves an empirical investigation of a particular contemporary phenomenon within a real-life context using multiple sources of evidence".*

Yin (1994) defines the case study research as *"an empirical inquiry that investigates contemporary phenomenon within its real-life context"* (p.79). Rather than using samples to examine a limited number of variables, case study methods involve in in-depth, longitudinal examination of a single instance or event (case). This research thus views a social or study unit as a whole in its real-life context. This study phenomenon could be a person, a family, a social group, an institution, a community, or even an entire culture.

A case study not only uses the sources and techniques of historical story but also employs several techniques and sources of data for examining current aspects of the phenomenon under study. A case study could be conducted in the field as well as a non-field setting (Shah,1972, p.11).

The investigator gathers pertinent data about the present status, past experiences and environmental forces that contribute to the individuality and behavior of the unit. After analyzing the sequences and inter-relationships of these facts he or she conducts a comprehensive study of the social unit as it functions in society.

Case studies need to be both comprehensive and systematic. That is, as much data as possible need to be collected in a way that ensures as little as possible is missed. Jensen and Rodgers (2001) set forth a typology of case studies as follows:

■ *Snapshot case studies are the detailed study of one unit.*

■ *Longitudinal case studies are studies of the same unit at multiple time points.*

■ *Pre post ease studies are undertaken at two time points separated by a critical event.*

■ *Cross-cut studies are studies of multiple case studies for the purpose of comparison.*

When selecting a case for a case study, researchers often use information-oriented sampling, as opposed to random sampling. This is because the typical case is often not the richest in information. Information-oriented cases may be distinguished as: extreme cases, critical cases, and exemplar cases. Extreme cases reveal more information because they activate more basic mechanisms and more actors in the situation studied.

It is sometimes impossible for us to handle the whole social reality; at other times, the conceptual basis for understanding some aspects of social reality is not available. In such cases, you may first want to explore the social reality before you formulate and test specific hypotheses. But you must recognize that a case does not represent the total reality. It is just one example of the social reality. Hence, a case study may be an intensive, integrated and insightful method of studying the social phenomena. It can also be used to illustrate a theory by providing an example.

In recent years, there has been increased attention to implementation of case studies in a systematic manner which increases the validity of associated findings. However, although case study research may be used in its own right, it is more often recommended as part of a multi- method approach (triangulation).

Characteristics

■ Case studies are in-depth investigations of a given social unit resulting in a complete, well- organized picture of that unit.

■ Compared to a survey study which tends to examine a small number of variables across a large sample of units, the case study tends to examine a small number of units across a large number of variables and conditions.

■ Because case studies are intensive, they bring to light the important variables, processes and interactions that deserve more extensive attention. They pioneer new ground and often are the source of fruitful hypotheses for further study.

■ Because of their narrow focus on a few units, case studies do not allow valid generalizations to the population from which their units came until the appropriate follow-up research is accomplished, focusing on specific hypotheses and using proper sampling methods.

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Limitations of Case Study

- A case study is more expensive because of its exploratory nature.
- A generalization drawn from a single case cannot be applied to all cases in a given population
- There is some element of subjectivity. You must guard against permitting personal biases and standards to influence your interpretation.

Analytical Research Design

Analytical Research designs can be experimental or observational and each type has its own features. A study design is critical to the research study because it determines exactly how we will collect and analyze our data. If we aim to study the relationship between two variables, then an analytical study design is the right choice. It's necessary to have a clear plan before we begin data collection. Analytical study designs can be experimental or observational and each type has its own features.

A study design is a systematic plan, developed so we can carry out our research study effectively and efficiently. Having a design is important because it will determine the right methodologies for our study. Using the right study design makes our results more credible, valid, and coherent.

Descriptive vs. analytical Research

Study designs can be broadly divided into either descriptive or analytical.

Descriptive studies describe characteristics such as patterns or trends. They answer the questions of what, who, where, and when, and they generate hypotheses. They include case reports and qualitative studies.

Analytical study designs quantify a relationship between different variables. They're used to test hypotheses and make predictions**.**

Experimental and observational

Analytical study designs can be either experimental or observational. In experimental studies, researchers manipulate something in a population of interest and examine its effects. These designs are used to establish a causal link between two variables.

In observational studies, in contrast, researchers observe the effects of a treatment or intervention without manipulating anything. Observational studies are most often used to study larger patterns over longer periods.

Experimental Research Method

The experimental method of research is used as the classical method in physical sciences. It is based on observation or experiments. It deals with actual experiments to determine the relationship between cause and effect of various experimental treatments. It is defined as 'the research method in which a researcher objectively observes phenomenon which is made to occur in a strictly controlled situation where one or more variables are varied and others are kept constant'.

The purpose of experimental research is to investigate cause and effect relationship by exposing one (or more) experimental groups to one (or more) treatment conditions & comparing the result to one (or more) control groups not receiving the treatments. In this method, the researcher undertakes control or manipulation (vary) of various variables under study. The usual approach is to hold all variables constant except one in controlled condition. By varying this one variable,

the out puts (the effects) are studied and documented.

Actually, in social sciences, in natural sciences, in biological phenomena and the human behavior control of variable is hardly possible. However, in physical sciences and experimental technology the investigation in controlled condition is highly acceptable.

Experiment is a test of a casual proposition, such as:

i) Do changes in variable 'A' cause changes in variable 'B' keeping other variables constant?

ii) How the changes in the value of one variable (called independent variable) affect another variable (called dependent variable)?

The mathematical form of the experimental method is given below: If x_1, x2, x3, x4... xn are n independent variables taken as the inputs of the process and y is the output of the process (a dependent variable), then y is defined as a function x and denoted by,

$y = f(x)$

Where,

x means x_1, x_2, x_3, x_4.....x_n and f denotes the function

Suppose for an example, yield (y) of a product in an agricultural field is influenced by the following four different independent variables:

x_1 - seed quality (qualitative variable say, Si, S2),

x_2 - amount of fertilizer (quantitative variable, in kg),

x_3 - irrigation scheme (categorical variable say, I_1, I_2,I_3)

x4 - labor input (quantitative variable say, in number)

The production or yield, which depends upon these four variables, can be related mathematically as

$Y = f(x)$

Or $Y= f(x_1, x_2, x_3, x_4)$

By taking any three (say x_1, x_2, x_3) constant one can observe the effect of x_4 in Y; x_4 may vary as researchers will, so it is said to be a controlled variable.

The various factors in an experiment are divided into two groups: independent variables and dependent variables. The first sets of a factor or factors are called an experimental group and the second sets of factors are called control group. Control group is also known as a group of individuals, items or objects used as a standard for comparison or accepted norm.

To make the experimental method of research effective and distinct from normal activity the method of local control (blocking) and statistical control methods are used. Control is necessary to reduce variations. In some experiments, some variables may be eliminated.

Types of Experiment

Experiment is the scientific investigation in which an investigator manipulates and controls one or more independent variables and observes the dependent variables for variation concomitant to the manipulation of the independent variable. There are four different types of experiments.

1. Positive and Negative Experiment If the subject of an experiment is such that i) the phenomenon and ii) its cause both are present, the experiment is said to be positive. For example, a bell rings in the air. Here both the sound and cause of its propagation are present; but if, on the other hand, a bell is rung in a vacuum, there will be no phenomenon of a sound because the cause of the propagation, namely air is absent. Such experiment is called negative experiment.

2. Natural Experiment These experiments are to be observed in natural phenomenon. In most of the natural state experiments, the controlling of variable is unnecessary to obtain, the real information about the phenomena. In such case, the whole phenomenon is divided into control group and experimental group to study the effects of seen and unseen variables.

3. Laboratory Experiment These are the experiments performed in physical sciences with full control of external conditions. A laboratory experiment is an artificially created situation in which the researcher controls one or more variables while manipulating other variable at will. The method of lab experiment is used in the experiments, mainly related to the physical, chemical, microbiological, clinical and such other sciences. If, it is difficult to conduct an experiment out-side or in the field or in the society then one tries to carry out it in the laboratories.

4. Field Experiment Field experiments are the experiments conducted in the field or in natural setting. Research study in a realistic situation in which one or more independent variables are manipulated by the experimenter under carefully controlled conditions as the situation will permit. In the social, managerial, agricultural, environmental researches, the method of field experiment is widely used. Some of the field experiments like agricultural or business field the controlling of the variable is possible but in the careful condition

Purposes of Experimental Method

a. To determine the effect of various treatments and to compare the differences of effects as significant or non-significant.

b. To estimate the interaction effects of various treatments and to compare them

c. To establish the mathematical relationship between various treatments and their effects.

Problem in Experimentation

- To single out one factor from the phenomena

It is always difficult to single out one factor from a social phenomenon for the purpose of measurement, because in any event there may be many factors interacted.

- Controlling the factors

Control of factors sometimes is not possible, because some factors may be unknown and uncontrollable. It is better to select several random samples as experimental and control groups. One solution here is the adoption of the control group technique.

- To get data from the control groups

There are difficulties in getting data from the control groups. The remedy may be found in matching the control and experimental groups on as many points as possible.

- To assign the level of significance

The determination of the required level of significance of the differences between the experimental and control groups is also fraught with difficulty. What difference can be taken as fraught with difficulty? What difference can be taken as significant? There is the problem of value judgment. But the scientific criterion is the determination of the statistical test of significance. However, this requires a reliable and valid socio-metric scale.

- Change in response of people

In field experiment related with human behaviors (society and clinical setup), when data collected through human interaction due to changes in time, situation, environment and types of questions to be asked people often changes their responses.

- Change in theme of trialing

Due to change in behavior of the respondents and unsatisfactory management of the investigator theme of trialing of the area under experiment (in social and clinical setup) may change at the end of the experiment from what it was started. Because of the changes made by experimentation may give different responses which may lead wrong conclusion.

- Problem of handling or operation

In social setup and to the medical trials, if the people under study area is not aware, attentive and responsive about the inquiry, true response cannot be possible.

Steps in Experimental Methods

Statement of the problem, research questions and the objectives

The first step in the application of field techniques is related in mentioning of problem, research questions and specific objective. The hypothesis, at this stage, should be stated explicitly in general terms.

Examination of possible outcomes and events through literature

The second step consists in setting up the field experiment by thorough reading of the available literature. The factors to be controlled must be assessed, the cooperation between the researcher and the subject must be set up.

Design of experiment

The next step is the choice of experimental design regarding its size, material, control groups etc. The choice of material should be based on the criterion of maximum possible accuracy. The basic problem of design relates to control. Control and experimental groups should be matched on all important factors.

Performing experiment

The next step of this method is to performing experiment in predefined circumstances. The principles of randomization, replication and blocking should be implemented as can as possible. The sensitiveness of experiments can be augmented by neutralizing the biases through random choice, by increasing the replication, improving the quantitative technique and by refinements of techniques.

Analysis of experimental out comes statistically

The analysis of the experimental data should be done starting from stating the descriptive nature of the data, measuring relationship between them and modeling data into some mathematical models. The analysis of variance permits a study of complex interrelationship, which is not possible by simpler designs. It permits more reliable conclusions about more hypotheses with fewer cases than if hypotheses were tested in separate design.

Drawing conclusions by measuring reliability

For an experimental research the conclusions are drawn based on the statistical significance testing. The tests can be performed as required level of design by the use of different statistical techniques. The results obtained then are put to test their reliability and the conclusions are made.

Testing the validity of the conclusion

The validity of the results should be measured before disseminating the results and reports. The validity of the experimental results is checked by the comparing with other similar phenomenon or to the standards.

Evaluation of the entire investigation through practice

The success of the experimental study can be measured only through putting into practice the experiments many times. If the repeated experiments give similar or better results, then the experimental results may be considered satisfactory.

Ethical Issues in Experimental Research Design

- The following practices are considered unethical:
  - Putting pressure on individuals to participate in experiments through coercion, or applying social pressure.
  - Deceiving subjects by deliberately misleading them as to the true purpose of the research.
  - Exposing participants to physical or mental stress.
  - Not allowing subjects to withdraw from the research when they want to.
  - Using the research results to disadvantage the participants, or for purposes not to their liking.
  - Not explaining the procedures to be followed in the experiment.
  - Not debriefing participants fully and accurately after the experiment is over.
  - Not preserving the privacy and confidentiality of the information given by the participants.
  - Withholding benefits from control groups.

Research Guides

Research Guides are **librarian-curated pathways to information, videos, databases, and other resources for your discipline**. That is, they pull many different types of resources on a subject or topic together in one place.

Hand Book

A handbook is a compilation of miscellaneous information in a compact and handy form. It contains data, procedures, principles etc. Tables, Graphs, diagrams and illustrations are provided. Scientists and technologists use handbooks in their fields.

A treaties on a special subject; often nowadays a simple but all-embracing treatment, containing concise information, and being small enough to be held in the hand; but strictly, a book written primarily for practitioners and saving for constant revision or reference. Also called a 'Manual'.
Example:

- Britain, 1948/49-, an official handbook, London, stationery Office, 1948-, Annual.
- Handbook of Chemistry and Physics: A ready reference book of Chemistry and Physical data, 52nd ed, Cleveland, Ohio, Chemical Rubber, 1971**.**

CITATION

A "citation" is **the way you tell your readers that certain material in your work came from another source**. It also gives your readers the information necessary to find the location details of that source on the reference or Works Cited page. A citation must include a set of parentheses.

For APA, IEEE and other reference style follow the web-link given below

APA

APA is the style of documentation of sources used by the American Psychological Association. This form of writing research papers is used mainly in the social sciences, like psychology, anthropology, sociology, as well as education and other fields.

IEEE

The Institute for Electrical and Electronics Engineers (IEEE) is a professional organization supporting many branches of engineering, computer science, and information technology. In addition to publishing journals, magazines, and conference proceedings, IEEE also makes many standards for a wide variety of industries.

IEEE citation style includes in-text citations, numbered in square brackets, which refer to the full citation listed in the reference list at the end of the paper. The reference list is organized numerically, not alphabetically

https://pitt.libguides.com/citationhelp/apa7

Citation Index

Citation indexes allow researchers to trace the impact of an article upon later publications. Besides including the bibliographic information about an article (author, article title, journal title, date, etc.), citation indexes also provide each article's references or bibliography (the list of sources cited).

For citation Index follow the web link: **https://www.isko.org/cyclo/citation**

SCIFinder

SciFinder is a database focused on the literature in chemistry. It is produced and published by CAS: Chemical Abstracts Service, a division of the American Chemical Society. CAS has, as its objective, "to find, collect and organize all publicly disclosed chemical substance information."

Follow the link **: https://library.ulethbridge.ca/scifinder/overview#s-lg-box-wrapper-9172764**

SCOPUS

Scopus Indexed Journals are considered better sources for citation as compared to other databases. Scopus publications enjoy a good reputation among peer researchers due to their rigid selection procedure that ensures high-quality content and reliable data. In addition, the journal database is recognized by scholars in research and academia.

Follow the link: **https://www.aimlay.com/scopus-indexed-journals/**

Science direct:

ScienceDirect is **a website which provides subscription-based access to a large database of scientific and medical research**. It contains the world's largest electronic collection of full-text and bibliographic information on science, technology and medicine

Follow the link: **https://cscitconf.cikd.ca/an-introduction-to-sciencedirect/**

Impact Factor

In any given year, the two-year journal impact factor is the ratio between the number of citations received in that year for publications in that journal that were published in the two preceding years and the total number of "citable items" published in that journal during the two preceding years:

$$\mathrm{IF}_y = \frac{\mathrm{Citations}_y}{\mathrm{Publications}_{y-1} + \mathrm{Publications}_{y-2}}.$$

For example, *Nature* had an impact factor of 41.577 in 2017

$$\mathrm{IF}_{2017} = \frac{\mathrm{Citations}_{2017}}{\mathrm{Publications}_{2016} + \mathrm{Publications}_{2015}} = \frac{74090}{880 + 902} = 41.577.$$

Follow the link: **https://en.wikipedia.org/wiki/Impact_factor**

H-Index

The *h*-index is defined as the maximum value of *h* such that the given author/journal has published at least *h* papers that have each been cited at least *h* times

Follow the link: **https://en.wikipedia.org/wiki/H-index#Calculation**

APA STYLE: SEVENTH EDITION

These guidelines follow the 2020 7th edition of the American Psychological Association's *Publication Manual*, which is widely used in the health and social sciences. They focus on documentation, but the manual addresses issues from abbreviations to layout and should be consulted for further information. In an APA-style paper, you'll identify the author and year of each source any time you use it. That information directs readers to more detailed entries on a reference list at the paper's end.

■ Citing Sources in Your Paper

Your readers can't know where any word, idea, or information in your sentence comes from unless you tell them. It could be your own idea, or from the source you just mentioned, or from a completely different source. That's why you need to tell them! Once you've told them, they may want to find out more about that source. To help them, your citation will always include the first word(s) of your reference page entry--usually the name of the person(s) or group considered the "author" of the work. Direct quotations require page or paragraph numbers, but paraphrases usually don't. Both can be cited **narratively** (author's name as part of the sentence) or **parenthetically** (author's name in parentheses after the sentence).

		Narrative Citation	**Parenthetical Citation**
DIRECT QUOTATION	**One author**	Sendak (2015) contended that "imagination is crucial" (p. 2).	Clearly, "imagination is crucial" (Sendak, 2015, p. 2).
	Two authors	According to Sendak and Wise (2010), "Imagination is crucial" (pp. 112-113).	It is true that "imagination is crucial" (Sendak & Wise, 2010, pp. 112-113).
	Three+ authors	"Imagination is crucial," Sendak et al. (2001) reflected (para. 5).	"Imagination," however, "is crucial," (Sendak et al., 2001, para. 5).
	Group author, first reference	The American Library Association (ALA; 2005) has insisted that "imagination is crucial" (para. 2).	Perhaps "imagination is crucial" (American Library Association [ALA], 2005, para. 2).
	Group author, late rreference	The ALA (2005) has insisted that "imagination is crucial" (para. 2).	Perhaps "imagination is crucial" (ALA, 2005, para. 2).
	Author unknown	The author of "Feeding Young Minds" (2010) noted that "imagination is crucial" (p. 5).	One article (2010) claimed that "imagination is crucial" ("Feeding," 2015, p. 5).
PARAPHRASE	**One author**	Sendak (2015) argued that children must develop imagination.	Children must develop imagination (Sendak, 2015).
	Two authors	Sendak and Wise (2015) believed that children must develop imagination.	Children must develop imagination (Sendak & Wise, 2015).
	Three+ authors	Children must develop imagination, observed Sendak et al. (2015).	Children must develop imagination (Sendak et al., 2015).
	Group author, first reference	Children must develop imagination, the American Library Association (ALA, 2015) has explained.	Children must develop imagination (American Library Association [ALA], 2015).
	Author unknown	In "Feeding Young Minds" (2015), the author suggested that children must develop imagination.	Children must develop imagination ("Feeding," 2015).

1. **Dates**. APA includes the year of publication in every parenthetical citation and in the first narrative citation of each source in any paragraph (although some teachers require it in all narrative citations). Only the year of publication goes in your in-text citation, even if the reference page entry includes a month. *Manual*, p. 262.

2. **Page numbers**. APA requires specific page, paragraph, or location numbers for all direct quotations. Specific page numbers are rarely included for paraphrases and most teachers don't allow them, although APA does.

   List all digits in every page number. For written sources without page numbers, use "para.," the paragraph number, and, when possible, the section heading. Put document-specific headings in quotation marks and shorten them if needed. For video or audio sources, use the timestamp; for PowerPoint presentations, use the slide number. *Manual,* p. 264.

   (Drew, 2002, para. 4)
   (Marvin, 2009, Introduction, para. 12)…
   (Fayne, 2013, "Idaho Dentists Find," para. 3)

   Major classical works like the Qur'an, *The Odyssey,* and *Macbeth* have standard numbering systems that cross all editions and translations, so use those systems instead of page numbers. *Manual,* p. 274.

   (Shakespeare, 1623/2003, 1.5.45-60)
   (*King James Bible*, 1769/2017, 2 Sam. 12:1-10)

3. **Names**. The body of an APA paper typically uses last names only, even on first reference. Endings like "Jr." and academic degrees are not included. *Manual,* p. 262.

   Garland and Wilder (2013) found that…
   Other research suggests that this model may be inadequate (Garland & Wilder, 2013).

   APA doesn't use first names or initials in citations unless that's the only way of distinguishing between two sources. However, be aware that some fields like English may expect first and last names on first narrative reference. *Manual,* p. 262.

4. **No author.** When you don't know the name of your source's author, use the first words of its title. Italicize the title of a periodical, book, or report; use quotation marks for an article. *Manual,* p. 265.

   Book: (*Eating Disorders*, 2018) or the book *Eating Disorders* (2018)
   Article: …benefits have been demonstrated ("Holistic Approach," 2002)

5. **Multiple authors**. If your source has two authors, cite both every time. If it has three or more authors, use the first author's name with "et al." Note that "et al." is not italicized and that there is a period after "al." If you name two authors in a narrative citation, write out the "and" between their names. In a parenthetical citation, use "&." *Manual,* p. 266.

   One study of peer relationships… (Granger & Patil, 1997).
   A later study of peer relationships… (Longbottom et al., 1999).

6. **Group authors.** When the author of your source is an organization, its name is spelled out in full on first reference. If it's well-known or will be used at least two more times, an abbreviation (in parentheses) follows the full name and replaces the full name later. Don't go back and forth between the full name and the abbreviation. *Manual,* p. 268.

7. **One author, multiple works**. If you're citing two works written by the same author(s) in different years, cite them as you normally would. If you have two works written by the same author(s) in the same year, however, those works will be listed alphabetically by title on your reference page, where they'll be labeled (YYYYa) and (YYYYb). *Manual,* p. 267.

    Cisneros (2011a) found….
    …..direction for future research (Cisneros, 2011a).

8. **One citation, multiple sources**. If you refer to several sources within the same parentheses, put them in the same order in which they appear in your reference list and separate them with a semicolon. *Manual,* p. 263.

    (Andrews et al., 1996; Gillis, 2017; Gillis, 2019; Shirley & Blythe, 2013)

9. **One paragraph, multiple references to same source.** If all the information in a paragraph comes from one part of one source, identify its author and date at the beginning. If you use transitional phrases and pronouns like "these findings" to show that each following sentence paraphrases material in the same source, you won't have to repeat the citation unless your teacher requires it. *Manual,* pp. 269-270.

    If you cite a source by putting the author's name in your sentence, you don't have to include the date again in other sentences within the same paragraph (although some teachers will expect you to). You do have to include the date in any parenthetical citations. *Manual,* p. 265.

    Travers (2006) found that the children underestimated the amount of sugar in their diets. Travers also found that the children in the study consumed more than twice the recommended amount of sugar. They also failed to recognize the sugar content of many common foods.

    If your paragraph moves back and forth between different sources or between one source and your discussion, you'll cite the source of each sentence to help keep the reader on track. Any sentence you don't cite is understood to represent your own words and ideas.

    Ray and Kelly (2014) proposed that creative writing assignments be integrated into composition classes. It is unclear, however, that this suggestion would improve test scores. Although 72% of students surveyed believed that creative writing exercises improved their written fluency (Ray & Kelly, 2014), other research suggests that those gains in fluency do not transfer to research assignments (Collins, 2011).

10. **Secondary citations.** If an idea or phrase that you want to use is quoted in another source, find the original source if you can. If not, name the original source in your sentence and then use parentheses and the words "as cited in" to identify the source (listed on your reference page) where you found it. *Manual,* p. 258.

    Laurence (2001) found no correlation between the variables (as cited in Brooke, 2003).
    No correlation was found (Laurence, 2001, as cited in Brooke, 2003).

11. **Email and personal interviews**. Personal communications that a reader can't retrieve (ex. letters, memos, e-mail, interviews, telephone conversations) appear as in-text citations only. Don't put them in your reference list. Include your source's initials and last name and as exact a date as possible. *Manual,* p. 260.

    S. Crewe argued that not all sources agree (personal communication, May 3, 2012).
    Not all sources agree (S. Crewe, personal communication, May 3, 2012).

12. **Long quotations.** If you use a quotation that's 40 or more words long (also called a "block quotation"), set it off from the rest of your paper by indenting it five spaces (one tab space). Double space it and don't use quotation marks. The final period goes before, not after, the citation at the end. *Manual,* p. 272-273.

13. **How much can I quote?** As a general rule, not more than 10% of any paper should consist of direct quotations. Formal research papers in APA style often include no quotations at all.

■ The Reference List

The reference list at the end of the paper contains all the sources cited in the paper. Its purpose is to help readers find the materials you used, so each entry must be complete and accurate.

14. **Page format**. The reference list starts on a new page. Every line is double-spaced, without extra spaces between entries. The word "References" is centered at the top and bolded. The pages are numbered as if they were part of your paper. *Manual,* pp. 66, 303.

    Use the "hanging indent" format: start the first line of each entry at the left margin, but indent all subsequent lines one tab space (five spaces). *Manual,* p. 66.

15. **Order of references**. List each source alphabetically by the last name of its first author. If there is no author, alphabetize the source by the first word of its title (excluding *a, an, the*) *Manual,* pp. 303-304.

16. **Names.** Shorten all first and middle names to initials. List all authors by last name first, then initials. If a source has multiple authors, don't change the order they're in. *Manual,* p. 286.

17. **Mulitiple authors**. If a source has up to 20 authors, list them all. If it has 21 or more, list the first 19, add an ellipse (three dots separated by spaces), and name the last. *Manual,* p. 286.

18. **One author, multiple works**. List more than one work by the same author in the order of the years they were published. If multiple works were published in the same year, alphabetize them by their titles and label them (2011a), (2011b). *Manual,* p. 304.

    World Health Organization. (2012). Immunization: Closing the gap…
    World Health Organization. (2015a). Global vaccination targets…
    World Health Organization. (2015b). Keeping Syrian children free from polio…

19. **Dates.** Put the year of publication in parentheses immediately after the author's name(s). In a book, the date is usually on the copyright page behind the title page. The date of a website is trickier: don't use a "Last Reviewed" date or a website copyright date. Use a "Last Updated" date only when the update clearly applies to the information you're reading as opposed to some other feature of the page. If your source truly provides no date, use the abbreviation "n.d." ("no date") instead of the year. *Manual,* pp. 262, 290.

    If you're citing a work that's been republished, put the recent publication date in the usual place, after the author's name. The original date closes the citation, after any DOI or URL, and looks like this: (Original work published 1815). *Manual,* p. 265, 325

20. **Capitalization**. In the title and subtitle of a book, chapter, or article, capitalize only the first word and any proper nouns. In journal, magazine, and newspaper titles, capitalize all major words. *Manual,* p. 291.

21. **Italics**. Italicize titles of books, journals, magazines, and newspapers. Also italicize volume numbers in journal references. Leave article and chapter titles alone: don't italicize them or put them in quotation marks. *Manual,* p. 293.

22. **Publication information**. The publication information required for books includes only the name of the publisher; if the publisher is the same as the author, it doesn't even need that. The requirement for articles includes volume, issue, and page numbers. *Manual,* pp. 295-296.

23. **Databases.** APA doesn't include database information unless a source is available **onl**y from a particular database, like Cochran. If you include a database name in your reference (some archival documents can only be found in electronic databases), put it in italics. *Manual,* p. 296.

24. **DOIs**. Many sources have a Digital Object Identifier (DOI), a permanent number that goes with them wherever they're published online. If your source has a DOI, your citation must include it. The doi itself looks something like 10.xxxx/gobbledygook. It can appear in many formats, but APA only uses one. If you find a doi as part of a larger URL that doesn't look like the one below, cut out everything except the doi and reformat it. Don't put a period at the end. *Manual,* pp. 299-300.

        htpps://doi.org/10.xxxx/gobbledygook

25. **URLs.** If an electronic source has a DOI, don't include the URL. No DOI? Try to find a URL that links to the source directly. Don't use a URL specific to a particular library; don't use a URL specific to a general database like EBSCO or Academic Search Complete. If those are the only URLs you can find, don't include a URL in your citation. *Manual,* pp. 299-300.

    If your source is available only from a specific database and the URL linking to the document doesn't require a login, use that URL. If it does require a login, list the URL for the database instead. A URL begins with "http" or "https": don't put a "retrieved from" statement before it (except in special situations—see F. below) or a period after it. You can leave your URLs live and hyperlinked (blue, underlined) or you can remove the hyperlinks. Check your teacher's preference. *Manual,* pp. 298-299.

26. **Retrieval dates.** Don't include retrieval dates for online sources unless the source is both unarchived and expected to change over time (e.g. online dictionary, Google map). Wikipedia pages are archived, so you don't need to include a retrieval date for them. *Manual,* p. 290.

Sample References

A. **Book with subtitle.** *Manual,* p. 321.

Fraser, C. (2017). *Prairie fires: The American dreams of Laura Ingalls Wilder.* Metropolitan Books.

B. **Book with two editors instead of author.** *Manual,* p. 322.

Melendy, R., & Kincaid, C. (Eds.). (2018). *Birth order and personality*. Doubleday.

C. **Essay, chapter, or section in edited work.** *Manual,* p. 326.

Gale, D. (2008). Innocence abroad. In L.F. Baum (Ed.), *The way home* (pp. 27-43). Cyclone Press.

D. **Journal article with DOI**. *Manual*, p. 317.

Slethaug, G. E. (1986). The paradoxical double in Le Guin's *A Wizard of Earthsea. Extrapolation, 27*(4), 326-333. https://doi.org/10.3828/extr.1986.27.4.326

E. **Magazine article, online, no volume issue or pages**. *Manual,* p. 320

Beck, J. (2015, May 3). Science's love affair with *The Lord of the Rings*. *The Atlantic.* https://www.theatlantic.com/health/archive/2015/05/sciences-love-affair-with-the-lord-of-the-rings/392216/

F. **Unsigned entry in continuously updated, unarchived online dictionary**. *Manual,* p. 328.

Merriam-Webster. (n.d). Literacy. In *Merriam-Webster dictionary*. Retrieved January 10, 2020, from https://www.merriam-webster.com/dictionary/literacy

G. **Wikipedia entry**. *Manual,* p, 329.

Stonehenge. (2020, January 16). In *Wikipedia*. https://en.wikipedia.org/wiki/Stonehenge

H. **Website article with author.** *Manual*, p. 351.

Spritzler, F. (2017, January 29). *13 ways to prevent type 2 diabetes*. Healthline. https://www.healthline.com/nutrition/prevent-diabetes

I. **Website article without author or date.** *Manual*, p. 351

What are pulses? (n.d.). Half-Cup Habit. https://pulses.org/nap/what-are-pulses/

IEEE EDITORIAL STYLE MANUAL FOR AUTHORS

IEEE Publishing Operations
445 Hoes Lane
Piscataway, NJ 08854 USA
Updated 29 July 2024

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I. INTRODUCTION

A. Purpose of Manual

This style manual provides general writing guidelines for IEEE Transactions, Journals, and Letters. For guidance in grammar and usage not included in this manual, please consult *The Chicago Manual of Style*, published by the University of Chicago Press.

B. Definition of a Transactions and Explanation of the Review Process

All IEEE Transactions are refereed archival journals. This means that each Transactions has a volunteer Editor or Editor-in-Chief (EIC) who is responsible for soliciting manuscripts and overseeing the peer review and revision process for the journal. The referees (at least two, according to IEEE policy), together with the Editor and sometimes with volunteer Associate Editors, determine the technical merit of each submitted article and make a recommendation to accept, accept with revision, or reject it.

Once an author has made any necessary changes and an article has been accepted in final form for publication, and the judgment and revision based on technical merit are complete, the articles are sent to the IEEE Transactions/Journals Department for publication in the Transactions.

C. IEEE Transactions Editing Philosophy

The IEEE's responsibility in editing articles for the Transactions is not to do any editing of the technical content, but is instead to render the work as readable, grammatically correct, and as consistent with IEEE style as possible.

Since we are concerned with style mainly in the sense of IEEE house style, we do not try to change an author's style of writing. We do a mechanical edit to correct or question grammatical errors, obvious inconsistencies or omissions, spelling, and punctuation. Since we work with highly technical text, we also do extensive formatting of mathematical material.

Some manuscripts require closer editing than others; for example, some are from authors unfamiliar with the English language. Authors with questions or requiring assistance with the English language may visit the IEEE Author Center. Often, an IEEE Staff Editor must determine how to correct a grammatical error or decide what can be safely changed or corrected without altering the author's original meaning. Because of the highly technical nature of the material we deal with, and because of our often limited understanding of that material, it is especially important that Staff Editors do not risk making any unnecessary changes or any that may affect the author's meaning.

II. WRITING PRINCIPLES

The sections of an article should generally be written in the following order:

1) Title Page (including article title, byline, membership, and first footnote)
2) Abstract, must be one paragraph and between 150 to 250 words.
3) Index Terms
4) Nomenclature (optional)
5) Introduction
6) Body of Article
7) Conclusion
8) Appendix(es)
9) Acknowledgment
10) References
11) Photographs and Biographies

A. Writing Parts of an Article

Title

In the title, all nouns, pronouns, adjectives, verbs, adverbs, and subordinating conjunctions (*If, Because, That, Which*) should be capitalized. Capitalize abbreviations that are otherwise lowercase (i.e., use DC, not dc or Dc) except for unit abbreviations and acronyms. Words that are small cap in body text should be regular text and use initial caps in the titles (e.g., ON-OFF). Articles (*a, an, the*), coordinating conjunctions (*and, but, for, or, nor*), and most short prepositions are lowercase unless they are the first or last word. Prepositions of more than three letters (*Before, From, Through, With, Versus, Among, Under, Between, Without*) are capitalized. Detailed equations are discouraged in titles. If they must be included, capitalization and formatting should follow IEEE style.

***Examples*:**

- Nonlinear Gain Coefficients in Semiconductor Lasers: Effects of Carrier Heating
- Geoscience and Remote On-Off Lidar Exploration
- Self-Pulsation in an InGaN Laser—Part I: Theory and Experiment

Byline, ORCID, and Membership Citation

Use the longest and most complete name given in either the biography or byline. Use the same information in both places. Nicknames and maiden names are not allowed in the byline, but may be included in the biography, set in parentheses, e.g., "**John (Jack) Smith** received the B.A. degree…" and "**Jane (Smith) Jones** received the B.S. degree…" Hebrew and secondary surnames may be included in the byline, e.g., "**Shlomo Shamai (Shitz)**." Names in native languages are also allowed.

Example:

T. Prikhna (Т. О. Пріхна), *Member, IEEE*, M. Eisterer, B. Büchner, R. Kluge, V. Sokolovsky, V. E. Moshchil (В. Є. Мощіль), A. Bodenseher, J. Filzmoser, D. Lindackers, S. S. Ponomaryov (С. С. Пономарьов), M. V. Karpets (М. В. Карпець), F. N. Werfel, U. Flögel–Delor, A. Vakaliuk, and V. B. Sverdun (В. Б. Свердун)

Titles and affiliations associated with the author should be omitted. Do not use commas to precede a suffix, such as a roman numeral or Jr./Sr., after the author's given name.

Example:

C.-Y. Chen, *Member, IEEE*, K. S. Snyder Jr., *Fellow, IEEE,*
and J. Fortunato III, *Senior Member, IEEE*

Mohammed Z. Ali, *Member, IEEE,* and Murat Torlak, *Fellow, IEEE*

ORCID

Open Researcher and Contributor ID is a nonproprietary alphanumeric code to uniquely identify scientific and other academic authors and contributors. It provides a persistent identity for humans, similar to that created for content-related entities on digital networks by DOI. ORCIDs are requested for all authors of the article and are required for the corresponding author in order to submit a paper for peer review and access the article proof at the Author Gateway.

IEEE Membership Grades

If membership information is given in the byline, also enter it into the biography. IEEE Membership Grades included in the byline and biography are Student Member, Graduate Student Member, Associate Member, Member, Senior Member, Fellow, Life Associate Member, Life Member, Life Senior Member, and Life Fellow.

Note: Affiliate Members are not considered members for the purposes of the byline and biography.

Consortia and group authorship

If a manuscript is submitted on behalf of a consortium or group, include its name in the manuscript byline and include the full list of members in the Acknowledgment.

Mohammed Z. Ali, *Member, IEEE,* and Murat Torlak, *Fellow, IEEE,* SiPBA Group

First Footnotes

The first footnote (or the author affiliation paragraph) is made up of at least three paragraphs. This footnote is not numbered. All other footnotes in the article are numbered consecutively. Do not use asterisks or daggers.

***Example**:*

Manuscript received 27 April 2012; revised 18 September 2012; accepted 25 July 2013. Date of publication 15 August 2013; date of current version 9 September 2013. This work was supported by a grant of the Romanian National Authority for Scientific Research, CNCS UEFISCDI, under Project PN-II-ID-PCE-2011-3-0566. *(Corresponding author: Florin Gherendi.)*

The authors are with the National Institute for Lasers, Plasma and Radiation Physics, Plasma Physics and Nuclear Fusion Laboratory, 077125 Bucharest-Magurele, Romania (e-mail: florin.gherendi@infim.ro; mnistor@infim.ro; mandache@infim.ro).

This article has supplementary material provided by the authors and color versions of one or more figures available at https://doi.org/10.1109/TFUZZ.2019.2933787.

First Paragraph:

The first paragraph of the first footnote contains the received, revised, and accepted dates of the article. When an article has more than one revised date, list all the dates. It also contains the two additional online published dates. The first date identifies the date of publication, i.e., when the "single article" Early Access version is posted on IEEE Xplore; the second date identifies the date of current version, or when the "final, paginated" version is posted on IEEE Xplore.

Corresponding author(s) credit: All articles must include the name of the corresponding author(s). However, an author may opt out upon review of the proof. Multiple corresponding authors may be listed. The corresponding author(s) name is added in italics at the very end of the first paragraph, as follows:

Manuscript received 2 May 2018; revised 9 September 2018; accepted 12 October 2018. Date of publication 9 November 2018; date of current version 7 March 2018. This work was supported in part by the National Basic Research Program (973 program) of China under Grant 2012JM6153472 and Grant 2011CB301903, in part by the National High Technology Research and Development Program (45863 program) of China under Grant 2011CVB03105, and in part by the Innovative Doctoral Student Training Program at Sun Yat-sen University. *(Corresponding authors: Jessie Y. C. Chen; Shiyuan Fan.)*

Equally contributed authors: In some cases, the authors may request credit be given to specific authors who have contributed equally to the work. This is added in italics at the very end of the first paragraph before the corresponding author. See example below.

Manuscript received 2 May 2018; revised 9 September 2018; accepted 12 October 2018. Date of publication 29 November 2018; date of current version 7 March 2019. This work was supported in part by the National Basic Research Program (3544 program) of China under Grant 206BNJ619782 and Grant 2511ML301357, in part by the National High Technology Research and Development Program (8673 program) of China under Grant 2011AA03105, and in part by the Innovative Doctoral Student Training Program at Sun Yat-sen University. *(Shanjin Fan and Shiyuan Fan contributed equally to this work.) (Corresponding authors: Jessie Y. C. Chen; Shiyuan Fan.)*

Co-first authors: In many fields, it is viewed as good to be the first author. But only one person can be first author, which leads to the practice of some labs having "co-first" authorship. The wording for this is: "(*Shanjin Fan and Shiyuan Fan are co-first authors.*)". There is no need to include the "contributed equally" phrase. In the byline, one of the authors must be listed first, but the last line in the first paragraph will indicate both authors as co-first authors. For example:

Manuscript received 2 May 2018; revised 9 September 2018; accepted 12 October 2018. Date of publication 29 November 2018; date of current version 7 March 2019. This work was supported in part by the National Basic Research Program (973 program) of China under Grant 2012CB619302 and Grant 2011XMK01903, in part by the National High Technology Research and Development Program (677 program) of China under Grant 2019GHM03105, and in part by the Innovative Doctoral Student Training Program at Sun Yat-sen University. *(Shanjin Fan and Shiyuan Fan are co-first authors.) (Corresponding author: Shanjin Fan.)*

Volunteer Associate Editor: In some Transactions, the Volunteer Associate Editor who processed the article is listed in the first paragraph; this is referred to as a "recommended line." See specific Transactions for placement and wording. Some examples are:

Manuscript received 5 February 2018; revised 29 March 2018; accepted 29 March 2018. Date of publication 8 June 2018; date of current version 18 January 2009. Article recommended by Associate Editor Thomas Lynch.

Manuscript received 5 February 2018; revised 29 March 2018. Date of publication 8 June 2018; date of current version 18 January 2009. This article was recommended by Associate Editor T. Lynch.

Manuscript received 4 July 2018; revised 4 September 2018. Date of publication 8 June 2018; date of current version 18 July 2018. This work was supported by the UDDHSCSU under Grant PN-JJ78/01.10.2067 and Grant FRII 331/94.57.2067. The associate editor coordinating the review of this article and approving it for publication was Prof. Vesa Valimaki. *(Corresponding author: Jinjun Ming.)*

Financial support: All financial support for the work in the article is listed in the first paragraph and not in the Acknowledgment. Examples of financial support are:

1) This work was supported by the National Science Foundation under Grant 90210 and Grant ECS-12345.
2) This work was supported in part by the Natural Sciences and Engineering Research Council of Canada under Contract 12345 and Contract 702589 and in part by the National Science Foundation.
3) This work was supported by grants from the Muscular Dystrophy Association of America and the Swedish Medical Research Council.
4) If an author/organization requests specific wording, e.g., by National Institutes of Health (NIH), use language provided.

If support was given to a *specific* author, the following wording is used:

The work of C. T. Walsh was supported by the National Institutes of Health.

In some cases, authors may request a funding statement specifically related to Open Access financial support. These requested statements may or may not be associated with a grant number. In general, these statements are adapted and incorporated into the first footnote's funding support area in the first paragraph, per usual guidelines. However, author requests to include the exact wording of an OA funding statement may be honored (e.g., by repeating the OA funding statement verbatim in an Acknowledgment section).

Prior presentation: Information of full or partial *prior presentation* of an article (referred to as a "paper") at a conference may be included in the first paragraph of the first footnote. It may not be necessary, however, to cite prior presentation of a paper at a conference if the paper is appearing in a special issue made up exclusively of papers presented at the conference. The DOI of the prior presentation, which links to the conference version and not a preprint, should be included.

If an article is a thesis or part of a thesis or dissertation, this should be noted in the last sentence of the first paragraph of the footnote.

Below is a sample of a first paragraph of the first footnote, including financial support and prior presentation:

Manuscript received 15 January 2018; revised 10 April 2018; accepted 29 April 2018. Manuscript received in final form on 20 May 2018. Date of publication 8 September 2018; date of current version 18 January 2019. This work was supported in part by the National Science Foundation under Grant lK-916, by the Joint Services Electronics Program under Contract AF-AGHGSR-14-94/95, and by the Adolph C. and Mary Sprague Miller Institute for Basic Research in Science. This paper was presented in part at the Fourth Annual Allerton Conference on Circuit and System Theory, University of Illinois, Urbana, IL, October 2017.

Human/Animal Research

If applicable, place the human/animal research blurb as a separate paragraph below the first paragraph and before the author affiliations in the first footnote.

Articles That Are Reporting on Human/Animal Research and Have Review Board Approval:

This work involved human subjects or animals in its research. Approval of all ethical and experimental procedures and protocols was granted by (Name of Review Board or Committee) (IF PROVIDED under Application No. xx, and performed in line with the (Name of Specific Declaration (IF APPLICABLE/PROVIDED)).

Example:

This work involved human subjects or animals in its research. Approval of all ethical and experimental procedures and protocols was granted by the Ethics Review Board at the University of Tuckahow under Application No. ETH178942, and performed in line with university requirements.

Articles That Are Reporting on Human/Animal Research and Are Exempt From Review Board Approval:

This work involved human subjects or animals in its research. The author(s) confirm(s) that all human/animal subject research procedures and protocols are exempt from review board approval.

Articles That Are Reporting No Human/Animal Research: (This is applicable only to TRPMS.)

This work did not involve human subjects or animals in its research.

Second Paragraph:

Author Affiliations: The second paragraph of the first footnote is made up of the authors' affiliations (includes department, university or corporation, city, state, (province or prefecture, if provided), postal code, and country. Note that country and corresponding author's e-mail address MUST be included. All authors may include their e-mail addresses which would be separated by semicolons.

Examples:

Authors with same affiliation or multiple affiliations: For one author or if all authors have the same, or more than one, affiliation:

The author is with the Department of Electrical Engineering, Rutgers University, Piscataway, NJ 08854 USA, and also with Bellcore, Morristown, NJ 07960 USA (e-mail: author@ieee.org).

The author(s) is (are) with the Laboratory for Information and Decision Systems, Massachusetts Institute of Technology, Cambridge, MA 02139 USA (e-mail: corresponding-author@ieee.org).

Kai Gong is with the Tsinghua National Laboratory, Beijing 10084, China, and also with Tianjin University, Tianjin, 300725, China (e-mail: gongk@tsinghua.edu.cn).

The authors are with the Laboratory for Information and Decision Systems, Massachusetts Institute of Technology, Cambridge, MA 02139 USA (e-mail: firstauthor@mit.edu; IamNext@mit.org; thirdauthor@ieee.org).

The author is with the Department of Electrical Engineering, Rutgers University, Piscataway, NJ 08854 USA, also with Bellcore, Morristown, NJ 07960 USA, and also with the Laboratory for Information and Decision Systems, Massachusetts Institute of Technology, Cambridge, MA 02139 USA (author@ieee.org).

Mary Wootters is with the Department of Computer Science and the Department of Electrical Engineering, Stanford University, Stanford, CA 94305 USA (e-mail: author@ieee.org).

Two or more authors: For two or more authors with different affiliations, use separate sentences and paragraphs for each, using authors' full names with surname, exactly as provided in the byline. Group the authors with the same

affiliation together; list the affiliations according to the order of the first author listed in the byline for each location. E-mail addresses are separated by semicolons.

Examples:

Ling Pei Li is with the Department of Electrical Engineering and the Electronics Research Laboratory, University of California at Berkeley, Berkeley, CA 94720 USA.

Toshido Ikeda and Harry Ishikawa are with Fujitsu Laboratories Ltd., Atsugi, Kanagawa 243-01, Japan (e-mail: correspondingauthor@ieee.org).

The authors are with Fujitsu Laboratories Ltd., Atsugi, Kanagawa 243-01, Japan, and also with the Department of Electrical Engineering and the Electronics Research Laboratory, University of California at Berkeley, Berkeley, CA 94720 USA (e-mail: corresponding-author@ieee.org).

Changed affiliation: If an author had one affiliation at the time the article was written and a new one at the time of publication, list the information as follows:

The author was with the Department of Electrical, Computer, and Systems Engineering, Rensselaer Polytechnic Institute, Troy, NY 12181 USA. He is now with the Institute for Microstructural Sciences, National Research Council, Ottawa, ON K1A 0R6, Canada.

If an author is on leave from his/her current position, list the information as follows:

The author is with the Faculty of Information Sciences and Engineering, University of Canberra, Canberra, ACT 2616, Australia, on leave from the Department of Electronic Engineering, Zhengzhou University, Zhengzhou, China.

Retired author: If an author is retired, list his/her last affiliation and current address (city, state, postal code, and country).

Lisa A. Tepper, retired, was with the Applied Research Laboratory, Bellcore, Morristown, NJ 07851 USA. She resides in Laguna Niguel, CA 92677 USA (e-mail: retiredauthor@yahoo.com).

Deceased author: For a deceased author, add "deceased" after the name and list his/her last affiliation.

Paolo Dorigo, deceased, was with the Progetto di Intelligenza Artificiale e Robotica, Dipartimento di Elettronica e Informazione, Politecnico di Milano, 20133 Milano, Italy.

Consultant: A consultant is treated similarly to a retired author: List the last professional affiliation and current city, state, postal code, and country.

Peter Leff Jr. was with the Department of Biomedical Engineering, University of Virginia, Charlottesville, VA 22908 USA. He resides in Charlottesville, VA 22908 USA.

Additional notes:

- Do not include street addresses of employers. For domestic authors, use official U.S. Postal Service abbreviations for states and include U.S. ZIP codes, and country. Note that there is no comma between the state, ZIP code, and country for U.S. affiliations. Use Canadian Province and international codes as listed in this manual. Also include international cities, countries, and postal codes.
- List department or subdivision first, then company or school. Write out the words "Company" and "Corporation." Abbreviate "Inc." and "Ltd." (One exception to this is Texas Instruments Incorporated.)
- In a book review, to avoid confusion with the author of a book, when listing the affiliation of the reviewer of a book, do not use "The author is with …"; instead, list the reviewer's affiliation ("The reviewer is with …").
- Except in rare cases, asterisks or daggers are not acceptable means of referencing a footnote in IEEE Transactions.

Third Paragraph:

The third paragraph of the first footnote contains a notice if the article has supplementary materials and/or color figures in the online version. The link would always begin with https://doi.org/theFullDOI.

If there is only supplementary material:
This article has supplementary downloadable material available at https://doi.org/10.1109/TFUZZ.2019.2933787, provided by the authors.

If there are both supplementary material and online-only color figures:
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If there are online-only color figures but no supplementary material:
Color versions of one or more figures in this article are available at https://doi.org/10.1109/TFUZZ.2019.2933787.

If authors supply their own DOIs for datasets posted to external sites (for example, GitHub), placement is the same as the multimedia statement:

Data is available on-line at https://doi.org/10.15129/ae577969-aa18-47f2-8dff-df6a20eba41e.

Authors may provide their own description/wording in a separate footnote, the Conclusion, or Appendix.

B. The Body of the Article

Abstract

Every published article must contain an Abstract. All variables should appear lightface italic; numbers and units will remain bold. Abstracts must be a single paragraph.

In order for an Abstract to be effective when displayed on IEEE *Xplore* as well as through indexing services such as Compendex, INSPEC, Medline, ProQuest, and Web of Science, it must be an accurate, standalone reflection of the contents of the article. They shall not contain numbered mathematical equations, numbered reference citations, nor footnotes.

Index Terms

All articles must contain Index Terms. These are keywords provided by the authors. Index Terms appear in alphabetical order and as a final paragraph of the Abstract section. Capitalize the first word of the Index Terms list; lowercase the rest unless capitalized in text. Include the definition of an acronym followed by the acronym in parentheses.

Example:

***Index Terms*—Abstraction, computer-aided system engineering (CASE), conceptual schema, data model, entity type hierarchy, ISO reference model, layered architecture meta model, reverse engineering.**

Note to Practitioners

This is formatted in the same style as Abstracts. It follows the Abstract and is separated by a line space. There may be more than one paragraph.

Example:

***Note to Practitioners*—Abstraction, computer-aided system engineering (CASE), conceptual schema, data model, entity type hierarchy, ISO reference model, layered architectural meta model, reverse engineering.**

Nomenclature

Nomenclature lists (lists of symbols and definitions) generally follow the Abstract and Index Terms and precede the Introduction. This type of list is characterized by the following.

1) The Nomenclature heading is a primary heading without a Roman numeral.
2) The first column of the list is flush left.
3) The second column is aligned on the left.
4) There is one em space from the longest item on the left side to the right side.
5) The first letter on the right-hand side is capitalized.
6) Each item ends with a period.
7) Do not use “is” or “the” at the beginning of items.
8) Do not use equality symbols between the left and right sides.

Equations in an item should be handled as follows.

1) When the equation is at the beginning of an item, align the equal sign with the right-hand side capitals, end the equation with a period, begin the definition with a capital, and end with a period.
2) When the equation is at the end of an item, end the definition with a comma, follow with an equal sign and the rest of the equation, then end with a period as shown in the following example.

NOMENCLATURE

SPQ	Strictly proper pole constraints.
M	Minimal weighted sensitivity.
P(*s*)	Physical feedback.
W	Weighting.
Q	= *P* – 1. Improper function.
S, l	Signal density, = *P, M*.

NOTE: Acronyms defined in a Nomenclature list do not need to be defined again in the text. If the section headings are made up of only previously defined acronyms, we should continue to add the acronym in parentheses next to the definition, as it becomes unreadable otherwise**.**

Text Section Headings

Standard specifications have been established for Transactions text section headings. There are four levels of section headings with established specs: primary (section), secondary (subsect1), tertiary (subsect2), and quaternary (subsect3) heads.

Enumeration of section headings is desirable, but not required. *Primary headings (section)* are enumerated by Roman numerals, centered above text, and set in 10-pt. and 8-pt. caps. Note that Introduction, Conclusion, and Acknowledgment are Singular heads.

Example:

I. INTRODUCTION

Secondary headings (subsect1) are enumerated by capital letters followed by periods (“A.,” “B.,” etc.), flush left, italic, upper and lowercase.

Example:

A. *Formal Frameworks*

Tertiary headings (subsect2) are enumerated by Arabic numerals followed by parentheses. They are indented one em, run into the text in their sections, italic, upper and lowercase, and followed by a colon.

Example:

1) *Sophisticated Local Control:* Sophisticated local control is applied when …

Quaternary headings (subsect3) are identical to tertiary headings, except that they are indented two ems instead of one em, lowercase letters are used as labels, and only the first letter of the heading is capitalized.

Example:

1a) *Communication policies:* Policies developed to improve communication …

Reference and Acknowledgment headings are unlike all other section headings in text. They are never enumerated. They are simply primary headings without labels, regardless of whether the other headings in the article are enumerated.

Example:

REFERENCES

ACKNOWLEDGMENT (note spelling here)

Appendix headings are a special case. The primary heading(s) in the Appendix or Appendixes are set according to the usual style, except that there is flexibility in the enumeration of the heading. Roman numerals as heading numbers (Appendix I) or letters (Appendix A) are acceptable. The Appendix is not preceded by a Roman numeral.

Follow the rules given earlier for labeling subsidiary heads. Note that if there is only one Appendix in the article, leave the Appendix unnumbered and unnamed as is. (Appendix subheads should also not be enumerated in this case.)

Examples:

APPENDIX

APPENDIX I
PROOF OF THEOREM

APPENDIX A
PROOF OF THEOREM

Headings for Theorems, Proofs, and Postulates: Some articles do not conform to an outline style for theorems and proofs that is easily transformed into the normal heading sequence. The preferred style is to set the head giving the theorem number as a tertiary heading (no Arabic numeral preceding) and the proof head as a quaternary head. This rule also applies to Lemmas, Hypotheses, Propositions, Definitions, Conditions, etc.

In-text references to text sections are written: "in Section II" or "in Section II-A" or "in Section II-A1." Capitalize the word "Section." Do not use the word "Subsection"; use "Section" and write out the complete citation. Note that there is no period in Section II-A1 to separate the subsections.

Introduction

Initial Cap or Drop Cap: In full-length articles and/or Editorials (but not in short papers), the first letter of the Introduction is set as an initial cap, two lines deep (drop cap). After the cap, the remaining characters of the word are capitalized, as well as another 1–2 words at most. Do not break up hyphenated words into cap and lowercase sections—extend the caps if necessary. If it is not possible to use the first word or character of the Introduction as an initial cap (i.e., if the article begins with a quotation mark), try rewriting the sentence.

Text Equations

Consecutive Numbering: Equations within an article are numbered consecutively from the beginning of the article to the end. There are some Transactions in which numbering by section, e.g., (1.1), (1.2.1), (A1), is permitted.

Appendix Equations: Continued consecutive numbering of equations is best in the Appendix, but equation numbering that starts over with (A1), (A2), etc., for Appendix equations is permissible.

Hyphens and Periods: Hyphens and periods are accepted, if consistent in the article, e.g., (1a), (1.1), (1-1).

Appendix

Refer to the Appendix in text as "given in the Appendix." Note that the plural of Appendix is Appendixes. Also note that all figures and tables in the Appendixes must be labeled in consecutive order with the other figures in the article.

Acknowledgment

The placement of the Acknowledgment appears after the final text of the article, just before the References and after any Appendix(es). The spelling of the heading for the Acknowledgment section is always singular, with no "e" between the "g" and the "m." As noted previously in the Text Headings section, the Acknowledgment head is a primary heading. Do not enumerate the Acknowledgment heading.

The use of content generated by artificial intelligence (AI) in an article (including but not limited to text, figures, images, and code) shall be disclosed in the acknowledgments section of any article submitted to an IEEE publication. The AI system used shall be identified, and specific sections of the article that use AI-generated content shall be identified and accompanied by a brief explanation regarding the level at which the AI system was used to generate the content. The use of AI systems for editing and grammar enhancement is common practice and, as such,

is generally outside the intent of the above policy. In this case, disclosure as noted above is recommended. An example of this wording is as follows:

Article

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ACKNOWLEDGMENT

Fig. X was created using <AI system used>. <Brief explanation regarding the level at which the AI system was used to generate the content.>

When citing names within the Acknowledgment, drop Mr., Mrs., or Miss (list first initial and last name only). For Dr. or Prof., use the Dr. or Prof. title with each name separately; do not use plural Drs. or Profs. with lists of names.

All acknowledgments of financial support are placed in the first footnote/author affiliation (with a few exceptions of some Transactions).

Any acknowledgments of permission to publish and disclaimers to the content of the work made to/by the author's employer may be added as an Acknowledgment section.

Write the Acknowledgment section in the third person.

Personal notes such as family announcements, proposals, etc., should be deleted from the Acknowledgment.

References

A few guidelines related to the writing of references are summarized here.

The numbering of references is employed by citing one reference per number. Every reference in a Transactions reference list should be a separate number entry. Use of one reference number to designate a group of references is not permitted.

Example:

[37] E. G. Bowen, *Radar Days*, Institute of Physics Publishing, 1987. The literature of WWII radar is vast. Among the most comprehensive references are L. Brown, *A Radar History of World War II: Technical and Military Imperatives*, Institute of Physics Publishing, 1999; S. Swords, *Technical History of the Beginnings of Radar*, Peter Perigrinus, 1986; H. Guerlac, *Radar in World War II*, Tomash Publishers, American Institute of Physics, 1987.

The References should be written as follows:

[37] E. G. Bowen, *Radar Days*. London, U.K.: Institute of Physics, 1987.
[38] L. Brown, *A Radar History of World War II: Technical and Military Imperatives*. London, U.K.: Institute of Physics, 1999.
[39] S. Swords, *Technical History of the Beginnings of Radar*. Stevenage, U.K.: Peregrinus, 1986.
[40] H. Guerlac, *Radar in World War II.* New York, NY, USA: Tomash Publishers/Amer. Inst. of Physics, 1987.

In the text, the following footnote would be added after the citation for ref. [37]:

"The literature of WWII radar is vast. Among the most comprehensive references are [38], [39], [40]."

Any references to the original refs. [38], [39], and [40] would be changed to [41], [42], and [43], respectively.

Footnotes or other words and phrases that are part of the reference format do not belong on the reference list. These full footnotes or extraneous phrases must always be removed from the list, changed into text or footnotes on the appropriate page, and the references renumbered (renumber reference citation in text as well). Even the words "For example" should not introduce references in the actual list, but should instead be included in parentheses in text (or in a footnote), followed by the reference number, i.e., "For example, see [5]."

Do not say "in reference [1] …"; rather, the text should be written to read simply, "in [1] …" The author's name should not be included in a text reference with a number (i.e., "In Smith [1]") and should be changed to "in [1]" except in such cases where the author's name is integral to the understanding of the sentence (e.g., "Smith [1]

reduced calculated time …"). Reference dates should not be used as reference identifiers and should be deleted in text except in rare cases where the date is somehow relevant to the article's subject.

Do not refer to a specific figure of a reference or to a specific page or equation from a reference. To avoid confusion, rewrite phrases such as "in Fig. 2 of reference [1]" to the IEEE cross-reference notation "in [1, Fig. 2]." Similarly, rewrite phrases such as "in equation (8) of reference [1]" to be [1, eq. (8)]. Other phrases may be rewritten as [1, Sec. IV], [1, Th. 4.2], or [1, Ch. 3].

If listing the same reference more than once on the reference list, giving a new reference number for each page or part of the same source that is cited, these separate references should all be made into one reference and the separate citations of pages, equations, etc., should be made in text using the notation explained in the previous paragraph.

If a reference author's name is mentioned in the text, check its spelling against the reference list.

Text Citation of Figures and Tables

Use of the Lena Image ***(EFFECTIVE 1 April 2024)***

IEEE's diversity statement and supporting policies such as the IEEE Code of Ethics speak to IEEE's commitment to promoting an inclusive and equitable culture that welcomes all. In alignment with this culture and with respect to the wishes of the subject of the image, Lena Forsén, IEEE will no longer accept submitted papers which include the "Lena image."

All first citations of figures and tables in the article must be in numerical order. Citations to figures in text always carry the abbreviation "Fig." followed by the figure number. The abbreviation is used even when it begins a sentence. Figure footnotes should be placed as part of the caption.

Figures: The general style for captions is such that each caption number should be cited with the abbreviation "Fig." and the number, followed by a period, an em space, and then the text of the caption. The first word of the caption should always be capitalized, regardless of any style that may be chosen to list caption parts (a), (b), etc., if included. If you are citing Fig. 1(a) and 1(b), the singular "Fig." is still used. In general, do not use A, An, or The at the beginning of a figure or table caption.

Example:

Fig. 1. Theoretical measured values of n.

There are several acceptable styles for listing the parts of the figure in the caption. Be consistent within each article, but otherwise use whichever style is most convenient for the figure. Regardless of which caption notation is used, the citation of (a), (b), etc., should always appear before the corresponding caption part.

Examples:

Fig. 1. Intercomplex crosstalk characteristics. (a) Electrode transmission. (b) Interelectrode crosstalk.

Fig. 2. (a) Variation of effective mode index with time. (b) Step-index change.

Fig. 3. Output resistance as a function of channel doping for 1-m-long gate. (a) InGaAs and (b) InP JFETs with pinchoff voltage as a parameter.

Fig. 4. (a) and (b) Plain and side views, respectively, of the experimental setup used to measure the effective diffraction loss which can be achieved using the feedback technique.

Fig. 1. (a) Electrode transmission. (b) Interelectrode crosstalk.

If parts of a figure after reduction will run the length of more than one page, the full descriptive part of the caption should be cited with the first part of the figure followed by the corresponding caption for the part. On the subsequent pages, the word (*Continued.*) will be placed under the carryover parts of the figure followed by a repeat of the full descriptive part of the caption and the corresponding caption for the carryover parts.

Captions for Landscape/broadside figures: The text should appear below the figures and facing outward at all times.

Examples:

Fig. 6. True and estimated spectra for a real data sequence. (a) True spectrum.

Fig. 6. (*Continued.*) True and estimated spectra for a real data sequence. (b) Estimated with the periodogram.

Tables: The general style for table captions is such that each caption number should be centered above the table with the label TABLE and the enumeration given in Roman numerals. The descriptive text of the caption should be centered directly below the table number caption

The descriptive text of the table caption does not contain a period at the end of the caption, although punctuation may be necessary within the caption itself. In general, table captions should be set as an inverted pyramid.

The style for listing the parts of a table in the caption and in text depends on whichever style is most convenient for the table. The most acceptable style is to follow the conventions for callouts of figures.

Example:

TABLE I
PARAMETER VALUES

TABLE II
OPTIMAL WAVELENGTH AS A FUNCTION OF POLARIZER ANGLE. (a) WAVELENGTH FOR EXTERNAL CAVITY. (b) ESTIMATED WAVELENGTH FOR LASER DIODE

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IEEE Transactions author biographies are generally divided into three paragraphs. However, if appropriate information for each paragraph is not available, the biography may be only one or two paragraphs. QR codes are not accepted in place of biographies and/or photographs (we will not send readers to a destination for which we cannot be confident of long-term accessibility).

Always defer to the pronoun or title provided by the author. If provided as "they" and "them," do not change to be singular; these should be considered non-binary singular pronouns.

The biography begins with the author's full name and IEEE membership history. The author's name appears in boldface type and must match the byline. A nickname or maiden name may appear within parentheses, e.g., Sung-Mo (Steve) Kang or Jane (Smith) Jones, but not in the byline. List current IEEE membership only; this is written out in full and should match the byline exactly.

Note that affiliate memberships are neither listed in the byline nor biography membership history.

Abbreviations for IEEE membership grades are S (Student Member), GS (Graduate Student Member), A (Associate Member), M (Member), SM (Senior Member), F (Fellow), LA (Life Associate Member), LM (Life Member), LSM (Life Senior Member), and LF (Life Fellow). Note that A stands for Associate, not Affiliate, Member. Affiliate memberships are not listed in the byline or biography membership history.

Do not include references to IEEE membership from the text of the biography.

Author photographs should be professional images of the head and shoulders. Current photographs are encouraged; baby and family photographs should not be used.

First Paragraph: The first paragraph may contain a place and/or date of birth (list place, then date). Next, the author's educational background is listed. When listing degrees earned, the biography should state "[S]he received the Ph.D. degree from …" (not "[S]he received [her] his Ph.D. degree from …"). Always add the word "degree" after a degree title. Include the years degrees were received. Abbreviations for some common international and domestic degrees are:

Dipl.Ing., Diplom-Physiker, Dr. Ing., Dr. Phil., Dr. Eng., B.S., S.B., B.Sc.(Hons.), B.E.E., B.S.E., M.Eng., M.Sc.(tech.), M.S.E.E., M.S.E., Civilingenir, Lic.es Sci., Lic.es Lett.

Add the full locations (city, state, country) of universities and colleges the first time they are mentioned. For U.S. state-named universities, repeat the state name in the location, and include the country (e.g., University of Colorado, Boulder, CO, USA); for city-named universities, repeat the name of the city when giving the location (e.g., University of Chicago, Chicago, IL, USA). For universities outside the U.S., give locations with the name of the city (postal abbreviations of Canadian Provinces, if used) and the country the first time.

Use lowercase for the author's major field of study.

Second Paragraph: The second paragraph of the biography lists military and work experience, including summer and fellowship jobs and consultant positions. Job titles are capitalized. The current job must have a location (city, state, country); previous positions may be listed without one. Do not abbreviate city names, Company, Laboratory, or Department. Use standard names for all countries. If there is space, information the author provides about previous publications may be included at the end of this paragraph. Edit out long lists of published books or articles. Instead use the sentence "s(he) is the author of several books and numerous published articles." The format for listing publishers of an author's books within the biography is: *Title of the Book* (publisher name, year) similar to a reference. (Note, use the word "titled" not "entitled" to introduce the book [e.g., He is the author of the book titled *Stochastic Analysis and Applications* (Taylor & Francis, 2012)]. List author affiliations with non-IEEE journals. Note IEEE Transaction and Journal Titles should be in small caps; *IEEE Magazine Titles* should be in italics; and non-IEEE titles should be in italics. List previous and current research interests. Do not repeat the author's name in the second paragraph; use "he" or "she."

Third Paragraph: The third paragraph begins with the author's title and last name (e.g., Dr. Smith, Prof. Jones, Mr. Kajor, Ms. Hunter). It lists the author's memberships in professional societies other than the IEEE and his or her status as a Professional Engineer if applicable. Finally, list awards and work for IEEE committees and publications, affiliation with other professional societies, and symposia.

Personal notes such as hobbies should not be included in the biography. Authors may include an external link to their work, this should appear as "For more information, see http://website.of.author" This should be the full URL and not an abbreviated link.

Examples:

Michael C. Author Jr. (Fellow, IEEE) was born in New York, NY, USA, in 1969. He received the B.S. degree in applied mathematics from the University of Michigan, Ann Arbor, MI, USA, in 1989, the M.S. degree in mathematical physics from Stanford University, Stanford, CA, USA, in 1991, and the Ph.D. degree in electrical engineering from the Massachusetts Institute of Technology, Cambridge, MA, USA, in 1995.

From 1993 to 1995, he was with Raytheon Corporation, Bedford, MA, USA. From 1995 to 1996, he was with the General Electric Space Laboratory, Valley Forge, PA, USA. From 1996 to 1997, he was a Fulbright Lecturer at the University of Madrid, Madrid, Spain. He is currently an Associate Professor of electrical engineering at the University of Maryland, College Park, MD, USA. His research has been concerned with reentry plasma effects and microwave diagnostics of plasmas.

Dr. Author is a Registered Professional Engineer in the State of Pennsylvania. For more information, see http://website.of.author.

Katsunari Okamoto was born in Hiroshima Prefecture, Japan, in 1949. He received the B.S. degree from Rutgers University, New Brunswick, NJ, USA, in 1979, and the M.S. degree from Monmouth University, Long Branch, NJ, USA, in 1984.

He was a Postdoctoral Fellow at the University of Tokyo, Japan, in 1978. He joined the Ibaraki Electrical Communication Laboratory, N.T.T., Ibaraki-ken, Japan, in 1979, where he was engaged in research on the optimum waveguide structure of optical fibers. At present, he is a Member of Technical Staff at Bellcore, Red Bank, NJ, USA.

Dr. Okamoto is a member of the Institute of Electronics and Communication Engineers of Japan.

Squibs

If the author chooses not to publish his/her biography and photograph, a squib is used. Example:

James A. Author (Fellow, IEEE), photograph and biography not available at the time of publication.

If *all* authors of the article opt not to publish his/her biography and photograph, no squib is used.

C. Other Text

Inclusive Language

To avoid the use of insensitive terms/phrases, please refer to the Inclusive Language Guide in the Appendix for replacement text. Use “people-first language,” i.e., the person has X; has been diagnosed with X; uses a X; etc.

Footnotes

Footnotes should be numbered in consecutive order throughout the text. Each footnote should be a new paragraph. The footnote numbers are superscripts in text and in the actual footnotes. In text, place the superscript footnote numbers after punctuation such as periods, commas, parentheses, and quotation marks, but generally before dashes, colons, and semicolons in a compound sentence. The footnotes should be placed at the bottom of the text column in which they are cited.

Lists in Text

There are three types of lists in text: run-in lists, displayed lists, and where lists. The ordering of labeling for all lists is 1), 2), 3) followed by a), b), c), and then i), ii), iii). Note the single (ending) parenthesis. The order of indentation is 1 em, 2 ems, 3 ems.

Run-In Lists: Lists that run in with text must be grammatically correct. They must also be introduced by a colon, separated by semicolons, and have parallel construction. Example:

> The carrier–phonon interaction matrices are given by: 1) polar optical phonons; 2) deformation potential optical phonons; and 3) piezoelectric acoustic phonons.

Displayed Lists: Lists that are displayed may be either incomplete sentence items or full sentence items. Incomplete sentence items contain a few items, are very short, are grammatically parallel, and are handled in two ways. If the items are not mentioned in the text or are fewer than three items, run in as shown in the example for run-in lists. If, however, the items are mentioned later in the text, introduce the item with a colon, number the items, begin the entry with a lowercase letter, and set block paragraph style. Use semicolons between items and a period at the end of the list. Example:

This operating scenario provides all of the contributors necessary to configure a resonant power distribution system:

1) implementation of capacitor power factor correction on the power line;
2) presence of nonlinear load;
3) tuning of the power line by the load adjustments to a frequency present in the nonlinear generator.

Incomplete sentence items that are mentioned in text may also be formatted as shown in the example for full sentence items.

Example:

The three problems are related in the following sense:
1) Additional cost constraint;
2) Relaxation of the constraints is permitted;
3) Limited budget optimization is a general optimization problem.

Full sentence items may be introduced by “that” or other words taking object and end with a period. Number all items, start each entry with a capital letter, and end with a period. Example:

The synthesis is performed in three major steps.

1) Geometry is generated for the selected module variants.
2) Shape variants using different fold counts for resistors are generated for each module.
3) Routing and postprocessing complete the final layout.

Where Lists: Where lists define variables in the equations preceding the list. They are characterized by incomplete sentences and follow the same rules as *Nomenclature* lists, with the following exceptions.

1) There is no primary heading.
2) The left-hand side is indented one em space.
3) The first letter on the right-hand side is lowercase.

4) Each item ends with a semicolon (except for the last item, which ends with a period).
5) The lists are at least three items long; if fewer than three items, the list is generally run in paragraph form.

Example:

where

$\Delta\upsilon_S = \Delta V_S \cos(\omega' t + \phi')$;

ΔV_S amplitude of supply voltage flicker;

ω' angular frequency of supply voltage flicker;

V_{Sf} supply voltage amplitude;

ω supply angular frequency.

Note the alignment of the equal sign with the right-hand side.

Lists having mixed items (start with an incomplete item, then have a full sentence explanation) are treated as a full sentence item list.

Dedication Line(s)

Dedication lines are usually run on the first page of an article, immediately above the Abstract.

Example: *Dedicated to the work of J. W. Walters.*

Note Added in Proof

One may wish to add a brief note in the proof stage, citing results obtained after acceptance of the article or mentioning additional references that have come to their attention since the article was accepted. This added information is usually inserted at the end of the Conclusion section of the article or in whatever section contains the last paragraph of the main body of the article. As long as the note is not a major change to the article or more than a few lines long, the addition generally does not require further review procedures. Use the tertiary heading "Note Added in Proof:" (run into text), but set in boldface italic with no enumeration and an em space indent.

Examples:

Note Added in Proof: The author is an owner of the company which manufactured the tubes used in these experiments.

Note Added in Proof: Additional information about similar research can be found at www.newreseachresults.com.

D. Other Types of Papers

Editorials

This category of papers includes the various types of introductory papers, such as Editorials, Guest Editorials, Forewords, Introductions, and Editorial Announcements that appear at the beginning of issues as nontechnical introductory material. The Editorial may contain illustrations, citations, and references. Citations to articles in the issue should be listed as "Related Works" instead of in the reference section. It may contain a photograph and biography of each guest editor when it is a Guest Editorial for a special issue or section. An acknowledgment does not contain a heading. *Note:* In the Editorial, the Acknowledgment does not need to be written in third person and there is no Abstract.

Byline: Note that the byline for the Editorial does NOT appear below the title as it does in a full-length article. The name of the author of the Editorial or Foreword (usually the Editor or Guest Editor) (called "signature") appears at the end of the Editorial.

Example:

MARVIN K. SAIN, *Guest Editor*
Department of Electrical Engineering
University of Illinois
Urbana, IL 60617 USA

Brief Papers

These articles contain Abstracts and an initial cap. The byline includes the membership grade. They do not contain biographies and photographs of the authors.

Short Papers, Letters, Correspondence, and Communications

Short papers are set up like full-length articles. The membership grade is not included in the byline. Author biographies and photographs are not included. Footnotes, captions, and references may be included.

Letters are a type of short paper that have a strict low page limit and appear at a back section of an issue. Note that these letters are not the same as research letters formatted as regular papers without biographies that make up entire volumes or issues (e.g., IEEE Antennas and Wireless Propagation Letters, IEEE Electron Device Letters, etc.).

Correspondence and communications also use the short paper format, but are typically only a few paragraphs in length. These include letters to the editor.

Comments and Replies

Comments are generally in response to a previously published article. The Comments and Author(s) Reply are short papers published together in that the "Reply" is in response to the Comments. These short items may appear without Abstracts. A special format applies for Comments and Author(s) Reply. Begin the first sentence with "In the above article [1], ..." Reference [1] is the commented article's citation and will appear as Reference [1] in the References section.

Some publications refer to these articles as Discussions and Closures. Index Terms are optional.

Example of the Comments:

Title: Comments on "Harmonics: The Effects on Power Quality and Transformers"

Byline: Keith H. Sueker

Footnote:
Manuscript received 15 July 2006.
The author is with the School of Engineering, Vanderbilt University, Nashville, TN 37235 USA (e-mail: k.sueker@ieee.org).
Digital Object Identifier 10.1109/JQE.2006.12345

NOTE: The footnote here relates back to the original article being commented upon. The title is not repeated.

Example of the Reply:

Title: Authors' Reply

Byline: Robert D. Henderson and Patrick J. Rose

Footnote:
Manuscript received 3 October 2006; accepted 5 October 2006. Date of publication 2 November 2006; date of current version 25 November 2006.
The authors are with RDH Consultants, Inc., Charlotte, NC 28241 USA (e-mail: corresponding@author.com).
Digital Object Identifier 10.1109/JQE.2006.12348

Corrections/Errata/Addendums

The format for a Corrections, Errata, and Addendums is basically the same as for the Comments, except that a Corrections/Errata/Addendum does not carry a Reply. All run a copyright line. A *Correction* is a notice that makes note of an error by the author in their original writing. An *Erratum* is a notice of an error introduced by the publisher. An Addendum is an additional, short statement that relates to/supplements the published article. It should follow the standard format of a Correspondence.

Note: The plural form of the word is used in the title, even if there may be only one correction. All Corrections/Errata ***must*** carry the byline as the same form as the original article; this ensures that the two articles will be linked properly.

Example of a "Corrections" article:

Title: Corrections to "On the Exact Realization of LOG-Domain Elliptic Filters Using the Signal Flow Graph Approach"

Byline: Costas Psychalinos and Spiridon Vlassis

Footnote:
Manuscript received 1 May 2003.
The authors are with the Physics Department, Electronics Laboratory, Aristotle University of Thessaloniki, GR-54124 Thessaloniki, Greece (e-mail: cpsychal@physics.auth.gr; svals@skiathos.physics.auth.gr).
Digital Object Identifier 10.1109/TCSII.2003.814788

Example of an Erratum:

Title: Erratum to "Harmonics: The Effects on Power Quality and Transformers"

Byline: Robert D. Henderson and Patrick J. Rose

Footnote:
Manuscript received 20 January 2004.
The authors are with RDH Consultants, Inc., Charlotte, NC 28241 USA (e-mail: pjrose@rdh.com).
Digital Object Identifier 10.1109/TVLSI.2004.830244

Example of an Addendum:

Title: Addendum to "Harmonics: The Effects on Power Quality and Transformers"

Byline: Robert D. Henderson and Patrick J. Rose

Footnote:
Manuscript received 20 January 2004.
The authors are with RDH Consultants, Inc., Charlotte, NC 28241 USA (e-mail: pjrose@rdh.com).
Digital Object Identifier 10.1109/TVLSI.2004.830244

Book Reviews

Some publications carry Book Reviews. They are the same as a short paper or correspondence; however, the title runs additional information about the book that is being reviewed. The title is separated from the book's author by an em dash. Included in parentheses is the city of publication, publisher, date of publication, the total number of pages of the book, and the price. Outside of the parentheses is the reviewer's name in italics. Some Transactions carry a short biography of the reviewer under the title. Book Reviews appear in the table of contents with a listing for both the author of the book and the reviewer. Example:

Title and Byline:
The Analysis and Design of Pneumatic Systems—B. L. Andersen. (New York: Wiley, 1987, 302 pp., $65.00.) *Reviewed by J. L. Shearer.*

First Footnote:
The reviewer is with the College of Engineering, Idaho State University, Pocatello, ID 83209 USA. Digital Identifier 0090-6778/TNN.2005.828433.

Table of Contents:
The Analysis and Design of Pneumatic Systems—B. L. Andersen .....*Reviewed by J. L. Shearer* 123

Obituaries/In Memoriam

Obituaries are usually run as the first page of an issue, like an Editorial. They are set up with the same specs as Editorials.

E. Writing Style for Transactions

The following provides a summary of the most important style distinctions to be made in the writing of a Transactions article.

Acronyms

Define acronyms the first time they appear in the Abstract as well as the first time they appear in the body of the article, written out first as part of the sentence, followed by the acronym in parentheses. Widely used or familiar terms should be defined (see the Common Acronyms and Abbreviations list in the Appendix for some terms that must be defined the first time they are used in text). Acronyms do not need to be defined in the text if mentioned in the Nomenclature. Coined plurals or plurals of acronyms do not take the apostrophe as per *Chicago Manual of Style*. Example: FET (singular); FETs (plural).

Indefinite articles are assigned to abbreviations to fit the sound of the first letter: an FCC regulation; a BRI.

Spelling

Note that IEEE Transactions use the first spelling of a word as given in the main entry of *The Merriam-Webster Dictionary.*

British Spellings and Terminology: Change all British spellings to American spellings. In particular, watch for "our" endings in words like "behaviour" (change to "behavior") and "re" endings in words like "centre" (change to "center"). Also watch for the use of "s" rather than "z" in words like "polarisation" (change to "polarization"). See "Common Hyphenations and Misspellings" in the Appendix.

Trademarks

The trademark symbols ™ and ® are no longer used. Capitalize the first letter in the trademark name only. The symbols ™ and ®, which often accompany registered trademark names on product packaging and in advertisements, need not be used in running text. Optionally, for the first occurrence of a trademarked product, a footnote superscript can be placed after the trademarked name, with a matching footnote that reads "Trademarked." or "Registered trademark."

Plurals

Plurals of units of measure take the "s." For example, the plural form of 3 mil is 3 mils; 3 bits/s instead of 3 bit/s. The plural of calendar years do not take the apostrophe before the "s." For example, the plural form of 1990 is 1990s.

Hyphenation Rules

For hyphenation and spelling guidelines, IEEE style follows: 1) the list of preferred spellings and hyphenated words can be found in the Appendix; 2) the guidelines discussed in the Grammar and Usage in Transactions section of this guide; and 3) the first version of the spelling given in the most recent edition of *The Merriam-Webster Dictionary*. Do not hyphenate most compound modifiers if they occur after the noun being modified, even if hyphenating them before the noun.

Examples:

The plan was well prepared. The man was little known. The woman was better qualified. His boat was 42 feet long. He has a 42-foot-long boat. T was the data period of the 40-Gb/s data signal. The 160-GHz MLLD was a diode in which a 40-nm-long saturable absorber was located.

NOTE: Do not use the *IEEE Standards Dictionary* for hyphenation guidelines as no attempt is made there for consistency in hyphenation. The *Standards Dictionary* is quite useful for its definitions and acronyms list in its back section.

The most important hyphenation guideline is to be certain that the hyphenation for a particular word or group of adjectives is consistent within a particular article.

The En, Em, or Two-Em Dash

The en dash represents the words "to," "through," or "and." Use it between page numbers, reference numbers, figure citations, academic years, proper nouns, names, a range of values, or for opposites.

Examples:

- pp. 10–15,
- 1984–1990,
- Jones–Smith theorem,
- input–output,
- voltage–current curve,
- analog–digital converter,
- 10–20 cm.

Also, use the en dash in chemical abbreviations such as Ni–Al–Si. When using the en dash to represent a range, if the word "from" occurs, the word "to" must be used rather than an en dash (e.g., ranges from 5 to 50 times).

The em dash is used in ordinary writing to mark a suspension of the sense. It is also used like parentheses, to mark a subordinate thought within a sentence.

Grammar

Check closely for lapses of clarity, subject/verb agreement, and parallel clause construction. See the following examples:

Number:

A number of samples were taken …
A number *N* expressing the relation *x/y* is chosen …

Data:

The data were collected … (always plural)

Series:

A series of tests was run … (always singular with "a")

Some, All, Half:

Some (all, half) of it is …
Some of them are …
For example:
Use "all of" with another pronoun, such as "these" or "those," and before singular nouns. For collective and plural nouns, use "all."

Quantity:

Three volts were applied …
Four grams were added …

Contractions

Contractions such as "don't" and "can't" are not used in technical text. Change to "do not" and "cannot."
Note: "don't care," "best-case," and "worst-case" are allowed and used often in journals like TCAD.

Capitalization

In general, discourage capitalization in text except where absolutely necessary. For example, only proper names attached to the names of laws, principles, theorems, etc., get capitalized (Abel's theorem, Newton's first law, etc.). Computer commands are in computer tags and remain small caps; most computer languages (Cobol, Java, LISP, PERL, etc.) are upper and lowercase. Earth should be capitalized when referring to the planet.

Dates

Use the international date format for all dates in the article. Spell out the month. (Note: This does not include references. Continue to follow IEEE Reference Style.)
4 June 2002
23-31 October 2019
3 November 2021–4 December 2021

Percentages and Decimals

Always use the number and the percent sign when dealing with percentages. The percentage symbol is repeated in lists and ranges.
Only 2% of the transformers failed the test.
The students made up 20%-30% of the population.

When using decimal fractions in text, include the zero before decimal if needed for clarity, otherwise omit it. Do not include the zero(s) after the last digit following a decimal:
.25
0.8

Ranges With Units

When reporting ranges, there should be no unit after each number unless the units are different:
40–50 mm
50 inches to 7 feet
2 × 5 cm

Math

Some brief guidelines for writing math are explained here.

1) Variables are set italic; vectors are usually boldface italic.
2) Remove commas around variables in text.
3) Always add a zero before decimals, but do not add after (e.g., 0.25).
4) Check the use of the parentheses and brackets i.e., [0,1).
5) Spell out units used in text without quantities (e.g., "where the noise is given in decibels"). For units appearing with quantities, use the standard abbreviations listed in the Table of Units and Quantity Symbols in the Appendix, and units used as compound adjectives may be hyphenated only if needed for clarity: 10-kV voltage, 5-in-thick glass. Do not insert a hyphen when they are not used as adjectives: a current of 2 A, a line 4 in long, a length of 3.05 mm.
6) Always use a regular space and not a thin space between numbers and units in text.
7) Use thin spaces instead of commas between numbers in tens or hundreds of thousands (e.g., 62 000, 100 000, but 4000).
8) Always make sure μ is μm, "micron" is "micrometer," "submicron" is submicrometer." Always change cycle per second to hertz (Hz); cycle per second may not appear as cycle, cps, c/s, csec.
9) In text, fractions may be broken down (shilled) multiline (built-up) so they can be placed on one line. Sometimes parentheses may need to be added to distinguish between expressions, especially when a minus appears [e.g., $\frac{a}{b-c}$ becomes $a/(b-c)$], $\frac{c-d}{k+4}$ becomes [$(c\text{-}d)/(k+4)$]. This may be done to save space, but is not a necessity.
10) In exponential expressions [e.g., $e^{-(jwt)xyzk}$], there are sometimes long and complicated superscripts. These may be brought down in line with the substitution of "exp" for "e" and the addition of square brackets (e.g., exp[–(*jwt*)*xyzk*]).
11) Distinguish between lowercase italic "ell" or "oh" versus one and zero.
12) Always use numerals for numbers written with units. Otherwise, spell out numbers below 11, and use numerals for others unless they begin a sentence or are combined in a phrase (gives 7 to 13 times more).
13) Use zeroth, first, *n*th, (*k* + 1)th, not 1st, 2nd, (*k* + 1)st, etc.

14) Use the word “Equation” at the start of a sentence, but in text, just use the number [e.g., in (1)].
15) Use the $ symbol versus “dollars” in sums of money.
16) The slash (/) is acceptable in place of the word “per” when it lends to the clarity of the sentence. For example: “the ratio of 16 samples/s to 35 samples/s as compared to …”

Ellipses: In mathematics, you may use dots (ellipses) to show continuation in an expression (e.g., x_2, ..., x_{16}). The type of mathematical expression will determine whether the ellipses points are set on the baseline or centered. If commas or operational signs are present, they are placed after each term and after the three ellipses points. If operational signs are used, the ellipses are centered on the operator. When commas are used, the ellipses are on the baseline. Example:

$x_1, x_2, \ldots, x_n$ not $x_1, x_2 \ldots x_n$
$x_1 + x_2 + \ldots + x_n$ not $x_1 + x_2 + \ldots x_n$
$y = 0, 1, 2, \ldots$ not $y = 0, 1, 2 \ldots$
$x_1 x_2 \ldots a_n$ not $x_1 x_2 \ldots a_n$

Conditions: In displayed equations, a comma or parentheses and a two-em space is inserted between the main expression and the condition following it. Example:

$$x = yn^{-2} \qquad \forall n = 3$$

$$x = yn^{-2}, \qquad \text{if } n = 3 - y^{-4}.$$

$$x = yn^{-2}, \qquad y = 3, \square, m$$

NOTE: There is no comma before a for all “ $\forall$ ” symbol.

Compound Units: Compound units should be separated by a center dot (e.g., 4 V · s), but a slash may be used since this has a different meaning (for instance, 6 V/s means volts per second). It is also possible to use a negative power to put a unit in the denominator: cm/s^2 = cm · s^{-2}. Parentheses may be used to clarify a unit: g/(cm · s) or g · cm^{-1} · s^{-1}.

Use of Periods and Commas: Equations which conclude a sentence should end with a period. The only time punctuation is used to lead into an equation is when the lead-in text is a complete sentence. Example:

where we had the following:

$$x = Y + Z.$$

or where, i.e.,

$$x = Y + Z.$$

Commas appearing at the ends of equations are deleted unless they are critical to the punctuation of the sentence containing the equation.

Equation Numbers

Equation numbering should be consecutive, should appear flush right on line with the last line of an equation, should not have repeats or missing numbers, and should use a correct numbering style.

Displayed Equations

Material in displayed equations is automatically italic unless you indicate otherwise. Some simple general rules apply. All variables are italic. Function names and abbreviations are Roman, as are units, unit abbreviations, complete words, and abbreviations of words. Superscripts and subscripts follow this same formula: when they are variables, they are italic; when they are abbreviations of words (such as “in” and “out” for input and output), they are Roman. Single-letter superscripts and subscripts may be italic even if they are abbreviations, unless this leads to inconsistency between italic and Roman characters for similar types of subscripts.

F. General Layout Rules

1) Figures and tables are placed at the tops of columns as close to their first mention as possible, but preferably after the mention.

2) Figures and tables progress vertically, not horizontally, on pages.
3) Footnotes must appear at the bottom of the column where they are first mentioned.

III. GRAMMAR AND USAGE IN TRANSACTIONS

A. Rules of Grammar

The principles of style below focus on fundamentals of modern usage. Particular emphasis is given to the rules most commonly violated.

1) **Form the possessive singular of nouns by adding "s"** (*Avogadro's theorem*). Follow this rule unless the final consonant is an s (*Burns' theorem*). Possessive pronouns (*hers, its, yours, theirs, ours*) have no apostrophe. Indefinite pronouns use the apostrophe to show possession (*someone's rule*). Contractions use an apostrophe (*it's for …*; *it is*). Possessives do not (*its losses*).
2) **In a series of three or more terms, use a comma immediately before the coordinating conjunction** (*usually and, or,* **or** *nor*).
3) **Enclose parenthetic expressions between commas** (*Improvement, as shown in Fig. 1, is attained by the addition of the cogeneration*). Brief phrases or single words, such as *however*, may or may not be parenthetic (such connectives at the head of a sentence are more commonly left unpunctuated). The commas may be omitted if the interruption to the flow of the sentence is slight. In this case, never omit one comma and leave the other. Remember that many seemingly single commas stand for a pair. Clauses or phrases at the beginning or end of sentences do not look parenthetical, but often they might just as well be placed in the middle, in which case they would be found punctuated at both ends. At the beginning of a sentence, such an element is set off by what should be thought of as the second comma in a pair. For instance, note the three possible positions illustrating a parenthetical element of this kind: *However the sum may later change, it is calculated now/The sum is calculated now, however it may later change/The sum, however it may later change, is calculated now.* In all three examples, the meaning remains constant; the single commas of the first and second sentences have the same parenthetical function as the paired commas of the third.

   Parenthetic material such as dates take the comma(s) as follows: *14 February 1996* or *April to June 1996* or *Saturday, 9 March 1996.*

   The abbreviations etc., i.e., and e.g., are parenthetic and use the comma as follows: cables, transformers, etc., are needed. Abbreviations for academic degrees, titles following a name, and certain restrictive terms of identification should be punctuated as follows:

   Robert D. Lorenz, Ph.D.

   Ian T. Wallace, Member, requests that…

   E. A. Brockmann Jr. states that…

   Restrictive clauses are not parenthetic and are not set off by commas: *The proof that (or which) (restrictive clause should be "that" while nonrestrictive is "which"; "who" can be restrictive or nonrestrictive, depending on how it is used) is given in this section is not complete.*

   Nonrestrictive clauses are parenthetic and are set off by commas: *The address i, which is the starting address of the message, is then transferred to a queue list on the processing part …*

   The nonrestrictive clause always takes "which" and is surrounded by commas. The restrictive clause can take "that" or "which"; "that" is preferred.
4) **A semicolon is used to link two independent clauses with no connecting words. You can also use a semicolon to join two independent clauses together with one of the following conjunctive adverbs: however, moreover, therefore, consequently, otherwise, nevertheless, thus, etc.**
5) **Use a colon after an independent clause to introduce a list.**
6) **Punctuation always goes inside quotation marks, except for the colon and semicolon.** Use single quotation marks around quotes within quotes. Quotes may be used around a new or special usage of a term the first time only, but use of quotes in this manner should be kept to a minimum.
7) **Direct quotes should be set in quotation marks in roman font.** Text should not be in italics.
8) **Do not use double parentheses in text expressions, but keep them in math.** For example, (see (10)) should become [see (10)].
9) **All acronyms and numerical plurals do not use apostrophes,** i.e., *FETs, 1980s* (Note: Some exceptions may apply in mathematical writing.)
10) **Compound nouns made from a one-syllable verb and a short adverb are one word when found that way in the dictionary** (setup, takeoff, breakup). Compound nouns are likely to be two words, without a hyphen, or one word (bandwidth, bypass, flowchart, phase shift, sideband, standing wave). Compound nouns of more than two words can be hyphenated.

11) **A pair of words, modifying a third word separately, does not get a hyphen** (a tall water tower, a hot metal cylinder). If the first word modifies the second, and the pair together modify the third, there is a hyphen between the pair (a highfrequency signal, a secondorder equation). The exception to this is the adverb ending in "ly," which needs no hyphen to join it to the next word.
12) **A hyphen is not used after the comparative or the superlative** (a higher order equation, a worst case value, nearest neighbor method). Do not hyphenate chemical compounds (sodium chloride crystals). Alloys and mixtures take the en dash (Ni–Co, He–Ne laser).
13) **Do not use commas between adjectives** (a planar equiangular spiral antenna).
14) **Do not hyphenate predicate adjectives** (… is well known, …is second order).
15) If you are unsure, check *The Merriam-Webster Dictionary* to see if words are hyphenated.
16) **Compound verbs are generally hyphenated** (arc-weld, freeze-dry). Keep the hyphen when using the participles of such verbs as adjectives (freezedried, arcwelded). However, verbs with up, out, down, off, on, etc., do not have a hyphen, although the nouns formed from them may be hyphenated or one word (verb: set up, break down, read out; noun: setup, breakdown, readout).

Words Often Confused

Affect: to change or modify (verb).
Effect: result (noun); cause (verb).

Alternate: a substitute.
Alternative: a matter of choice.

Among: involves more than two things.
Between: involves more than two things, but considers each individually.

Compare to: point out resemblances between different objects.
Compare with: point out similarities and differences between same objects.

Compose: to make up or form: a set composed of members.
Comprise: to be made up of; to be formed by: a set comprising members; members comprising a set.

Farther: distance.
Further: quantity.

Fewer: modifies plural nouns specifying countable units, e.g., fewer tubes.
Less: modifies singular mass nouns and singular abstract nouns, e.g., less air.

Imply: something suggested though not expressed.
Infer: something deduced from evidence.

Number: used when objects can be counted: a large number of people.
Amount: used when objects cannot be counted: a large amount of water.

Principal: chief, main, most important (adjective).
Principle: a rule (noun).

Precede: come before.
Proceed: continue, advance.

That: (defining, restrictive).
Which: (nondefining, nonrestrictive)

IV. APPENDIX

A. Some Common Acronyms and Abbreviations

NOTE: Asterisks (*) indicate terms which must be defined the first time they are used in text. Other terms listed here may be used without definition.

#	
1-D	one-dimensional
2-D	two-dimensional
3-D	three-dimensional
4-D	four-dimensional
A	
ac	alternating current
A–D, A/D	analog-to-digital
AF	audio frequency*
AFC	automatic frequency control*
AGC	automatic gain control*
AM	amplitude modulation
APD	avalanche photodiode
AR	antireflection*
ARMA	autoregressive moving average*
ASIC	application-specified integrated circuit*
ASK	amplitude shift keying
ATM	asynchronous transfer mode
av	average (subscript)*
avg	average (function)
AWGN	additive white Gaussian noise*
B	
B–E	base–emitter source
BER	bit error rate*
BPSK	binary phase-shift keying
BWO	backward-wave oscillator*
C	
c.c.	complex conjugate (in equations)
CCD	charge-coupled device*
CDMA	code division multiple access*
CD-ROM	compact disk read-only memory
CIM	computer integrated manufacturing*
CIR	carrier-to-interference ratio*
CMOS	complimentary metal–oxide–semiconductor
CPFSK	continuous phase frequency-shift keying*
CPM	continuous phase modulation*
CPSK	continuous phase-shift keying*
CPU	central processing unit
CRT	cathode-ray tube
CT	current transformer*
CV	capacitance–voltage
CW	continuous wave*
D	
dc	direct current
DC	directional coupler

DF	direction finder*; deuterium fluoride; degree of freedom*
DFT	discrete Fourier transform*
DMA	direct memory access*
DPCM	differential pulse code modulation*
DPSK	differential phase-shift keying*
E	
EDP	electronic data processing
EHF	extremely high frequency*
ELF	extremely low frequency*
EMC	electromagnetic compatibility*
EMF	electromotive force*
EMI	electromagnetic interference*
ems	expected value of mean square*
F	
FDM	frequency division multiplexing*
FDMA	frequency division multiple access*
FET	field-effect transistor
FFT	fast Fourier transform*
FIR	finite-impulse response*
FM	frequency modulation
FSK	frequency-shift keying*
FTP	file transfer protocol
FWHM	full-width at half-maximum*
G	
GUI	graphical user interface
H	
HBT	heterojunction bipolar transistor
HEMT	high-electron mobility transistor
HF	high frequency
HTML	hypertext markup language
HV	high voltage
HVdc	high voltage direct current
I	
IC	impedance compensation*; integrated circuit
ID	inside diameter; induced draft*; interdigital*
IDP	integrated data processing*
IF	intermediate frequency
IGFET	insulated-gate field-effect transistor
i.i.d.	independent identically distributed*
IM	intermediate modulation
IMPATT	impact ionization avalanche transit time (diode)
I/O, I–O	input–output
IR	infrared
IR	current-resistance
ISI	intersymbol interference
I–V	current–voltage
J	
JFET	junction field-effect transistor
JPEG	Joint Photographers Expert Group
L	
LAN	local area network
LC	inductance–capacitance
LED	light-emitting diode

LHS	left-hand side*
L–I	light output–current
LMS	least mean square
LO	local oscillator*
LP	linear programming*
LPE	liquid phase epitaxy*
LR	inductance–resistance
M	
MESFET	metal–semiconductor field-effect transistor
MF	medium frequency*
MFSK	minimum frequency-shift keying
MHD	magnetohydrodynamics
MIS	metal–insulator–semiconductor
MLE	maximum-likelihood estimator*
MLSE	maximum-likelihood sequence estimator*
MMF	magnetomotive force
MMIC	monolithic microwave integrated circuit*
MoM	method of moments*
MOS	metal–oxide–semiconductor
MOSFET	metal–oxide–semiconductor field-effect transistor
MOST	metal–oxide–semiconductor transistor
MPEG	Motion Pictures Expert Group
N	
NA	numerical aperture*
NIR	near infrared response*
NMR	nuclear magnetic resonance*
n-p-n	(diode)
NRZ	nonreturn to zero*
O	
OD	outside diameter
OEIC	optoelectronic integrated circuit*
OOP	object-oriented programming
P	
PAM	pulse-amplitude modulation*
PC	personal computer
PCM	pulse-code modulation*
pdf	probability density function*
PDM	pulse-duration modulation*
PF	power factor*
PID	Proportional-integral differential
p-i-n, p-n-p	(diode)
PLL	phase-locked loop*
PM	phase modulation*
PML	perfectly matched layer
pp, p–p	peak-to-peak*
PPM	pulse-position modulation*
PRF	pulse-repetition frequency*
PRR	pulse-repetition rate*
PSK	phase-shift keying*
PTM	pulse–time modulation
p.u.	per unit*
PWM	pulse width modulation*
Q	

Q	quality factor; figure of merit
QoS	quality of service
QPSK	quaternary phase-shift keying
R	
RAM	random access memory
RC	resistance–capacitance
R&D	research and development
RF	radio frequency
RFI	radio frequency interference*
RHS	right-hand side*
RIN	relative intensity noise*
RL	resistance–inductance
rms	root mean square
ROM	read-only memory
RV	random variable
S	
SAW	surface acoustic wave*
SGML	standard generalized markup language
SHF	super high frequency*
SI	International System of Units; severity index*
SIR	signal-to-interference ratio
S/N, SNR	signal-to-noise ratio
SOC	system-on-a-chip*
SSB	single sideband*
SW	short wave*
SWR	standing-wave ratio*
TDM	time-division modulation*; time-division multiplexing*
TDMA	time-division multiple access*
TE	transverse electric
TEM	transverse electromagnetic
TFT	thin-film transistor*
TM	transverse magnetic
TVI	television interference*
TWA	traveling-wave amplifier*
U	
UHF	ultrahigh frequency
UV	Ultraviolet
V	
VCO	voltage-controlled oscillator*
VHF	very high frequency*
V–I	voltage–current
VLF	very low frequency*
VLSI	very large scale integration*
W	
WAN	wide area network
WDM	wavelength division multiplexing*

B. Common Hyphenations and Misspellings

A
a posteriori
a priori
Abelian
accommodate
acknowledgment
acoustoelectric
acoustooptical
ad hoc
ad hoc networks
adder
aerospace
aftereffect
airborne
all-pass (adj)
Alnico
alphameric
alphanumeric
analog (not analogue)
appendixes
arc-back (n, adj)
arc-over (n, adj)
axle
B
back EMF
back-end (adj)
backscatter
band-limited (adj)
bandpass
band-shared (adj)
bandwidth
bang-bang
base–emitter [en dash]
base–collector [en dash]
baseband
baseline
Bayes' rule
beamwidth
Bernoulli polynomial
Bessel function
bimetallic
biomedical
blackbody
Boltzmann's constant
Boolean algebra
broadband
bulk–source [en dash]
bus (not buss)
bypass
C
C-band
Cartesian
Cascade
cascode
Cauchy's inequality
Chebyshev (not Tchebbycheff)
chi-square
Clebsch–Gordan coefficient
coauthor (also, coworker)
coax (coaxial)
collinear (not colinear)
continuous-time (adj)
coset
costate
Coulomb wave function
counterclockwise
counterexample
coworker
coupled-mode (adj)
cross correlation
crossover
cross section
cross-sectional (adj)
crosstalk
cutoff
cybersecurity
D
database
deadtime (or dead time)
debug, debugged
Debye temperature
Dewar
diagramed
dielectric
diesel
digamma function
Dirac
discretization
discusser
Doppler
drain–source [en dash]
dropout
dyadic
E
eccentricity
eigenfunction
eigenvalue
eigenvector
elastance
elastooptical
electrooptic
elliptical coordinates
elliptic integrals
emitter–bulk [en dash]
end-effector
endfire
endpoint
et al.
Euler function
exponentiate
F
fan-in
fan-out
far-field (adj)
fast Fourier transform
feedback
feedback-free (adj)
first-order (adj)
flat-band
flip-flop
flowchart
flowmeter
flowthrough
fold (twofold, *n*-fold)
foreword
formulas (not formulae)
forward scatter
4-vector
front-end (adj)
Fresnel
G
gate–source [en dash]
gate–drain [en dash]
gauge (not gage)
Gaussian distribution
Gegenbauer

gimbaled
gradient
(the) Green’s function
Gudermannian
H
half-angle
half-plane
half-space
half-wave
halfway
Hankel function
Heaviside
Hermite
Hermitian
Hertzian
higher order (adj)
high-order (adj)
high-pass (adj)
hookup
hydroelectric
I
iff (if and only if)
imbalance (n)
inasmuch as
indexes (plural of index)
indices (plural used in math)
infrared
inhomogeneous
input, inputted
input–output [en dash]
in situ
insofar as
in vitro
in vivo
integer
integral
integrand
integrator
integro-differential
Internet
Itô
J
Jacobian
Jacobi’s polynomials
K
Ka-band
Kronecker delta
L
L-band

Lagrange
Lagrangian
Laguerre polynomial
Lame’s transform
Laplace transform
Laplacian
Laurent series
left-hand side
leftmost
Legendre
Leibnitz (or Leibniz)
leveled
lightweight
like (suffix, close up)
line shape
lineup
linewidth
lockout
log-likelihood (adj)
lookup table
loudspeaker
lower order (adj)
low-order (adj)
low-pass (adj)
Lur’e
Lurie
Lyapunov (not Liapunov)
M
macro (noun)
magnetohydrodynamics
magnetooptic
main lobe
makeup
manhole
man-hour
man-made
manpower
Markov process
m-ary
Mathieu’s equation
matrices
mean-square
mid (prefix) close up
midband
midline
midplane
midpoint
miniscule
missile

modem
modulo (mod)
modulus
monotonic
monotonically
monotonicity
Mossbauer
m-sequence (noun)
multi (prefix) usually one word
multithreshold
Mylar
N
narrowband (adj)
n-ary
nearby
near-field (adj)
neoprene
Neumann
n-junction
n-layer
non (prefix) one word
non-Euclidean
non-Gaussian
non-Hermitian nonnegative
non-Stokes’
nonzero
NP-hard
*n*th-order (adj)
n-tuple
n-type
n-well
O
ohmmeter
one-dimensional (adj)
ORed, ORing
ON-OFF
output, outputted
overall (adj)
P
parameterization
particle
passband
percent
Permalloy
Perspex
phaselength
phase shift

phasewidth
photoelectric
photoetch
photoresist
pickup
piecewise linear
piezoelectricity
p-i-n
pinchoff
p-junction
Planck’s constant
p-n junction
p-n-p (not PNP)
p^+-n-p^++
Poisson distribution
positive definite
postmultiplication
pothead
potline
powerhouse
power plant
preceding
premultiplication
printout
proceeding
programmed
proof (suffix) one word
propagation
pseudo (prefix) one word
pseudorandom
p-type
pull-in
pull-out
pulselength
pulse shape
pulsewidth
punchthrough
p-well
Q
quadratic
quarter-wave
quartic
quasi- (prefix) hyphen
quaternary
Q value
R
radioactive
radio-astronomic
radio astronomy
radio frequency
random access (adj)
readback
READ head
readin (noun)
readout (noun)
real-valued (adj)
reentry
reexamine
Riccati
Riemann
right-hand side
rise time
root-mean-square (adj)
roundoff (adj)
Runge–Kutta
S
saddle point
scalar (magnitude)
scaler (machine)
scalor (rare)
self- (prefix) hyphen
self-adjoint
semi (prefix) usually one word
semi-infinite
servo (servomechanism)
servo amplifier
-shaped (hyphen)
sideband
sidelobe
signaling
slip ring
slow wave
so-called
solid-state (adj)
space-time
special-purpose (adj)
spirule
state of the art (noun)
state-variable (adj)
step-down
step-up
Stirling numbers
Stokes’
stopband
straightforward
strain gauge
Struve’s function
Sturm–Liouville [en dash]
suboptimum
subproblem
succeeding
successive
summable, asummable
supercoding
supermartingale
supersede
switchgear
switchyard
T
table lookup
takeoff
Taylor expansion
Tchebbyscheff (use Chebyshev)
Teflon
Teletype
teletypewriter
tensor
thin-film (adj)
threefold
3-space
throughput
time dependence
time-varying (adj)
tradeoff
traveling
two-port (or 2-port)
two’s complement
-type (hyphen)
U
ultrahigh frequency
ultrasonic
ultraviolet
unbalance (verb)
V
Van de Graaf
van der Waals
vector
versus
vertical
vertices
W
watthour meter
wattmeter
waveband
waveform

wavefront
wave function
waveguide
wavelength
wavenumber
wave shape
wave vector
wideband
wide-sense (adj)
widespread
wise (suffix) one word
worldwide
worst case (adj)
WRITE head

X
x-axis
X-band
x-direction
X-ray (adj)
xy plane
Y
Yagi
Z
Zener diode
zero-input (adj)
zero-sum (adj)
zeroth-order (adj)
z transform

C. Table of Units and Quantity Symbols

NOTE: Asterisks (*) indicate SI units, preferred multiples of SI units, or other units acceptable for use with SI.

Unit	**Unit Symbol**	**Sometimes Occur as: (do not use)**	**Applications and Notes**	**Quantity Symbol (for use as variables, etc.)**
*ampere	A	amp, a	SI unit of electric current.	*I* *U* *F*
ampere-hour	Ah	amp-hr	Also A · h.	
*ampere (turn)	A	At	SI unit of magnetomotive force.	*F*
*ampere per meter	A/m		SI unit of magnetic field strength.	*A* *H*
ångström	Å	Å	Å $\underline{\Delta}$ 10^{-10} m. Deprecated (see ANSI/IEEE Std 268-1992).	
atmosphere, standard	atm		atm $\underline{\Delta}$ 101 325 Pa. Deprecated (see ANSI/IEEE Std 268-1992).	
atmosphere, technical	at		at $\underline{\Delta}$ kgf/cm^2. Deprecated (see ANSI/IEEE Std 268-1992).	
*atomic mass unit (unified)	u		The (unified) atomic mass unit is defined as one-twelfth of the mass of an atom of the carbon-12 nuclide. Use of the old atomic mass unit (amu), defined by reference to oxygen, is deprecated.	
*atto	a		SI prefix for 10^{-18}.	
*attoampere	aA			
bar	bar	b, barye	bar $\underline{\Delta}$ 100 kPa. Use of the bar is strongly discouraged (see ANSI/IEEE Std 268-1992). Except for limited use in meteorology.	

barn	b		b $\underline{\Delta}$ 10^{-28} m^2.	
barrel	bbl		bbl = 42 gal_{US} = 158.99 L. This is the standard barrel used for petroleum and petroleum products. Different standard barrels are used for other commodities.	
barrel per day	bbl/d			
baud	Bd	baud (w/prefix)	In telecommunications, a unit of signaling speed equal to one element per second. The signaling speed in bauds is equal to the reciprocal of the signal element length in seconds.	$1/\tau$
bel	B	b		
*becquerel	Bq		SI unit of activity of a radionuclide.	
billion electronvolts	GeV	bev, BeV	The name *gigaelectronvolt* is preferred for this unit.	
bit	b		In information theory, the bit is a unit of information content equal to the information content of a message, the *a priori* probability of which is one-half. In computer science, the name bit is used as a short form of *binary digit.*	
bit per second	b/s			
British thermal unit	Btu			
byte	B		A byte is a string of bits, usually eight bits long, operated on as a unit. A byte is capable of holding one character set.	
calorie (International Table)	cal_{IT}		$\underline{\Delta}$ cal_{IT} 4.1868 J. Deprecated (see ANSI/IEEE Std 268-1992).	
calorie (thermochemical)	cal		$\underline{\Delta}$ cal 4.1840 J. Deprecated (see ANSI/IEEE Std 268-1992).	
*candela	cd		SI unit of luminous intensity.	*I*
candela per square inch	cd/in^2		Use of the SI unit cd/m^2 is preferred.	
*candela per square meter	cd/m^2	nit	SI unit of luminance.	*L*
candle	cd		The unit of luminous intensity has been given the name *candela*. Use of the name *candle* for this unit is deprecated.	
*centi	c (prefix)		SI prefix for 10^{-2}.	
*centimeter	cm			
centipoise	cP		cP $\underline{\Delta}$ mPa · s. The name centipoise is deprecated (see ANSI/IEEE Std 268-1992).	
centistokes	cSt		cSt $\underline{\Delta}$ mm^2/s. The name centistokes is deprecated (see ANSI/IEEE Std 268-1992).	
*circular mil	cmil		cmil $\underline{\Delta}$ $(\pi/4) \cdot 10^{-6} in^2$.	
*coulomb	C	c	SI unit of electric charge.	Q
*cubic centimeter	cm^3	cc	Volume. (Preferred SI unit multiple.)	
cubic foot	ft^3			
cubic foot per minute	ft^3/min	cfm		
cubic foot per second	ft^3/s			
cubic inch	in^3			
*cubic meter	m^3			
*cubic meter per second	m^3/s			

cubic yard	yd^3			
curie	Ci	C	Ci $\underline{\Delta}$ 3.7 x10^{10} Bq. A unit of activity of a radionuclide. Use of the SI unit, the becquerel, is preferred.	
cycle per second	Hz	c/s, cps, c/sec, cycle	See hertz.	
darcy	D		D $\underline{\Delta}$ cP·(cm/s)·(cm/atm) = 0.986923 μm^2. A unit of permeability of a porous medium. By traditional definition, a permeability of one darcy will permit a flow of 1 cm^3/s of fluid of 1 cP viscosity through an area of 1 cm^2 under a pressure gradient of 1 atm/cm. Deprecated (see ANSI/IEEE Std 268-1992).	
day	d		day $\underline{\Delta}$ 24 h.	
deci	d (prefix)		SI prefix for 10^{-1}.	
decibel	dB	db, DB		
degree (plane angle)	…°	deg		
degree (temperature)				
degree Celsius	°C	degree centigrade	SI unit of Celsius temperature. The degree Celsius is a special name for the kelvin, used in expressing Celsius temperatures or temperature intervals.	*t*
degree Fahrenheit	°F		Note that the symbols for °C, °F, and °R are comprised of two elements, written with no space between the ° and the letter that follows. The two elements that make the complete symbol are not to be separated.	
degree kelvin	K		See kelvin.	
degree Rankine	°R			
deka	da		SI prefix for 10.	
dyne	dyn	dyne	dyn $\underline{\Delta}$ 10^{-5} N. Deprecated (see ANSI/IEEE Std 268-1992).	*F*
*electronvolt	eV	ev		
erg	erg		erg $\underline{\Delta}$ 10^{-7} J. Deprecated (see ANSI/IEEE Std 268-1992).	
exa	E		SI prefix for 10^{18}.	
exbi	Ei		Prefix for 2^{60}.	
*farad	F	f, fd	SI unit of capacitance.	*C*
*femto	f		SI prefix for 10^{-15}.	
femtometer	fm			
foot	ft		ft $\underline{\Delta}$ 0.3048 m.	
foot of water	ftH_2O		ftH_2O = 2989.1 Pa. (ISO).[1]	
foot per minute	ft/min	fpm		
foot per second	ft/s	fps, ft/sec		
foot per second squared	ft/s^2			
foot pound-force	ft · lbf			
footcandle	fc		fc $\underline{\Delta}$ lm/ft^2. The name *lumen per square foot* is also used for this unit. Use of the SI unit of illuminance, the lux (lumen) per square meter, is preferred.	

footlambert	fL		fL $\underline{\Delta}$ $(1/\pi)$ cd/ft^2. A unit of luminance. One lumen per square foot leaves a surface whose luminance is one footlambert in all directions within a hemisphere. Use of the SI unit, the candela per square meter, is preferred.	
gal	Gal		Gal $\underline{\Delta}$ cm/s. Deprecated (see ANSI/IEEE Std 268-1992).	
gallon	gal		1 gal$_{UK}$ = 4.5461 L. 1 gal$_{US}$ $\underline{\Delta}$ 231 in^3 = 3.7854 L.	
gauss	G		The gauss is the electromagnetic CGS unit of magnetic flux density. Deprecated (see ANSI/IEEE Std. 268-1992).	*B*
gibi	Gi		Prefix for 2^{30}.	
*giga	G	kM	SI prefix for 10^9.	
gigabyte	GB		GB $\underline{\Delta}$ 10^9 B.	
*gigaelectronvolt	GeV	bev, BeV		
*gigahertz	GHz	kMHz, KMC, Gc/s		
			[1]The term "(ISO)" means that the definition is from ISO 31.	
gilbert	Gb		The gilbert is the electromagnetic CGS unit of magnetomotive force. Deprecated (see ANSI/IEEE Std 268-1992).	
grain	gr		gr $\underline{\Delta}$ lb/7000.	
*gram	g	gm		*m*
gram per cubic centimeter	g/cm^3			
*gray	Gy		SI unit of absorbed dose in the field of radiation dosimetry.	
*hecto	h		SI prefix for 10^2.	
*henry	H	Hy, hy	SI unit of inductance.	*L* *P*, P_m
*hertz	Hz	cps, c/s, cycle	SI unit of frequency.	f, v *B*
horsepower	hp		hp $\underline{\Delta}$ 550 ft · lbf/s = 746 W. The horsepower is an anachronism in science and technology. Use of the SI unit of power, the watt, is preferred.	
*hour	h	hr		
inch	in	in.	in $\underline{\Delta}$ 2.54 cm.	
inch of mercury	inHg		inHg = 3386.4 Pa (ISO).	
inch of water	inH_2O		inH_2O = 249.09 Pa (ISO).	
inch per second	in/s	ips		
*joule	J		SI unit of energy, work, and quantity of heat.	*E* *W* *Q*
*joule per kelvin	J/K		SI unit of heat capacity and of entropy.	*S*
kelvin	K		In 1967, the CPGM gave the name *kelvin* to the SI unit of temperature, which had formerly been called *degree kelvin*, and assigned it the symbol K (without the symbol °).	
kibi	Ki		Prefix for 2^{10}.	

*kilo	k		SI prefix for 10^3. The symbol k shall not be used for kilo. The prefix kilo shall not be used to mean 2^{10} (that is, 1024).	
*kilobit per second	kb/s			
*kilobyte	kB		kB $\underline{\Delta}$ 1000 bytes.	
kilogauss	kG		Deprecated (see ANSI/IEEE Std 268-1992).	
*kilogram	kg		SI unit of mass.	
kilogram-force	kgf		Deprecated (see ANSI/IEEE Std 268-1992). In some countries the name kilopond (kp) has been used for this unit.	
*kilohertz	kHz			
*kilohm	kΩ			*R*
*kilometer	km			
*kilometer per hour	km/h			
kilopound-force	klbf		Kilopound-force should not be misinterpreted as kilopond (see kilogram-force).	
*kilovar	kvar			*Q*
*kilovolt	kV			
*kilovoltampere	kVA	KVA, kva		
*kilowatt	kW			
kilowatthour	kWh		Also kW·h.	
knot	kn		kn $\underline{\Delta}$ nmi/h. 0.514 m/s.	
lambert	L		L $\underline{\Delta}$ $(1/\pi)$cd/cm^2. A CGS unit of luminance. One lumen per square centimeter leaves a surface whose luminance is one lambert in all directions within a hemisphere. Deprecated (see ANSI/IEEE Std 268-1992).	
*liter	L		L $\underline{\Delta}$ 10^{-3} m^3. In 1979, the CGPM approved L and l as alternative symbols for the liter. Because of frequent confusion with the numeral 1, the letter symbol l is not recommended for U.S. use (see Federal Register notice of December 20, 1990, vol. 55, no. 245, p. 52242). The script *l* shall not be used as a symbol for liter.	*V, v*
liter per second	L/s			
*lumen	lm		SI unit of luminous flux.	Φ
lumen per square foot	lm/ft^2		A unit of illuminance and also a unit of luminous exitance. Use of the SI unit, lumen per square meter, is preferred.	
*lumen per square meter	lm/m^2		SI unit of luminous exitance.	*M*
*lumen per watt	lm/W		SI unit of luminous efficacy.	*K(λ)* *K, K$_t$*
*lumen second	lm·s		SI unit of quantity of light.	*Q*
*lux	lx		1x/lm $\underline{\Delta}$ /m^2. SI unit of illuminance.	*E*
maxwell	Mx		The maxwell is the electromagnetic CGS unit of magnetic flux. Deprecated (see ANSI/IEEE Std 268-1992).	
mebi	Mi		Prefix for 2^{20}.	
*mega	M		SI prefix for 10^6. The prefix mega shall not be used to mean 2^{20} (that is, 1 048 576).	

megabit per second	Mb/s			
*megabyte	MB		MB $\underline{\Delta}$ 1 000 000 bytes.	
*megaelectronvolt	MeV			
*megahertz	MHz			
*megohm	MΩ	M		
*meter	m		SI unit of length.	*L*
metric ton	t		t $\underline{\Delta}$ 1000 kg. Use of the name *tonne* is deprecated in the U.S. (see ANSI/IEEE Std 268-1992).	
mho	S		Ω^{-1}. The name *mho* was formerly given to the reciprocal ohm. Deprecated; see siemens (S).	
*micro	μ		SI prefix for 10^{-6}.	
*microampere	μA			
*microfarad	μF			
*microgram	μg			
*microhenry	μH			
microinch	μin			
*microliter	μL		See note for liter.	
*micrometer	μm	μ		
micron	μm	μ	The name micron is deprecated. Use micrometer.	
*microsecond	μs			
*microwatt	μW			
mil	mil		mil $\underline{\Delta}$ 0.001 in.	
mile (statute)	mi		mi $\underline{\Delta}$ 5280 ft = 1609 m.	
mile per hour	mi/h	mph	Although use of mph as an abbreviation is common, it should not be used as a symbol.	
*milli	m		SI prefix for 10^{-3}.	
*milliampere	mA			
millibar	mbar		Use of the bar is strongly discouraged in ANSI/IEEE Std 268-1992, except for limited use in meteorology.	
*milligram	mg			
*millihenry	mH			
*milliliter	mL		See liter.	
*millimeter	mm			
millimeter of mercury	mmHg		mmHg = 133.322 Pa. Deprecated (see ANSI/IEEE Std 268-1992).	
millimicron	nm		Use of the name millimicron for the nanometer is deprecated.	
*millipascal second	mPa · s		SI unit-multiple of dynamic viscosity.	
*millisecond	ms			
*millivolt	mV			
*milliwatt	mW			
*minute (plane angle)	′			
*minute (time)	min		Time may also be designated by means of superscripts as in the following example: $9^{h}46^{m}30^{s}$.	

*mole	mol		SI unit of amount of substance. The mole is the amount of substance of a system that contains as many elementary entities as there are atoms in 0.012 kg of carbon 12. When the mole is used, the elementary entities shall be specified and may be atoms, molecules, ions, electrons, other particles, or specified groups of such particles.	
month	mo			
*nano	n		SI prefix for 10^{-9}.	
*nanoampere	nA			
*nanofarad	nF			
*nanometer	nm			
*nanosecond	ns			
nautical mile	nmi		nmi $\underline{\Delta}$ 1852 m.	
*neper	Np			
*newton	N		SI unit of force.	
*newton meter	N · m			
*newton per square meter	N/m^2		SI unit of pressure or stress. See pascal.	
oersted	Oe	oe	The oersted is the electromagnetic CGS unit of magnetic field strength. Deprecated (see ANSI/IEEE Std 268-1992).	
*ohm	Ω		SI unit of resistance.	
ounce (avoirdupois)	oz		oz $\underline{\Delta}$ 1/16 lb = 28.350 g.	
*pascal	Pa		Pa $\underline{\Delta}$ N/m^2. SI unit of pressure or stress.	
*pascal second	Pa · s		SI unit of dynamic viscosity.	
pebi	Pi		Prefix for 2^{50}.	
*peta	P		SI prefix for 10^{15}.	
phot	ph		ph $\underline{\Delta}$ lm/cm^2. CGS unit of illuminance. Deprecated (see ANSI/IEEE Std 268-1992).	
*pico	p		SI prefix for 10^{-12}.	
*picofarad	pF			
*picowatt	pW			
pint	pt		pt (U.K.) = 0.568 26 L. pt (U.S. dry) = 0.550 6 L. pt (U.S. liquid) = 0.473 18 L.	
poise	P		Deprecated (see ANSI/IEEE Std 268-1992).	
pound (avoirdupois)	lb		lb $\underline{\Delta}$ 0.453 592 37 kg.	
pound per cubic foot	lb/ft^3			
pound-force	lbf		lbf = 4.4482 N.	
pound-force foot	lbf · ft			
pound-force per square foot	lbf/ft^2			
pound-force per square inch	lbf/in^2	psi	Although use of the abbreviation psi is common, it should not be used as a symbol.	
poundal	pdl		pdl $\underline{\Delta}$ lb · ft/s^2 = 0.1383 N	
quart	qt		qt (U.K.) = 1.1365 L. qt (U.S. dry) = 1.1012 L. qt (U.S. liquid) = 0.946 35 L.	
rad	rd		rd $\underline{\Delta}$ 0.01 Gy. A unit of absorbed dose in the field of radiation dosimetry. Use of the SI unit, the gray, is preferred.	

*radian	rad		SI unit of plane angle.	
rem	rem		rem $\triangleq$ 0.01 Sv. A unit of dose equivalent in the field of radiation dosimetry. Use of the SI unit, the sievert, is preferred. 1 rem = 0.01 Sv.	
revolution per minute	r/min		Although use of rpm as an abbreviation is common, it should not be used as a symbol.	
revolution per second	r/s			
roentgen	R		A unit of exposure in the field of radiation dosimetry.	
*second (plane angle)	″		$1'' = 4.848 \cdot 10^{-6}$ rad.	
*second (time)	s		SI unit of time.	
*siemens	S		S $\triangleq \Omega^{-1}$. SI unit of conductance.	
*sievert	Sv		SI unit of dose equivalent in the field of radiation dosimetry.	
slug	slug		slug $\triangleq$ lbf $\cdot$ s^2/ft = 14.594 kg.	
square foot	ft^2			
square inch	in^2			
*square meter	m^2			
*square meter per second	m^2/s		SI unit of kinematic viscosity.	
*square millimeter per second	mm^2/s		SI unit-multiple of kinematic viscosity.	
square yard	yd^2			
*steradian	sr		SI unit of solid angle.	
stilb	sb		sb $\triangleq$ cd/cm^2. A CGS unit of luminance. Deprecated (see ANSI/IEEE Std 268-1992).	
stokes	St		Deprecated (see ANSI/IEEE Std 268-1992).	
tebi	Ti		Prefix for 2^{40}.	
*tera	T		SI prefix for 10^{12}.	
terabyte	TB		TB $\triangleq 10^{12}$ B.	
*tesla	T		T $\triangleq$ N/(A $\cdot$ m)^2 $\triangleq$ Wb/m^2. SI unit of magnetic flux density (magnetic induction).	
therm	thm		thm $\triangleq$ 100 000 Btu.	
ton (short)	ton		ton $\triangleq$ 2000 lb.	
ton, metric	T		t $\triangleq$ 1000 kg. Use of the *tonne* for this unit is deprecated in the U.S. (see ANSI/IEEE Std 268-1992).	
torr	torr		A unit of pressure equal to 0.001316 atmosphere; named after Torricelli.	
*(unified) atomic mass unit	u		The (unified) atomic mass unit is defined as one-twelfth of the mass of an atom of the carbon- 12 nuclide. Use of the old atomic mass unit (amu), defined by reference to oxygen, is deprecated.	
*var	var		IEC name and symbol for SI unit of reactive power.	
*volt	V		SI unit of voltage.	
*volt per meter	V/m		SI unit of electric field strength.	
*voltampere	VA	va	IEC name and symbol for SI unit of apparent power.	
*watt	W		SI unit of power.	
*watt per meter kelvin	W/(m $\cdot$ K)		SI unit of thermal conductivity.	

*watt per steradian	W/sr		SI unit of radiant intensity.	
*watt per steradian square meter	$(W/sr \cdot m^2)$		SI unit of radiance.	
watthour	Wh			
*weber	Wb		Wb $\underline{\Delta}$ V·s. SI unit of magnetic flux.	
yard	yd		yd $\underline{\Delta}$ 0.9144 m.	
year	a		Also W·h.	
yobi	Yi		Prefix for 2^{80}.	
yocto	y		SI prefix for 10^{-24}.	
yotta	Y		SI prefix for 10^{24}.	
zebi	Zi		Prefix for 2^{70}.	
zepto	z		SI prefix for 10^{-21}.	
zetta	Z		SI prefix for 10^{21}.	

D. Miscellaneous Alphabetical Abbreviations, Acronyms, and Symbols

NOTE: Key: fn—function name (roman); s—symbol (italic); u—unit abbreviation (roman); *—acronyms that must be defined in text.

A	
A	(s) Hermitian conjugate of *A*
Å	(u) angstrom
ab	(prefix) denotes absolute system of (CGS) units. Abampere, abcoulomb, abvolt, abohm, abfarad, abmho, abhenry (use not recommended, see units list)
abs	absolute
ABS	air-bearing surface
Ac	alternating current
ACB	air circuit breaker*
ACSR	steel-reinforced aluminum cable*
AD	attention display*
A–D, A/D	analog-to-digital
ADF	automatic direction finder*
a.e.	almost everywhere (in equations)
AEW	airborne early warning*
AF	audio frequency*
AFB	Air Force Base
AFC	automatic frequency control*
AFM	atomic force microscopy
AGC	automatic gain control*
AGFM	alternating gradient force magnetometer
AGM	arithmetical–geometric mean*
A·h (u)	ampere hour
Ai (fn)	Airy integral
AM	amplitude modulation

A.M.	ante meridiem (morning)
ama	automatic message accounting*
AND	(small caps) logical AND operation
ANI	automatic number identification
ANN	artificial neural network*
antilog (fn)	antilogarithm
AOGM	accelerated optimum gradient method*
AOPT	air-operated press type*
APD	avalanche photodiode
API	air position indicator*
AQL	acceptable quality level
AR	antireflection*; autoregressive*
arcsin arccos arctan arccot arcsec arccsc	(fn) inverse trigonometric functions
arg	(fn) argument
ARMA	autoregressive moving average*
a.s.	almost surely (in equations)
ASE	amplified spontaneous emission*
ASIC	application specified integrated circuit*
ASK	amplitude-shift keying
ASW	antisubmarine warfare* (note: for acoustic surface wave use SAW)
at (u)	technical atmosphere: 1 kgf/cm
At (u)	ampere turn (note: no longer in use; change to A)
ATM	asynchronous transfer mode*
atm (u)	atmosphere
ATR	antitransmit receive*
ATT	avalanche transit time*
av	average (subscript)
AVC	automatic volume control*
avg (fn)	average (use av as subscript)
AWE	asymptotic wave evaluation*
AWG	American wire gauge
AWGN	additive white Gaussian noise*
B	
bar (u)	bar
barye (u)	barye: microbar (use not recommended; see units list)
bbl (u)	barrel (see units list)
bcc	body-centered cubic (of crystals)
BCD	binary coded decimal
BCH	Bose–Chaudhuri–Hocquenghen (codes)

BCT	bushing current transformer*
Bd (u)	baud* (see units list)
B–E	base–emitter source
Be	Baume
bei, ber (fn)	Kelvin forms of Bessel function
BEM	boundary-element method
BER	bit error rate*
BeV, bev (u)	use GeV
BFO	beat-frequency oscillator*
B–H B–H curve:	curve of magnetic induction (magnetic flux–density) versus magnetic intensity (field intensity) B–H relationship. B–H loop: hysteresis loop
Bhp	brake horsepower*
Bi (fn)	Airy integral: (u) bit: = 10 A*
BIL	basic impulse insulation level*
BJT	bipolar junction transistor*
BMEP	brake mean effective pressure*
bpi (u)	bit per inch: use b/in
bps (u)	bit per second: use b/s
BPSK	binary phase-shift keying
BRA	biased rectifier amplifier*
BS	breaking strength*
BS	British Standards*
B&S	Brown and Sharpe gauge*
BSF	bulk shielding facility*
BSL	basic switching surge insulation level*
BTU	(u) British thermal unit
BWG	Birmingham wire gauge*
BWK	Brillouin–Wentzel–Kramers (method)*
BWO	backward-wave oscillator*
BWR	boiling water reactor*
C	
C (u)	coulomb
°C (o)	degree Celsius
c (u)	cycle: use Hz; centi- (prefix to unit abbreviation)
c (s)	speed of light in a vacuum
cal (u)	calorie (use not recommended; see units list)
CATV	community antenna television system
cc (u)	cubic centimeter: use cm^3
c.c.	complex conjugate (in equations)
CCB	coin collecting box (British telephones)*
CCD	charge-coupled device*
CCR	closed-cycle refrigerator*
cd (u)	candela

cdf	cumulative distribution function*
CDMA	code division multiple access*
CDO	community dial offices*
CD-ROM	compact disk read-only memory
cdrx	external critical damping resistance: use caps*
CEMF	counterelectromotive force*
cf.	compare
cfm (u)	cubic feet per minute: use ft^3/min
cfs (u)	cubic feet per second: use ft^3/s
CGS	centimeter-gram-second (system of units)
Ci (fn)	cosine integral; (u) curie
CIM	computer integrated manufacturing*
CIR	carrier-to-interference ratio*
ckVA	capacitive kilovoltamperes (write out)
cmil (u)	circular mil
CMOS	complementary metal–oxide–semiconductor
CNN	cellular neural network
COP	coefficient of performance*
cos cosec cosh cot coth covers	(fn) cosine (fn) cosecant: use csc (fn) hyperbolic cosine (fn) cotangent (fn) hyperbolic cotangent (fn) coversine
cP (o)	centipoise (see units list)
CPFSK	continuous phase frequency-shift keying*
CPM	continuous phase modulation*
CPSK	continuous phase-shift keying; coherent phase-shift keying*
CPU	central processing unit
CRO	cathode-ray oscilloscope
CRS	cold-rolled steel*
CRT	cathode-ray tube
c/s (u)	cycle per second: use Hz
csc (fn)	cosecant
csch (fn)	hyperbolic cosecant cs (u) centistokes: use cSt or write out (see units list)
CSP	completely self-protected
cSt (u)	centistokes (see units list)
CSV	corona-starting voltage
CT	current transformer*
CTC	centralized traffic control
ctn (fn)	cotangent: use cot
curl (fn)	curl
CV	capacitance–voltage
CVD	chemical vapor deposited
CW	continuous wave*

D	
DA	design automation
dB (u)	decibel
dc	direct current (DC at start of sentence or in article title)
DC	directional coupler
DDA	digital differential analyzer*
DDD	direct distance dialing*
DE	disruptive effect*
det (fn)	determinant
DF	direction finder*; deuterium fluoride; degree of freedom*
DFB	distributed feedback
DFT	discrete Fourier transform*
diag	(diagonal)
diam	diameter
DIC	Diploma of membership in Imperial College of Science and Technology
div (fn)	divergence; division (u) in charts
DMA	direct memory access*
DME	distance-measuring equipment*
DOD	diameter over dielectric; Department of Defense
DOF	degree of freedom (unit)
DP	dial pulse*
DPCM	differential pulse code modulation*
DPDT	double-pole double-throw switch*
DPH	diamond pool hardness*
DPQSK	differential quadrature phase-shift keying*
DPSK	differential phase-shift keying*
DRCPR	differential reactive current protective relay*
DRO	destructive readout*; doubly resonant oscillator
DS	dielectric strength*; direct sequence*
DSB	double sideband*
DSP	digital signal processor
DVP	differential vapor pressure*
DWT	discrete wavelet transform*
dyn (u)	dyne
E	
EB	emergency bank*
EC	eddy current; electrical conductivity* (grade of Al)
ECG	electrocardiogram
ECL	emitter-coupled logic*
ECM	electronic countermeasures
ECT	eddy current testing
ED	enforced draft

EDFA	erbium-doped fiber amplifiers*
EDP	electronic data processing
EDS	energy dispersive spectrometer
EDX	energy dispersive X-ray
EEG	electroencephalogram
EHD	electrohydrodynamic*
EHF	extremely high frequency*
EHIPS	extra heavy iron pipe size*
EHV	extra high voltage
Ei (fn)	exponential integral
ELF	extremely low frequency*
EM	electromagnetic*
EMC	electromagnetic compatibility*
EMF	electromotive force*
EMI	electromagnetic interference*
ems	expected value of mean square*
EMU	electromagnetic units
EOF	end of file
erf (fn)	error function
erfc (fn)	complementary error function
erg (u)	erg
ERP	effective radiated power*
ESS	electrical sheet steel*
ESU	electrostatic units
eV (u)	electronvolt
EXOR	EXCLUSIVE-OR circuit (small caps)
exp (fn)	exponential function
exsec (fn)	exsecant
F	
f (*f*-stop, f/22)	ratio of focal length to aperture
F (u)	farad
°F (u)	degree Fahrenheit
FA	forced-air-cooled transformer*
fcc	face-centered cubic (of crystals)
FCC	Federal Communications Commission
FD	flux density*
FDA	finite difference approximations*
FDM	frequency-division multiplexing*
FDMA	frequency-division multiple access*
FDTD	finite-difference time domain*
FEA	finite-element analysis
FET	field-effect transistor
ff.	following pages

FFT	fast Fourier transform*
FIFO	first-in first-out
FIM	field intensity meter*
FIR	finite-impulse response*
fL (u)	footlambert
FL	full load
FM	frequency modulation
FMFB	FM feedback receiver*
FMR	frequency of maximum reliability*; ferromagnetic resonance
FPGA	field-programmable gate array*
fpm, fps (u)	feet per minute: use ft/min; feet per second: use ft/s
FS	full scale
FSK	frequency-shift keying*
FSM	finite-state machine*
ft (u)	foot
FTL	flat tie-line*
FTP	file transfer protocol
FW	full wave
FWHM	full-width at half-maximum*
FWM	four-wave mixing*
G	
G	giga- (prefix to unit abbreviations) = 10^9
G (u)	gauss
g	acceleration of gravity, “gee force”; use as unit with metric prefix, as in 3 mg
G (s)	gravitational constant
Gal (u)	gal (gravitational unit)
gal (u)	gallon
Gb (u)	gilbert
GCA	ground-controlled approach*
gcd	greatest common denominator (may be function name)
GenAI	generative artificial intelligence
GLB	greatest lower bound*
GMD	geometric mean distance*
GMEC	generalized minimum effort control*
GMF	geometric mean frequency
GMR	geometric mean radius
GMT	Greenwich mean time
gpd (u)	gallon per day: use gal/day
GPS	Global Positioning System
GPU	graphical processing unit, General Public Utilities*
grad (fn)	gradient
GSE	ground support equipment*
GTD	geometrical theory of diffraction

GUI	graphical user interface
GW	ground wire
H	
h (s)	Planck's constant
H (u)	henry
H (s)	magnetic intensity; magnetic field strength
hav, havers (fn)	haversine
HBT	heterojunction bipolar transistor
hcp	hexagonal close-packed (of crystals)
HD	hard-drawn*
HDBC	hard-drawn bare copper*
HDC	hard-drawn copper*
HDD	hard disk drive
HDT	hard-drawn tubing*
HEMT	high-electron mobility transistor
HF	high frequency; hydrogen fluoride
HFET	heterojunction FET
HG	mercury
hipot	high potential (write out)
hp (u)	horsepower
HTC	high-tension cable*
HTML	hypertext markup language
HV	high voltage
HVdc	high voltage direct current
Hz (u)	hertz
I	
I (s) current (fn)	imaginary part of: use Im
IACS	International Annealed Copper Standard*
IC	impedance compensation*; integrated circuit
ICW	interrupted continuous wave*
ID	inside diameter; induced draft*; interdigital*
IDP	integrated data processing*
IF	intermediate frequency
iff	if and only if
IFT	interfacial tension*
IGFET	insulated-gate field-effect transistor
i.i.d.	independent identically distributed*
IIR	infinite-impulse response
ILS	instrument landing system*
Im (fn)	imaginary part of
IM	intermediate modulation
IMPATT	impact ionization avalanche transit time (diode)

INE	irredundant normal equivalent*
inf (fn)	infimum
int (fn)	integer value of
I/O, I–O	input–output
IoT	Internet of Things*
IP	Internet Protocol
ips (u)	inch per second: use in/s
IPS	iron pipe size; international pipe standard*
IR	infrared
IR	current–resistance
ISB	independent sideband*
ISE	integral of squared error*
ISI	intersymbol interference
itae	integral of time-multiplied absolute value of error
ITI	inter-track interference
I–V (s)	current–voltage (characteristic or curve)
IVA	induced voltamperes
IX	current–reactance (drop)
IZ	current–impedance
J	
J (u)	joule
JFET	junction field-effect transistor
JPEG	Joint Photographers Expert Group
K	
k	kilo (prefix to unit abbreviations) = 10^3
K (u)	Kelvin
Kayser (u)	= cm^{-1} (wavenumber)
kbps (u)	kilobits per second: use kb/s
KCL	Kirchhoff's current law
kcm, KCM (u)	thousand circular mils: use kcmil
kg (u)	kilogram
KGO, KGOe, KGoe, KgOe (u)	use kO·Oe
kgp (u)	kilogrampois (French): use kg
kG.Oe (u)	kilogauss oersted
kip	thousand pounds
kn (u)	knot (nautical mile per hour)
KOH	potassium hydroxide
kp (u)	kilopound (German): use kg
kt (s)	Boltzmann's constant × time
KVL	Kirchhoff's voltage law
kVp (u)	kilovolt peak*

L	
l (u)	liter
L (u)	lambert
LAN	local area network
lb (u)	pound
lbf (u)	pound-force
LC	inductance–capacitance
lcm	least common multiple (may be function name)
LCR	inductance–capacitance–resistance
LCS	load current substation*
LDC	line drop compensator*; load division circulation
LED	light-emitting diode
LF	low-frequency
LHP	left-half plane*
LHS	left-hand side*
Li (fn)	logarithmic integral
lim (fn)	limit
l.i.m. (fn)	limit in the mean
L–L	line to line*
lm (u)	lumen
LMLT	locus of major loop tips*
LMS	least mean square
LMT	local mean time*
ln (fn)	natural logarithm (base *e*)
L–N	line to neutral*
LNA	low noise amplifier
LO	local oscillator*
log, $\log_n$ (fn)	logarithm, logarithm base *n* (where *n* = 2, 10, etc.)
LP	linear programming*
LPE	liquid phase epitaxy*
LR	inductance–resistance
LRC	load ratio control*
LSB	least significant bit
LSI	large-scale integration*; large-scale integrated*
LST	local standard time
LTC	load tap-changing*
LTE	long-term evolution
LTS	laser-triggered switching*
LUF	lowest usable frequency*
lx (u)	lux
M	
m (u)	meter; milli- (prefix to unit abbreviations) = 10^{-3}

M	mega- (prefix to unit abbreviations) = 10^6; mole
MAG	maximum available gain
MAP	maximum *a posteriori*
max (fn)	maximum; also used as subscript
MC	Monte Carlo
mcm, MCM (u)	thousand circular mils: use kcmil
mc/mM (u)	millicuries per millimole: use mCi/mM
MCS	multicircuit substation*
MCT	movable core transformer*
MCW	modulated continuous wave*
MDF	manual direction finder*
MDS	minimum detectable signal
MEMS	micro-electromechanical systems
MESFET	metal–semiconductor field-effect transistor
MEW	microwave early warning*
MF	medium frequency*
MFM	magnetic force microscopy
MFSK	minimum frequency-shift keying
MGO (u)	megagauss oersted: use MG·Oe
MG·Oe (u)	megagauss oersted
MHD	magnetohydrodynamics
mho (u)	mho (also Ω^{-1})
mi (u)	mile
MIM	metal–insulator–metal
MIMO	multi-in multi-out*
mio (fn)	minimum; also used as subscript
MIS	metal–insulator–semiconductor*
MKS	meter–kilogram–second (system of units)
ml	milliliter
MLE	maximum-likelihood estimation*
MLSD	maximum-likelihood sequence detector
MLSE	maximum-likelihood sequence estimator*
MMF	magnetomotive force
mmHg (u)	millimeter of mercury
MMIC	monolithic microwave integrated circuit*
mm_2O (u)	millimeter of water
mmse	minimum mean square error
MOCVD	metal–organic chemical vapor deposition*
mod	modulo
MOKE	magnetooptic Kerr effect
MoM	method of moments*
MOS	metal–oxide–semiconductor
MOSFET	MOS field-effect transistor
MOST	MOS transistor

MOVPE	metal–organic vapor phase epitaxy*
MPEG	Moving Pictures Expert Group
MPIE	mixed potential integral equation
MRAM	magnetic random access memory
MRI	magnetic resonance imaging
MSB	most significant bit
mse	mean square error
MSIC	medium scale integrated circuits*
MTBE	mean time between explosions
MTBF	mean time between failures*
MTI	multiple target indicator*; moving target indicator
MTJ	magnetic tunnel junction
MTL	multiconductor transmission line
MU	multiple unit*
MUF	maximum usable frequency*
MVQE	minimum variance quantum estimator
Mx (u)	maxwell
MZI	Mach–Zehnder interferometric*
N	
n	nano (prefix to unit abbreviations) = 10^{-9}
N (u)	newton
NA	numerical aperture*
NAND	NOT-AND circuit (small caps)
nat (u)	nat
NC	diode negative-conductance diode*
NDRO	nondestructive readout
NDT	nondestructive testing*
NIC	negative impedance converter*
NIR	near infrared response*
nit (u)	nit
Nkw-hr (u)	net kilowatthour: use net kW·h
NL	no load
nmi (u)	nautical mile
NMR	nuclear magnetic resonance*
NOR	NOT-OR circuit (small caps)
NP	nameplate (rating)
Np (u)	neper
n-p-n	semiconductor forms: Roman, lowercase, hyphens
NRZ	nonreturn to zero*
NTC	negative temperature coefficient*
NWP	network protector
O	

OCB	oil circuit breaker*
OCR	oil circuit recloser*
OD	outside diameter
Oe (u)	oersted
OEIC	optoelectronic integrated circuit*
OFDA	optical-fiber frequency-domain analysis*
OGM	optimum gradient method
OOK	on–off keying
OOP	object-oriented programming*
opt (fn)	optimum: also used as subscript
OR	OR circuit (small caps)
OSM	omni spectra miniature
OTDM	optical time-division multiplexing*
O-wave	ordinary-wave (ionogram)
OZ (u)	ounce
P	
p	pico- (prefix to unit abbreviations) = 10^{-12}
P (u)	poise
Pa (u)	pascal
PAE	power-added efficiency
PAM	pulse-amplitude modulation*
PAX	private automatic exchange*
PBX	private branch exchange*
pc (u)	parsec
PC	personal computer
PCM	pulse-code modulation*; pulse-count modulation*
PD	potential difference*
pdf	probability density function*
pdl (u)	poundal (see units list)
PDM	pulse-duration modulation*
P_e (s)	probability of error
PER	probability of error
PES	position error signal
PF	power factor*
ph (fn)	phase
pH	power of hydrogen (acidity or alkalinity of solution)
PI	polarization index
PID	proportional–integral–differential*
PILC	paper-insulated lead-covered*
PIN	use p-i-n for diodes, etc.
p-i-n	semiconductor forms: Roman, lowercase, hyphens
PL/1	a programming language
PLC	power line carrier*

PLL	phase-locked loop*
PM	phase modulation*
P.M.	post meridiem (small caps)
PML	perfectly matched layer
PMMA	polymethyl methacrylate*
PMR	perpendicular magnetic recording
p-n-i-p	semiconductor forms: Roman, lowercase, hyphens
p-n-p	semiconductor forms: Roman, lowercase, hyphens
POD	para-operational device*
POW_p (u)	picowatts psophometrically weighted at a point of zero relative level*
pp, p-p	peak to peak*
PPI	plan-position indicator*
ppm (u)	parts per million; pulse per minute*
PPM	pulse-position modulation*
pps (u)	pulse per second*
Pr (fn)	probability (appears as Pr $x \mid x = \mathrm{U}$)
PRA	pulse relaxation amplifier
PRF	pulse-repetition frequency*
PRML	partial response maximum likelihood
Prob.,	P, x|· use Pr (usually)
PRR	pulse-repetition rate*
PSD	power spectral density
PSF	power separation filter*
psi (u)	pounds per square inch: change to $\mathrm{lb/in^2}$ unless paper also contains psia and/or psig
psia (u)	pound-force per square inch absolute (stet)
psig (u)	pound-force per square inch gauge (stet)
PSK	phase-shift keying*
PTM	pulse–time modulation
p.u.	per unit
PVC	polyvinyl chloride*
PWL	piecewise linear
PWM	pulse width modulation*
PWR	pressurized water reactor*
PZT	lead zirconate titanate
Q	
Q	quality factor; figure of merit
QAM	quadrature-amplitude modulation*
Q.E.D.	quod erat demonstrandum (end of proof) (set flush right)
QoS	quality of service
QP	quasi-peak*
QPSK	quaternary phase-shift keying
QW	quantum well*

R	
R (u)	roentgen
R (fn)	real part of: use Re
°R (u)	degrees Rankine
rad (u)	radian
RAM	random access memory
RB	circuit transient blocking relay circuit*
RC	resistance–capacitance
RCF	radar cross section*
R&D	research and development
Re (fn)	real part of: use Re (be sure of this meaning before changing)
redox	reduction–oxidation
rem (u)	Roentgen equivalent, man
RF	radio frequency
RFI	radio frequency interference*
RFU	reclosing fuses*
RH	relative humidity*
RHS	right-hand side*
RI	radio interference*
RIFI	radio interference and field intensity*
RIL	radio interference level*
RIN	relative intensity noise*
RL	resistance–inductance
RMI	radiomagnetic indicator*
rms	root-mean-square (error); root mean square
ROM	read-only memory
rpm (u)	revolution per minute: use r/min
rps (u)	revolution per second: use r/s
RSG	recurrent surge generator*
RTD	resistance temperature detectors
RV	random variable
RX	resistance–reactance
S	
s (u)	second
S (u)	siemens
SAR	specific absorption rate
SATT	Strowger Automatic Toll Ticket*
SAW	surface acoustic wave*
SC	switched-capacitor*(adj)
SCA	steel-reinforced aluminum cable*
SCC	signal component control*
scfm	standard cubic feet per minute*

SCL	space-charge limited*
scr	short-circuit ratio*
SCR	silicon-controlled rectifier
sec (fn)	secant; (u) second: use s; second of arc*
sech (fn)	hyperbolic secant
SEM	scanning electron microscope
SF	single frequency*
SGML	standard generalized markup language
sgn (fn)	signum function
SHF s	upper high frequency*
SI	severity index*; Systeme International d'Unites (International System of Units)
Si, si (fn)	sine integral
sin (fn)	sine
sinc (fn)	sinc $x = (\sin x) / x$
sinh (fn)	hyperbolic sine
SINR	signal-to-interference-plus-noise ratio*
SIR	signal-to-interference ratio
SISO	single-in, single-out*
SLAR	side looking airborne radar
SLG	single line to ground
SMSA	standard metropolitan statistical area
S/N	signal-to-noise ratio
SNR	signal-to-noise ratio
SoC	system-on-chip*
SPDT	single-pole double-throw (switch)*
SPICE	Simulation Program with Integrated Circuit Emphasis
SPT	single-pole type
sq square:	if on a unit, change to ^{2}
SQUID	superconducting quantum interference device
sr (u)	steradian
SR	saturable reactor*
SS	subsystems*
SSB	single sideband*
s.t.	subject to
St (u)	stokes
sterad (u)	steradian: use sr
SUL	soft underlayer
SUMT	sequential unconstrained minimization techniques
sup (fn)	supremum
sus	Saybolt universal seconds (oil viscosity)*
sw	sine wave*
SW	short wave*
SWG	standard wire gauge*
SWR	standing-wave ratio*

T	
t (u)	tonne
T (u)	tesla
tan (fn)	tangent
tanh (fn) hyperbolic tangent	
TCUL	tap-changing under load*
TDM	time-division modulation*; time-division multiplexing*
TDMA	time-division multiple access*
TE	transverse electric (appears as TE^0_{01} and TE_{01})
TEFC	totally enclosed fan-cooled*
Telex	teleprinter exchange*
TEM	transverse electromagnetic
TFT	thin-film transistor*
tg (fn)	tangent: use tan
th (u)	thermie
TIF	telephone influence factor*
TLM	transmission-line matrix
TM	transverse magnetic
tof	thermal ohms per foot (spell out)
torr (u)	torr
tpc (u)	turns per centimeter: turns/cm
TPC	turns per coil*
tr (fn)	trace
Tr	transpose
TSS	time sharing system
TTL	transistor–transistor logic
TTY	teleprinter
tu	traffic units*
TVI	television interference*
TWA	traveling-wave amplifier*
TWM	traveling-wave maser*
TWP	traveling-wave phototube*
TWT	traveling-wave tube
U	
UHF	ultrahigh frequency
ult (fn)	ultimate
UPS	uninterruptible power system*
	uniform *RC* sections (stet overbar)
URL	uniform resource locator
XRD	X-ray diffraction
UT	universal time

UTS	ultimate tensile strength
UV	ultraviolet
V	
V (u)	volt
V (s)	voltage
VA (u)	voltampere; Viterbi algorithm*
var (u)	var
VCL	varnished-cambric lead-covered*
VCO	voltage-controlled oscillator*
VCW	type V copper weld*
VDS	voltage divider switching*
ver, vers (fn)	versine
VF	voice frequency*
VFO	variable-frequency oscillator*
VHF	very high frequency*
V–I	voltage–current (characteristic of curve)
VLF	very low frequency*
VLSI	very large scale integration*
VOR	very high-frequency omnidirectional radio
VR	voltage regulator*
VSB	vestigial sideband*
VSWR	voltage standing-wave ratio
VTB	voltage time to breakdown*
VTVM	vacuum-tube voltmeter
vu	volume units*
W	
W (u)	watt
WAN	wide area network
Wb (u)	weber
WDM	wavelength-division multiplexing*
WDMA	wavelength-division multiple access*
WKB	Wentzel–Kramer–Brillouin*
wpl, w.p.l.	with probability 1*
wrt, w.r.t.	with respect to
WT	watertight*
wt%	weight percent
X	
XPM c	ross-phase modulation
XOR	EXCLUSIVE-OR circuit (small caps)
X-wave	extraordinary-wave (ionogram)

Y	
YAG	yttrium aluminum garnet
yd (u)	yard
YIG	yttrium iron garnet

Factor by Which the Unit Is Modified	Prefix	Symbol
$1000000000000 = 10^{12}$	tera	T
$1000000000 = 10^{9}$	giga	G
$1000000 = 10^{6}$	mega	M
$1000 = 10^{3}$	kilo	k
$100 = 10^{2}$	hecto	h
$10 = 10^{1}$	deka	da
$0.1 = 10^{-1}$	deci	d
$0.01 = 10^{-2}$	centi	c
$0.001 = 10^{-3}$	milli	m
$0.000001 = 10^{-6}$	micro	μ
$0.000000001 = 10^{-9}$	nano	n
$0.000000000001 = 10^{-12}$	pico	p
$0.000000000000001 = 10^{-15}$	femto	f
$0.000000000000000001 = 10^{-18}$	atto	a

For prefixes indicating powers of 2, see Table 7 at the NIST site.

E. Inclusive Language Guide

Overall recommendations:

- Use “people-first language,” i.e., the person has X; has been diagnosed with X; uses a X; etc.
- Do not spell out the acronyms LGBTQIA+, LGBT, LGBTQ, LGBTQIA.

Insensitive Term/Phrase	Replace With	Definition/Background	Additional Notes
A.D. (when referencing history/time)	C.E., common era	Abbreviation of the Latin phrase anno Domini, translated as “the year of the Lord.” Traditionally, it is used to date years after the birth of Jesus	This contradicts AP style.
Able-bodied	non-disabled/does not have a disability		

Afro-American/Negro/ Colored/Nigger (in reference to race)	Avoid in all instances; African American*; Black†	People of African descent have widely varied cultural backgrounds, family histories, and family experiences. Some will be from Caribbean islands, Latin America, various regions in the United States, countries in Africa, or elsewhere. Some American people of African ancestry prefer "Black," and others prefer "African American"; both terms are acceptable.	* Specific to people of specific African descent; not to be used as an umbrella for people of African ancestry worldwide. † Widely accepted to encompass multiple ethnicities and/or national origins.
B.C. (when referencing history/time)	B.C.E., before common era	Literally, before Christ or the Christian era.	This contradicts AP style.
Black box	Closed box		Preferred term from IEEE Thesaurus
Blacklist; black list	Blocklist; block list	The Hollywood blacklist was instituted by the House Un-American Activities Committee in 1947 to block screenwriters and other Hollywood professionals who were purported to have Communist sympathies from obtaining employment. A list or compilation that identifies entities that are denied, unrecognized, or ostracized. The term's racist connotations derive from the idea that black equates to negative; this view can be controversial.	Preferred term from IEEE Thesaurus
Blind	blind*; limited vision; low vision; partially sighted†	According to the American Foundation for the Blind, the term "legally blind" denotes a person with 20/200 visual acuity or less. Therefore, "blind" or "legally blind" is acceptable for people with almost complete vision loss. Many people with vision loss are not considered blind.	* Use only with people who are "legally blind" (a person with 20/2000 visual acuity or less) † Used most often in British publications
Blind channel estimation	Source signal equalizers		Preferred term from IEEE Thesaurus
Blind equalizers	Source signal equalizers		Preferred term from IEEE Thesaurus
Blind signal separation	Mix source separation		Preferred term from IEEE Thesaurus
Blind source separation	Mix source separation		Preferred term from IEEE Thesaurus
Caretaker	caregiver	A caregiver is an individual who assists another, including a person with a disability, with his or her daily life, according to Merriam-Webster.	Caretaker denotes taking care of property; Caregiver denotes giving care to people.

Caucasian	European American*; White	The use of the term “Caucasian” as an alternative to “White” or “European” is discouraged because it originated as a way of classifying White people as a race to be favorably compared with other races. As with all discussions of race and ethnicity, it is preferable to be more specific about regional (e.g., Southern European, Scandinavian) or national (e.g., Italian, Irish, Swedish, French, Polish) origin when possible.	* Adjust as needed for location (i.e., European, European American, European Australian, etc.)
Chairman	chairperson		
Committed suicide	died by suicide		
Crazy/loony/mad/ psycho/nuts/deranged/ insane/insanity/ mentally deranged/ psychopathology	mental illness*; mental disorder*; psychopathology(ical)	Once commonly used to describe people with mental illness; commonly used informally to denote mental instability or mental illness.	* Except in a quote or when referring to a criminal defense.
Cripple	Avoid in all instances*; use people first language and their diagnosis, i.e., “person with X”	Merriam-Webster defines the noun “cripple” as “a lame or partly disabled person or animal” and as “something flawed or imperfect.” It is also used as a verb. The word dates back to Old English, where it was related to words that meant to creep or bend over.	
Deaf	D(d)eaf*; hard of hearing	Having total or partial hearing loss.	* NCDJ Recommendation: Lowercase when referring to a hearing-loss condition or to a deaf person who prefers lowercase. Capitalize for those who identify as members of the Deaf community or when they capitalize Deaf when describing themselves. “D(d)eaf” should be used as an adjective, not as a noun; it describes a person with profound or complete hearing loss. Other acceptable phrases include “woman who is deaf” or “boy who is hard of hearing.” When quoting or paraphrasing a person who has signed their responses, it’s appropriate on first reference to indicate that the responses were signed. It’s acceptable to use the word “said” in subsequent references. Per the National Association of the Deaf, "D(d)eaf" is acceptable.

Deformed/deformity (when referencing a person)	Avoid in all instances*; refer to specifics description rather than generalized term of deformity	Merriam-Webster defines as a part of the body that does not have the typical or expected shape	
Dumb (mute)	non verbal	Once widely used to describe a person who could not speak and also implied the inability to express oneself; however, someone who does not use speech still may have the ability of expression.	
Dwarf/vertically challenged/midget	Dwarf*; short stature; little person	Dwarfism is a medical or genetic condition that results in a stature below 4’10,” according to Little People of America. The terms “little people” and “little person” refer to people of short stature and have come into common use since the founding of the Little People of America organization in 1957.	* Use only when applied to a medical diagnosis or in a quote.
Gay marriage/same-sex marriage	Marriage*		* When writing about the inability to legally marry, use “exclusion from Marriage” or “denial of marriage.”
Handicap	Use people first language; refer to the person's condition	The Oxford English dictionary defines a handicap as “a condition that restricts a person’s ability to function physically, mentally or socially.”	
Homesexual/Gay	gay*; lesbian, bi(sexual)†	Short form term to reference gay, lesbian, and bisexual orientations, though not transgender people or gender identity. Anti-gay activists use “homosexual” as a slur to stigmatize gay people by reducing their lives to purely sexual terms.	* Only when used as an adjective (ie, gay people); † Use bisexual as an adj. and as needed on first reference for clarity, otherwise default to bi.
Indian (when referencing Indigenous People)	Indigenous People; specific tribe	The Oxford English dictionary defines Indian in two ways: 1) a native or inhabitant of India;* and 2) a member of any of the indigenous peoples of North, Central, and South America, especially those of North America.	* Acceptable use for Indian in this instance
Invalid (noun: in·va·lid)	Avoid in all instances*; use people first language and their diagnosis, ie, “person with X”	The Oxford English dictionary defines an invalid as “a person made weak or disabled by illness or injury.” It is probably the oldest term for someone living with physical conditions that are considered seriously limiting.	* Except when used in a direct quote
Lame	“difficulty walking”	Commonly used to describe difficulty walking as the result of an injury to the leg.	

LGBT (when talking with those who are unfamiliar with the issues or are not supportive of the issues)	Gay and transgender; lesbian, gay, bisexual, and transgender*	Per "The Ally's Guide to Terminology": Reference sexual orientation and gender identity when talking about issues pertaining to both. (See Transgender for more information.) The abbreviation "LGBT" can be confusing and alienating for those who are unfamiliar with the issues or not yet supportive—though it is essential when talking to LGBT and strongly supportive audiences. Use the term that allows your audience to stay focused on the message without creating confusion about your intended meaning.	* If needed for clarity
Master/Slave	leader/follower; parent/child; primary/secondary; main/secondary*		* Preferred term from IEEE Thesaurus
Mentally ill/ emotionally disturbed	Person with a psychiatric disability		
Minorities	People of color*; underrepresented groups†	The use of "minority" may be viewed pejoratively because it is usually equated with being less than, oppressed, or deficient in comparison with the majority (i.e., White people).	* POC (people of color). † When possible, use the specific name of the group or groups to which you are referring.
Normal People	Person without X		
Oriental (when referencing race)	Asian*; Asian American†	"Orientals" is considered pejorative; be more specific by providing nation and region of origin (Japanese, Chinese, Vietnamese, etc.).	* For people from Asia; † People of Asian descent in North America

Retarded/Slow learner	Learning disability*	According to the University of Kansas Research & Training Center on Independent Living: "...describes a neurologically based condition that may manifest itself as difficulty learning and using skills in reading (called dyslexia), writing (dysgraphia), mathematics (dyscalculia) and other cognitive processes due to differences in how the brain processes information. Individuals with learning disabilities have average or above average intelligence, and the term does not include a learning problem that is primarily the result of another cause, such as intellectual disabilities or lack of educational opportunity."	* Only when the condition has been medically diagnosed
Schiophrenic/Schizo	Person with schizophrenia		
Sex change (operation)	Transition	Per hrc.org: The process by which some people strive to more closely align their internal knowledge of gender with its outward appearance. Some people socially transition, whereby they might begin dressing, using names and pronouns, and/or be socially recognized as another gender. Others undergo physical transitions in which they modify their bodies through medical interventions.	Transition is the accurate term that does not fixate on surgeries, which many transgender people do not or cannot undergo. Terms like "pre-op" or "postop" unnecessarily fixate on a person's anatomy and should be avoided.
Sexual identity/ transgender identity	Gender identity/gender expression	Gender identity is one's internal sense of gender. Gender expression is how a person outwardly expresses their gender. (Terms are not interchangeable.)	Many transgender people identify as male or female and not simply transgender. Pronouns express this identity: He/him; She/her; They/them.
Sexual Preference/Gay lifestyle/homosexual lifestyle/same-sex attractions/sexual identity	sexual orientation	"Sexual preference" is used by anti-gay activists to suggest that being gay is a choice; therefore, being gay can be changed. Using "lifestyle" insinuates much the same and stigmatizes gay people suggesting their lives should be viewed strictly as sexual.	
Transgendered/ a transgender (n.)/ transgenders (n.)/ transvestite/tranny	Transgender	Transgender is an adjective, not a noun. "Trans" as shorthand is often used within the LGBTQ+ community, but not generally understood by general audiences.	Always use a transgender person's chosen name. Also, a person who identifies as a certain gender should be referred to using pronouns consistent with that gender (he/him, she/her, they/them).
Unmanned aerial vehicles	Autonomous aerial vehicles		Preferred term from IEEE Thesaurus

Unmanned automobiles or cars	Autonomous automobiles		Preferred term from IEEE Thesaurus
Unmanned underwater vehicles	Autonomous underwater vehicles		Preferred term from IEEE Thesaurus
Unmanned vehicles	Autonomous vehicles		Preferred term from IEEE Thesaurus
Unsuccessful suicide	Attempted suicide		
Wheelchair-bound	Wheelchair user/Uses a wheelchair		
White box	Glass box		Preferred term from IEEE Thesaurus
Whitelist; white list	Access list	A whitelist (or white list) is a list or register of entities that, for one reason or another, are being provided a particular privilege, service, mobility, access or recognition. This can be a controversial view for some.	Preferred term from IEEE Thesaurus

Manuscript preparation

Prepare and submit the manuscript strictly as per "Guidelines for authors". Manuscript NOT prepared as per Guidelines will not be considered.

1) **For units**, use standard symbols conforming to the International System of Units (SI), e.g., km, m, cm, mm, µm, Å, nm; kg, g, mg, l (liter), ml (milliliter), µl (micro liter), yr (year), wk (weak), d (day), hr (hour), min (minute), sec (second), ppm (parts per million), 0C (centigrade), SD (standard deviation), SE (standard error), CV (coefficient of variation), mg l-1 (milligram per liter), ms-1 (meter per second), g l-1 (grams per liter).
2) **For enzymes**, use trivial names as recommended by IUPAC-IUB Commission.
3) **For abbreviations,** full form of abbreviation should be given at the first citation with abbreviation in the bracket e.g., Jaynes Cummings Model (JCM).
4) **Tables** should be typed in Microsoft-Word Table format on separate pages, and should be numbered using Arabic numerals. They should be supplied with headings and should be referred to as "Table 1, 2, …".
5) **Figures** Only original figures & photographs of high resolution and contrast should be given, prepared by Coral Draw / EPS software as vector-based files.

- The figure width should be **8** cm OR **16** cm and height should not exceed **23** cm with the screen resolution of **300-600 dpi** in **JPEG or TIFF** format. Scanned line figures and images should be of minimum resolution **800 dpi** and for halftone **300 dpi**.
- Symbols and lettering size should be of 9 point in Arial Narrow. Use units as specified in "Authoring Guidelines". The axis of the graph should be 0.5 point or 1.0 point. Do not draw figures with hairlines. Use black & white, hatched and cross hatched patterns for distinctness. Overlapping of the symbols and data should be avoided. Avoid variations in font size in a single figure.
- Use Cyan, Magenta, Yellow & Black (CMYK) colors rather than Red, Green or Blue (RGB) for color figures. Use zero before a decimal number e.g. 0.3, 0.55 etc.
- Electronic changes or manipulation of micrographs or other digital figures / images are not allowed. Linear adjustment of contrast & brightness of color must be applied to the entire image or plate equally. The legend of each figure should be given at the bottom.

6) **Paper structure:** Complete Information should be given *(mandatory) and* should contains the following information:

- **Title of the manuscript:** Short, informative, should not exceed two lines. Numbers and abbreviations should NOT be included (Example, Fixed-Time Analysis of Neural Networks).
- **Author(s) name(s):** The names should be in the order: initials of first and middle names and then surname (family name), (Examole, M. Abdel-Aty[1], H. Servistava[2] and M. Ahmed[3]), Check that all names are spelled correctly.

- **Author(s) affiliations:** Full designation, professional address with postal code, country name and mobile number of all the authors (Example, [1]*Mathematics Department, Faculty of Science, 82524 Sohag, Sohag University, Egypt*)
- **E-mail ID** of all the authors
- **Short running title:** only of 4 or 5 words (Example, Fixed-Time Analysis of ……)
- ***Abstract:*** Content should be concise and factual, not exceeding 300-400 words, with no references, history of the subject, general sentences and abbreviations and should be written under the following sub-headings: Objective describing research methods used, mentioning to significant findings and recommendation and relevance of the study. (Example: Abstract: We propose a method to engineer stroboscopically arbitrary one-dimensional optical potentials. Our approach is based on …… . We demonstrate the ability of the method to engineer …… . We analyze the influence of …… . It is shown that ……..)

✓ ***Key words:*** only 4-5 Key words to serve as subject index. They should be arranged alphabetically.

✓ ***Introduction:*** should be precisely includes the history of the subject, the importance of this work, recently related work, exactly what will be done i.e. objective of the study, the organization of the rest of the paper, concise and specific with no sub-headings, no long paragraphs and accurate citations starting from [1], [2], [3] etc. (Example:

Introduction

Quantum entanglement is at the heart of quantum information processing and quantum computation [1–4]. In recent years, many efforts have been devoted to the study of the evolution of joint systems formed by two qubits [5–15]. In particular, Yu and Eberly [5, 6] have found out that ……

On the other hand, the long-lived entanglement in cavity QED or solid state systems was investigated by several authors [18–22]. In [18], the authors ……

In the present paper, we investigate the entanglement dynamics and coherence of a quantum system formed by two two-level atoms within two spatially separated …….

The present paper is organized as follows. In section 2, we obtain an explicit analytical solution of one atom interacting with a dissipative cavity in the dispersive limit. In section 3, we consider a quantum system consisting of two atoms within two spatially separated cavities. In section 4, the entanglement dynamics and coherence of the two two-level atoms are investigated by employing the concurrence and linear entropy, respectively. Finally, we summarize our results in section 5.

- **Text** which should be subdivided into the following main headings:
  - ❖ 1. Introduction
  - ❖ 2. Materials and Methods
  - ❖ 3. Results and Discussion (Combined)
  - ❖ 4. Acknowledgments
  - ❖ 5. References

- Materials and Methods should be sufficiently detailed to enable the experiments to be reproduced. The standard techniques and methodology should be adopted and supported with references of standard protocols only.
- Results and Discussion should be combined. Results may be split into sub-headings. Results should be co-related and discussed. Data emerging out from the study should be included, arranged in a unified and coherent sequence, and statistically analyzed with significance. It should deal with interpretations and the conclusions drawn, based on results and supported by relevant references. Position of figures and tables should be indicated. The same data should not be presented in both tabular and graphic forms.

Latest references should also be cited. Unpublished references should not be cited.

- Acknowledgments should include the names of those who contributed substantially to the work and the sponsor or the funding agency.
- References should be cited in the Text by numbers [1], [2], [3] etc. While giving the names of the periodicals, standard abbreviations listed in the International Serials Catalogue, published by International Council of Scientific Unions Abstracting Board (ICSUAB) should be used. Under the heading of References at the end of the manuscript, full and complete references should be written as per style and punctuation given below (see box), arranged alphabetically by first author's surname. (Example:

(How to prepare your references)

✓ **Article in a Journal**
Author(s). Article title. *Journal title*, vol., pages, year.
Example:
[1] B. Gates, Why word is used, *Microsoft Lett.*,**69**, 53-60 (998).

✓ **Book**
Author(s). *Book title*. Publishing company, Location: Page, year.
Example:
[1] M. Nelsin and I. Chuang, *Quantum Information and Computation*, Oxford Press, London UK, 53-60, (1998).

✓ **Book Chapters**
Author(s). *Chapter title*, in Book title, edition, volume. Editors name, Ed. Publishing company, Publishing location: page, year.
Example:
[1] J. E. Bourne. *Synthetic structure of industrial plastics*, in Plastics, 2nd ed., vol. **3**. J. Peters, Ed. New York: McGraw-Hill, 15-67, (1964).
[2] M Abdel-Aty: *Quantum Information Prossing*, in Plastics, 9th ed., vol. **5**. J. Peters, Ed. New York: McGraw-Hill, 1-61, (2001).

✓ **Articles from Conference Proceedings (published)**
Author(s). *Article title*, Conference proceedings, page, year.
Example:
[1] D.B. Payne and H.G. Gunhold. *Digital sundials and broadband technology*, in Proc. IOOC-ECOC, 557-998, (1986).

✓ **Papers Presented at Conferences (unpublished)**

Author(s). *Paper's title*, Conference name, Location, year.
Example:
[1] B. Brandli and M. Dick. *Engineering names and concepts*, presented at the 2nd Int. Conf. Engineering Education, Frankfurt, Germany, (1999).

- ✓ **Standards/Patents**
  Author(s)/Inventor(s). *Name/Title*. Country where patent is registered. Patent number, date.
  Example:
  [1] E.E. Rebecca. *Alternating current fed power supply*. U.S. Patent 7 897 777, Nov. 3, (1987).

- ✓ **Dissertations and Theses**
  Author. *Title*. Degree level, school, location, year.
  Example:
  [1] S. Mack. *Desperate Optimism*. M.A. thesis, University of Calgary, Canada, (2000).

Authors Biography:

- Author short biography and recent photo with white background should be used (Passport Photo)

Example:

Professor Mahmoud Abdel-Aty completed his doctorate in quantum optics at Max-Plank Institute of Quantum Optics, Munch, Germany in 1999. He received the D. Sc. (Doctor of Science), in 2007. His current research interests include quantum resources, optical and atomic implementations of quantum information tasks and protocols. He has published more than 240 papers in international refereed journals, 14 book chapters and 2 books. Abdel-Aty's research has been widely recognized and he has received several local and international awards. In 2014 he has been elected as a vice-president of the African Academy of Science.

Dr. Susan Jing completed her doctorate in economic at University of Reggio Calabria. She was the Founder and Director of MEDAlics, Research Canter of Mediterranean Relations and Vice Rector at University Dante Alighieri of Reggio Calabria. She is referee and Editor of several international journals in the frame of pure and applied mathematics, applied economics. Her main research interests are: dynamical systems, patterns of growth and sustainable development, economics, game theory, applied economics, differential geometry and applications, geometric dynamics and applications.

Call for NUTA Journal (Volume X) 2023

NUTA Journal ISSN (2616-017X) is a yearly publication journal of Nepal University Teacher's Association (NUTA) Central committee, Kathmandu, Nepal. It is a multidisciplinary, double blind peer reviewed journal designed to serve as an outlet for an intellectual forum through their innovative articles. The submission of research articles to this journal assumes that the article has not been published and not submitted elsewhere for publication. NUTA Journal volume X is going to publish, so all the interested teachers of the universities within the country are requested to send their articles for publication.

Guidelines for authors

1) The journal publishes original research articles, both in English and Nepali. The article should be research oriented and relevant to the field of higher education in the concerned subject and ongoing recent issues.

2) The full length (with title, abstract & references) of the article should be between the range of 3000 to 6000 words (should not exceed 16 printing pages) and the article should follow the sixth edition of APA manual.

3) Title should be brief, clear, concise and informative with 120 characters. The author's name and present affiliation should appear just below the title.

4) Abstract should have 250 – 400 words for a full-length article. It should be brief summary of the research including the objective, methods, results and major conclusions. Do not include literature citations in the abstract.

5) At least five key words should be provided at the bottom of the abstract in alphabetical order.

6) The articles should be typed double-spaced on one side of A4 size paper with 1.5′ margins in all sides, and 1.5 line space, in Times New Roman 12 point normal font and in case of Devanagari script, it should be in 1.5 line space, typed in 14 point (Preeti font) and electronic copies of the articles along with author's bio-data.

7) Foot notes are not permitted in the text and do not underline any text. Only bold and italics may be used.

8) Main text should be organized under the following headings:

a) Introduction: It should have significance of the paper beginning with a paragraph of explanation that describes the existing knowledge and gap leading to the main research objectives and questions.

b) Material and Methods: This section should include study area and time, study unit, experimental design and data analysis. The methods should be written in the past tense.

c) Results: Results should be stated concisely and clearly in descriptive, tabular and graphical forms etc. without interpretation. This section should address objectives/specific objectives systematically.

d) Discussion: It should provide interpretation of the results, comparison of the results with previous research findings, impacts and suggestions for further research.

e) Conclusion: Conclusion should clearly point out the main findings, which must be justified by the analysis of data.

9) Conflict of Interest: Any potential conflict of interest must be clearly stated.

10) Acknowledgements: Anyone (individual/ company/institution) who has substantially contributed to the study for important intellectual content or was involved in the drafting or revising the manuscript must also be acknowledged. Any financial support/funding should be acknowledged.

11) References: All works cited should be arranged in alphabetical order of the author's name and listed at the end of the paper. Both the references and the citations should be as per the sixth version of American Psychological Association (APA) style guidelines (http:/apastyle.apa. org).

12) Appendix: if needed, appears after the references.

13) Publication charges: The Journal of Nepal University Teachers' Association does not levy any charges for submission, processing and publication.

14) Potential Reviewers: Authors should suggest three potential reviewers with their affiliation, mobile no. and Email address, with the understanding that they may or may not be asked to review the manuscript.

15) The peer Review Process: Following the submission of the manuscript to the journal the editorial board will check whether the submitted manuscript is appropriate for the Journal or not. The manuscript will go through a plagiarism check before starting the review process. If deemed suitable for the Journal, the chief editor will assign the article to reviewers corresponding to their expertise. The reviews are given two weeks period of reviewing the articles. Double – blind peer review is applied for the article submitted. Once the author submits the corrected paper addressing the reviewers comments, it will be sent to the corresponding reviewers again to decide whether the manuscript has the potential for acceptance.

16) The journal encompasses all the field of science, Sanskrit, humanities, management, engineering, medicine, education, law, computer science etc.

17) The editorial board has the discretion to accept or reject the articles and edit the contents (if necessary).

18) Article contributor will be honored with two copies of journals if the reviewed article is published.

The deadline of article submission is 15th Shrawan 2080 (31st July 2023)

For Article Submission and other Information

Editor-in-Chief **Prof. Dr. Ramesh Kumar Joshi**

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CHAPTER 4

Data Analysis and Interpretations

MEASUREMENTS AND SCALES

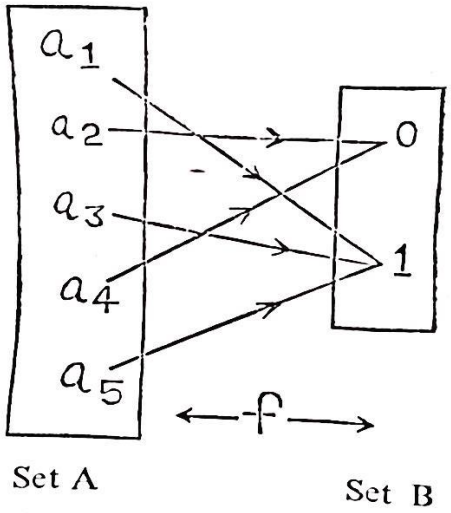
Definition

Measurement is the assignment of numerals to objects or events according to some rules. A numeral is a symbol used to distinguish objects from each other and has no quantitative meaning unless we give such a meaning. In other words, numerals are the symbols assigned to objects according to some prescribed rule. Numerals are usually the symbols 1. 2, 3...or I, II, III...etc ascribed to the objects such as players (Ex: Football players).

When numerals are assigned quantitative meaning, they become numbers. The term assignment means mapping of objects of **one set** onto the objects of **another se**t. A function, f, is the rule of correspondence.

Example 1: Suppose a family consists of five persons and we want to measure their sex. Assuming that we have a prior rule that allows unambiguously to determine the sex, the rule is to assign a symbol if the person is male and another symbol if the person is female. If the symbols used are 1 and 0 respectively, then we have two sets. A={a_1 , a_2 , a_3 , a_4, a_5} and B=(1, 0} where a_1 , a_2, a_3, a_4 and a_5 are the members of the family A.

If the members a_1, a_3 and a_5 are males, then the mapping of the sets will be as:



Thus, measurement may be defined as the mapping of objects of one set to objects of other set.

The kind of measurement achieved is a function of the rule which assigns the numerals (symbols) to objects/observations. The rule is called a **scale**.

Steps in Measurement Procedure

The **first** step in any measurement procedure is to define the objects of the universe of discourse. **Second,** the properties of the objects must be defined. Then the universe `U' is partitioned into at least two mutually exclusive and exhaustive subsets, That is, each object must be assigned to one subset only and all objects must be so assigned.

After the objects of the universe have been classified into designated subsets, the member of the sets can be counted. When set members are counted in this fashion, all objects of a sub-set are considered to be equal to each other and unequal to the members of other sub-sets.

Example: Let U= All tenth grade pupils in a certain high school. Let the measurement character-istics be sex of the pupil. Then U is partitioned into two mutually sub-sets B and G where B is the subset of U which includes all males of U and G is the subset of U which includes all females of U so that U= B+ G

Physical Scales: There are four types of physical scales. They are:

Nominal Scale

A nominal scale is one that allows the researcher to assign subjects to certain categories or groups. This is simplest and lowest form of data and it gives very basic information. This sale is usually used to obtain personal data, where grouping of individuals or objects is required.

EXAMPLE	Gender:	Male, Female
	Religion:	Hindu, Buddhist, Muslim, Christian
	Occupation:	Teacher, Manager, Doctor, Businessman, Civil servant
	Nationality:	Nepali, Indian, American, Japanese
	Department:	Sales, Finance, Personnel, Production

All categories are mutually exclusive. Every respondent has to fit into one of these categories. Therefore, one cannot rank these and say that a male is a higher value than a female, or that 3 teacher has a high value than a manager. Nominal data results from qualitative variables.

The information that can be generated from nominal scaling is to calculate the percentages and frequencies. For example, if you interviewed 150 students in a campus, and assigned a code number 1 to all male students and number 2 to all female students, then computer analysis of data might reveal that 100 were male and 50 were female students. This frequency distribution

tells you that 66.6 percent of the respondents are male and 33.4 percent female. Nominal scale, thus, tells you nothing more than basic or gross information. Chi-square test is the most common test applicable to nominal data. Due to its limitations concerning statistical treatment, a nominal scale has the characteristic of exploratory research where the emphasis is on uncovering relationships rather than on specifying the form of relationship.

Ordinal Scale

A scale is ordinal when objects can be assigned order on some characteristic but they cannot be assigned values that represent degree of difference on that characteristic. This scale is usually used to rate the preferences of the respondents. It applies to data which can be ranked according to value but cannot be given a particular numerical value which actually is descriptive of the data. For example, one can rank drinks (coca-cola, tea, coffee, soda water, mineral water) in order of his or her preference from most preferred to least preferred. This means one likes coca-cola better than soda water or prefers coffee to mineral water.

EXAMPLE Rank the following occupations in terms of their social status.

Jobs.	**Rank of Social Status**
Manager	.....
Doctor	.....
Engineer	.....
Professor	.....
Lawyer	.....
Civil Servant	.....
Police Officer	.....

In this example, if the respondents give higher rank to doctors than engineers, we can say doctors have relatively higher social status than engineers. We cannot, however, conclude that the doctors have three times higher social status than the engineers.

EXAMPLE Rank the following cities in terms of their suitability to open a branch office of a commercial bank.

Cities	**Rank**
Biratnagar	.....
Hetauda	.....

Janakpur .....

Butawal . .....

Nepalgunj .....

Dhangadhi .....

Ordinal scales represent numbers, letters, or any symbols used to rank items. The significant amount of business research relies on ordinal measures. The most common usage of ordinal scale is in obtaining preference measurements. For example, the employees of an organization maybe asked to rank their preferences for the newspapers they would like to read, or the games they would like to play. Ordinal scale thus provides more information than the nominal scale.

In ordinal data, median is an appropriate measure of central tendency. Percentile and quartile analysis are used for measuring dispersion. In most cases, rank-order correlations can be used Because of the nature of data; only non-parametric tests can be used.

Interval Scale

This scale assumes that the data have equal intervals. For example, there are five sisters who are all one year apart in age. Radha, Rambha, Reshma, and Rohini are 4, 3, 2 and 1 year older than the youngest sister Rabina. The important point is that we cannot say that the oldest sister Radha is twice as old as Reshma and four times older than Rohini. The reason is that we do not know what the age of the youngest sister, Rabina, is.

Interval scale is like ordinal but with constant intervals. The numbers tell both position and distance. Thus, the interval scale not only groups individuals according to certain categories and taps the order of these groups; it also measures the magnitude of the differences in the performances among the individuals. As such, it is more powerful scale than the nominal and ordinal scales.

Interval scales, or any other attempts at creating such scales, are found often in behavioral research. This is particularly true for measurement of attitudes and certain psychological characteristics, such as intelligence and learning. In analyzing interval data, many options are available. Mean can be appropriately used to measure central tendency. Standard deviation is widely used for dispersion. Product moment correlation can be calculated, and t-test and F•test can be used for significance testing.

Ratio Scale

The ratio scale is the most powerful of the four scales because it has an absolute zero origin and subsumes all the properties of the other three scales. This allows the researcher to calculate the ratio of difference between the age of the individuals. For instance, one can say that the boy who is 8 years old is twice as old as the boy who is 4 years old. Also, we can say that a man who worked 40 hours, worked twice as many hours as the man who worked 20 hours. Some examples of ratio scales are actual age, income, the number of organizations an individual has worked for. The responses could range from 0 to any figure.

EXAMPLE

How many children do you have? .....

What is your annual household income? .....

How many workers are working in your factory? .....

How many workers are the members of the union? .....

What is the highest level of education you have completed? .....

How long have you lived in Kathmandu? .....

Ratio scales are found more commonly in the physical sciences than in the social sciences. Measurement of weight, length, time intervals, area, velocity, etc., all conform to ratio scales. Various types of statistical analysis and mathematical operations can be done on ratio data. Geometric and harmonic means can be used. Likewise, coefficient of variation can be worked out.

अनुसूची- २

General Guidelines for Project Work (PRO 406) Format

It is a mandatory to maintain the uniformity in the format of the Project Work (PRO-406) carried out by B.Sc. IV year students in different departments of several campuses under Institute of Science and Technology (IoST), Tribhuvan University, Nepal.

The format of the Project Work included the following headings/items:

i. Cover Page
ii. Board of Examination and Certificate of Approval
iii. Letter of Forward
iv. Recommendation
v. Declaration
vi. Acknowledgements
vii. Abstract
viii. List of Acronyms and Abbreviations
ix. List of Symbols
x. List of Tables
xi. List of Figures
xii. Table of Contents

1. Chapter 1: Introduction
2. Chapter 2: Literature Review
3. Chapter 3: Materials and Methods
4. Chapter 4: Result and Discussions
5. Chapter 5: Conclusions and Recommendations
6. Reference
7. Appendix

The details of these headings/items are given

(Format for cover page)

[TITLE OF THE PROJECT WORK]

(Comment: Center, All caps, Bold, Font size 16)

[Logo of T.U.]
(Comment: Center, size 2"×1.72")

A PROJECT WORK SUBMITTED TO THE
(Comment: Center, All caps, not bold, Font size 14)

DEPARTMENT OF … (Name of Department) ....
…(Name of campus)…… CAMPUS
INSTITUTE OF SCIENCE AND TECHNOLOGY
TRIBHUVAN UNIVERSITY
NEPAL
(Comment: Center, All caps, Bold, Font size 14)

FOR THE AWARD OF
BACHELOR OF SCIENCE (B.Sc.) IN … (Name of subject)….
(Comment: Center, All caps, Bold, Font size 14)

BY
(Comment: Center, All caps, not bold, Font size 14)

[FULL NAME OF THE STUDENT]
SYMBOL No….
T.U. REGISTRATION No…..
(Comment: Center, All caps, Bold, Font size 14

[MONTH, YEAR]
(Comment: Center, All caps, Bold, Font size ~~14~~)

RECOMMENDATION

(Comment: Center, All caps, Bold, Font size 16)

This is to recommend that … **(Name of student, bold faced letter)……,** (Symbol No…… , T.U. Registration No……), has carried out project work entitled "…..**(Title, bold faced letter)**……." for the requirement to the project work in Bachelor of Science (B.Sc.) degree in …(Name of subject)…… under my/our supervision in the Department of …… (Name of department)……, …(Name of Campus/Institute)… Campus, Institute of Science and Technology (IoST), Tribhuvan University (T.U.), Nepal.

To my/our knowledge, this work has not been submitted for any other degree.

He/She has fulfilled all the requirements laid down by the Institute of Science and Technology (IoST), Tribhuvan University (T.U.), Nepal for the submission of the project work for the partial fulfillment of Bachelor of Science (B.Sc.) degree.

(Comment: Times New Roman, Font size 12)

…. (Name) ….
Supervisor
Department:
Campus/Institute:
University:

…. (Name) ….
Co-Supervisor
Department:
Campus/Institute:
University:

[DAY, MONTH, YEAR]

DECLARATION

(Comment: Center, All caps, Bold, Font size 16)

This project work entitled "… **(Title, bold faced letter)** ….." is being submitted to the Department of … (Name of department)…., …(Name of Campus)…… Campus, Institute of Science and Technology (IoST), Tribhuvan University (T.U.), Nepal for the partial fulfillment of the requirement to the project work in Bachelor of Science (B.Sc.) degree in …(Name of subject)…. This project work is carried out by me under the supervision of ….(Name of supervisor)…… and co-supervision of …..(Name of co-supervisor)…… in the Department of …… (Name of department)……, … (Name of Campus/Institute) …… Campus, Institute of Science and Technology (IoST), Tribhuvan University (T.U.), Nepal.

This work is original and has not been submitted earlier in part or full in this or any other form to any university or institute, here or elsewhere, for the award of any degree.

(Comment: Times New Roman, Font size 12)

Signature
Name of student
Symbol No. ……..
T.U. Registration No……

[DAY, MONTH, YEAR]

LETTER OF FORWARD

(Comment: Center, All caps, Bold, Font size 16)

[Date: Day/Month/Year]

On the recommendation of **…… (name of supervisor, bold faced letter) …..** and **…… (name of co-supervisor, bold faced letter) …..**, this project work is submitted by **…… (name of student)…..,** Symbol No. ….., T.U. Registration No……., entitled **…….(title, in bold faced letter)**…….” is forwarded by the Department of … (Name of department)……, …(Name of Campus)…..Campus, for the approval to the Evaluation Committee, Institute of Science and Technology (IoST), Tribhuvan University (T.U.), Nepal

He/She has fulfilled all the requirements laid down by the Institute of Science and Technology (IoST), Tribhuvan University (T.U.), Nepal for the project work.

(Comment: Times New Roman, Font size 12)

…. (Name) ….
Head of Department
Department of …….
…… Campus
Tribhuvan University

BOARD OF EXAMINATION AND CERTIFICATE OF APPROVAL

(Comment: Center, All caps, Bold, Font size 16)

This project work (PRO-406) entitled "**…(Title, bold faced letter)….**" by …(Name of student)…. (Symbol No……and T.U. Registration No……..) under the supervision of ….(Name of supervisor)…… and co-supervision of …..(Name of co-supervisor)…… in the Department of ……(Name of department)…., -…(Name of Campus)…..Campus, Institute of Science and Technology (IoST), Tribhuvan University (T.U.), is hereby submitted for the partial fulfillment of the Bachelor of Science (B.Sc.) degree in …(Name of subject)…. This report has been accepted and forwarded to the Controller of Examination, Institute of Science and Technology, Tribhuvan University, Nepal for the legal procedure.

(Comment: Times New Roman, Font size 12)

…. (Name) ……..
Supervisor
Department:
Campus/Institute:
University:

….. (Name) ….
Co-Supervisor
Department:
Campus/Institute:
University:

…. (Name) ….
External Examiner
Department:
Campus/Institute:
University:

…. (Name) ….
Internal Examiner
Department:
Campus/Institute:
University:

…. (Name) ….
Head of Department
Department of …….
…… Campus
Tribhuvan University

[DAY, MONTH, YEAR]

ACKNOWLEDGEMENTS

(Comment: Center, All caps, Bold, Font size 16)

Text: (Times New Roman, Font size 12)
No. of pages: (Not more than 2 pages, write in justified form)

(Comment: Times New Roman, Font size 12, spacing within a paragraph 1.5, spacing between two paragraph 2.0)

(Name of student)
Symbol. No. …
T.U. Registration No……..
[Month, Year]

ABSTRACT

(Comment: Center, All caps, Bold, Font size 16)

Text: (Times New Roman, Font size 12)
No. of pages: (preferable within a page, write in justified form)

(Comment: Times New Roman, Font size 12)

Keywords (**Comment:** Times New Roman, Font size 10, Italics)**: …., …., …., …., …. (Comment:** Write five keywords, Times New Roman, Font size 10, not in Italics).

शोधसार (अनिवार्य)

(टिप्पणी: मध्य, **बाक्लो,** प्रीति, १८)

मुल पाठ: (प्रीति, १६)
पाना संख्या : (एक पानाभित्र समेटिने गरी लेख्नुपर्ने)

(टिप्पणी: हरफ मिलेको, प्रीति, १६)

Keywords (**Comment:** Times New Roman, Font size 10, Italics)**: …., …., …., …., …. (Comment:** Write five keywords, Times New Roman, Font size 10, not in Italics).

LIST OF ACRONYMS AND ABBREVIATIONS

(Comment: Center, All caps, Bold, Font size 16)

Text: (Times New Roman, Font size 12)
Examples:

FTIR:	Fourier Transforms Infrared Spectroscopy
GC-MS:	Gas Chromatography-Mass Spectroscopy
LPG:	Liquefied Petroleum Gases
NGO:	National Governmental Organization

(Comment: Times New Roman, Font size 12, line spacing 1.5, arrange in alphabetical order)

LIST OF SYMBOLS

(Comment: Center, All caps, Bold, Font size 16)

Text: (Times New Roman, Font size 12)
Examples:

μ	Dipole moment
γ	Activity Coefficient
ε	Relative Dielectric Constant

(Comment: Times New Roman, Font size 12, line spacing 1.5)

LIST OF TABLES

(Comment: Center, All caps, Bold, Font size 16)

Text: (Times New Roman, Font size 12)

Table No (bold faced letter): Title of the table (not bold, font size 12) **Page No.**

Examples:

Table 1: Calorific value of different petroleum fuels **..**
Table 2: Free radical scavenging effects of ascorbic acid **..**

(Comment: Times New Roman, Font size 12, line spacing 1.5)

LIST OF FIGURES

(Comment: Center, All caps, Bold, Font size 16)

Text: (Times New Roman, Font size 12)

Figure No (bold faced letter): Title of the figure (not bold, font size 12) **Page No.**

Examples:

Figure 1: Thin layer chromatogram of ethyl acetate extract of *A. Coronans* **…**
Figure 2: FTIR spectrum of ethyl acetate extract of *A. Coronans* **…**

(Comment: Times New Roman, Font size 12, line spacing 1.5)

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CHAPTER 1

(All caps, bold faced letter, Font size 16)

1. INTRODUCTION (All caps, bold letter, Font size 14)

1.1 General Introduction (Bold, Font size 12)
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1.2 Rationale (Bold, Font size 12)
(Text: Times New Roman, Font size 12, not bold)

1.3 Objectives (Bold, Font size 12)

1.3.1 General objective: (Bold, Font size 12)
(Text: Times New Roman, Font size 12, not bold)

1.3.2 Specific objectives: (Bold, Font size 12)
(Text: Times New Roman, Font size 12, not bold)

CHAPTER 2

(All caps, bold faced letter, Font size 16)

2. LITERATURE REVIEW (All caps, bold letter, Font size 14)

2.1 (Sub-heading, if any) (Bold, Font size 12)
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2.2 (Sub-heading, if any) (Bold, Font size 12)
(Text: Times New Roman, Font size 12, not bold)

CHAPTER 3

(All caps, bold faced letter, Font size 16)

3. MATERIALS AND METHODS (All caps, bold letter, Font size 14)

3.1 Materials

3.1.1 (Sub-heading, if any) (Bold, font size 12)
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3.1.2 (Sub-heading, if any) (Bold, font size 12)
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3.2 Methods:

3.2.1 (Sub-heading, if any) (Bold, Font size 12)

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3.2.2 (Sub-heading, if any) (Bold, Font size 12)
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CHAPTER 4

(All caps, bold faced letter, Font size 16)

4. RESULTS AND DISCUSSION (All caps, bold letter, Font size 14)

4.1 (Sub-heading, if any) (Bold, Font size 12)
(Text: Times New Roman, Font size 12, not bold)

4.2 (Sub-heading, if any) (Bold, Font size 12)
(Text: Times New Roman, Font size 12, not bold)

CHAPTER 5

(All caps, bold faced letter, Font size 16)

5. CONCLUSION AND RECOMMENDATION (All caps, bold letter, Font size 14)

5.1 Conclusions (Bold, Font size 12)
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5.1.2 (Sub-heading, if any) (Bold, Font size 12)
(Text: Times New Roman, Font size 12, not bold)

5.2 Novelty and National Prosperity aspect of Project work (Bold, Font size 12)
(Text: Times New Roman, Font size 12, not bold)

5.3 Limitations of the work (Bold, Font size 12)
(Text: Times New Roman, Font size 12, not bold)

5.4 Recommendations for further work (Bold, Font size 12)
(Text: Times New Roman, Font size 12, not bold)

REFERENCE

(All caps, bold faced letter, Font size 16)

APPENDIX

(All caps, bold faced letter, Font size 16)
(Scientific publication, questionnaires, long computational algorithms, if necessary)

(Comment: Times New Roman, Font size 12, spacing through body of text 1.5 spacing, 1.5 spacing within each entry but 2.0 spacing between each entry)

Note: Project work for some of the departments (Mathematics, Statistic) may not fit into the above mentioned patterns, for such situations, the body part of the project work should have the following order.

a) **Introduction**
b) **Chapters with special heading, which covers the project work performed by the student.**
c) **Summary and conclusions: It includes the overall summary, conclusions and the recommendation for further work, if applicable.**

Language of Project work:

- The project work must be written in English.
- Presentation of the project work in viva-voce examination should also be conducted in English medium.

Length and quality of printing of Project work:

- The project work should be printed in single sided white bond paper of A4 size with body text not less than 30 pages.
- Photocopy of printing is not acceptable.

Typeface and font size:

- The project work should be written in Times New Roman.
- The font size should be 12 throughout the text except as mentioned above.
- Equations and formulae should be preferably written in 10 font size.
- The scientific names should be written in italics.
- The text should be justified.

Tables and Figures:

- Tables and figures should appear in the text closely to the point where it is first discussed.
- Table number and its heading should be placed above the body of the table.
- Figure number and its heading should be placed below the body of the figure.
- The font size for both table and figure caption should be 10.
- Table number and figure number must be continuous in the report.
- Table number and figure number are written in bold faced letter while their titles are written not in bold.
  Examples:
  Table 1 (font 10, bold): …..Title (font 10, not bold)…….
  Figure 1 (font 10, bold): …..Title (font 10, not bold)…….

Margins:

- In printing- top, right and bottom margins should be 2.5 cm and left margin should not be less than 3.5 cm.
- Page number should be at least 1.5 cm above from the lower edge of the paper.

Spacing:

- Spacing for text: 1.5 spacing throughout the body of text
- Spacing for references: 1.5 spacing within each entry and 2.0 spacing between each entry.

Pagination:

- Every page has a number.
- Use small Roman numerals (i, ii, iii, …..) for the preliminary pages such as *Board of Examination and Certificate of Approval*, *declaration, certificate of approval, table of contents etc.*
- Count the inner cover page as page i and the other pages such as *Board of Examination and Certificate of Approval, declaration, certificate of approval, table of contents etc.* ii, iii, iv, …. etc.
- Do not print the page number on inner cover page.
- Use Arabic Hindu numbers (1, 2, 3, 4, …) starting with page 1 from chapter 1.

Reference and citation in the text:

- American Psychological Association (APA) format should be preferably followed for references and citations in the text. The references should be arranged in alphabetical with chronological order by surname of the first author. Spacing for references should be 1.5 within each entry but double spacing between each entry. Use hanging indents: entries should begin flush left with subsequent lines indented.
- Other standard format such as AMS (American Mathematical Society), AIP (American Institute of Physics), ACS (American Chemical Society), etc. can also be accepted.
- Every reference cited in the text and present in the reference list should be linked and synchronize in standard reference management program such as EndNote, Latex, Zotero etc.

Examples of using APA format in reference and citation:

i) Book of single author:

Surname, Initial uppercase letter of author's name (Year), Title of the Book, Place, Publication.

Barron L. D. (1983), *Molecular Light Scattering and Optical Activity*, Cambridge University Press, Cambridge, UK.

Citation in the text: (Barron, 1983) or Barron (1983) explained …….

ii) Book of two authors:

Gosney, I. & Rowley, A. G. (1979), "Transformations via Phosphorus-stabilized Anions, Stereoselective Synthesis of Alkenes via the Wittig reaction", *Organophosphorus Reagents in Organic Synthesis*, Academic, New York, p.17.

Citation in the text: (Gosney & Rowley, 1979) or Gosney and Rowley (1979) stated that……

iii) Book of three or more authors:

Pelter, A., Smith, K., & Brown, H. C. (1988), *Borane Reagents*, Academic, London

Citation in the text: (Pelter, *et al.*, 1988) or Pelter, *et al.* (1988) explained …….

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डीनको कार्यालय
कीर्तिपुर २०७५

iv) Journal of single author:

Evans, D. A. (1982), "Studies in Asymmetric Synthesis. The Development of Practical Chiral Enolate Synthons," *Aldrichin. Acta*, **15**, 23

Citation in the text: (Evans, 1982) or Evans (1982) explained …….

v) Journal of two authors:

Denmark, S. E., & Marble, L. K. (1990), "Auxillary-Based, Asymmetric SN_2' Reactions: A Case of 1,7-Relative Stereogenesis," *J. Org. Chem.,* **55**, 1984

Citation in the text: (Denmark and Marble, 1990) or Denmark and Marble (1990) highlighted ……

vi) Journal of three or more authors:

Gautam, D. R., Protopappas, J., Fylaktakidou, K. C., Litinas, K. E., Nicolaides, D. N., and Tsoleridis, C. A. (2009), *Tetrahedron Lett.,* **50**, 448.

Citation in the text: (Gautam, *et al.*, 2009) or Gautam, *et al.* (2009) found that …….

Note: The names of journals should be typed in italic exactly as the name of the journal examples: *J. Am. Chem. Soc., J. Org. Chem., J. Am. Stat Assoc., Tetrahedron Lett., etc.*

vii) Ph.D/Master's Dissertation:

Rajbhandari (Nyachhyon), A. (2011), *Investigation on Inorganic Salts based Ions Selective Electrodes* (Unpublished doctoral thesis). Central Department of Chemistry, Institute of Science and Technology, Tribhuvan University, Kathmandu, Nepal.

viii) Internet article with DOI assigned:

Stultz, J. (2006), Integrating exposure therapy and analytic therapy in trauma treatment. *American Journal of Orthopsychiatry*, **76** (4), 482-488, doi:10.1037/0002-9432.76.4.482

In case of more than 7 authorships, author can be used *et al.* in the text and reference respectively. For example

Van Decar, J. C., Russo, R. M., James, D. E. *et al*. (2003). A seismic continuation of the Lesser Antilles slab beneath northeastern Venezuela. *Journal of Geophysical Research*, **70** (3), 212-219, doi.org/10.1029/2001JB000884

ix) Internet article without DOI assigned:

Sillick, T. J. & Schutte, N. S. (2006), Emotional intelligence and self-esteem mediate between perceived early parental love and adult happiness. *E-Journal of Applied Psychology*, **2** (2), 38-48. Retrieved from http://ojs.lib.swin.edu.au/index.php/ejap/article/view/71/100, Accessed on (dd/mm/yy).

अनुसूची– ३ (क)

…….. Campus
Department of …….
Institute of Science and Technology, Tribhuvan University

Project Work Evaluation Form

Name of Student:
Title of Project work:

Course Code: PRO-406 Symbol No.: Date: ……/..…/…

Evaluation Scheme

10	Extraordinary	9	Excellent	8	Very Good
7	Good	6	Average	5	Poor

Evaluation Criteria	**Evaluation (Circle One)**						**Total Evaluated Number**
Novelty	10	9	8	7	6	5	
Problem of Identification	10	9	8	7	6	5	
Project Design	10	9	8	7	6	5	
Procedure, Data collection and analysis	10	9	8	7	6	5	
Conclusion and Future works	10	9	8	7	6	5	
Literature review	10	9	8	7	6	5	
Writing format	10	9	8	7	6	5	
Presentation	10	9	8	7	6	5	
Viva-voce Performance	10	9	8	7	6	5	
Social Impact	10	9	8	7	6	5	

Additional Comments (If any):

$$Marks obtained = \frac{Total Evaluated Number}{100} \times Full Marks of the Examiner = ¿$$

[F.M. for out of 100: Supervisor (40)/ External Examiner (25)/ Internal Examiner (20)/ Head of the Department (15)]

Name:
Signature:
Date:

Supervisor/External Examiner/Internal Examiner/Head of the Department

अनुसूची– ३ (ख)

Mark ledger of the Project work student

Date: ……/…/…

To,
The Office of the Controller of Examination,
B. Sc. Exam Section,
Tribhuvan University,
Balkhu, Kathmandu, Nepal.

Subject: Marks of B. Sc. Project work (PRO 406)

Sir,

Marks obtained by Mr./Ms. ……..…….. (Batch ……..) for the evaluation of Project work conducted at the Department of ……., ……. Campus for the partial fulfillment of B. Sc. in …… has been forwarded. The details are as follows:

Year: Fourth **Course Code:** PRO 406

Full Marks: 100 **Pass Marks: 50**

Title of Project work:

Date of Submission : …….. (BS)/ …… (AD)
Date of Viva-voce : …… (BS)/ …… (AD)

S.N.	Symbol No.	Regtistration No.	Name of Student	Marks obtained (In figure and words)
1.				

Name and Signature of the members of Project work Evaluation committee/Board:

	Name	Signature
Supervisor :		
Co-Supervisor :		
External Examiner :		
Internal Examiner :		
Head of the Department :		

…….
(Name)
Head of the Department
…… Campus

विज्ञान तथा प्रविधि अध्ययन संस्थान
डीनको कार्यालय
कीर्तिपुर २०७५

Note: Dean Office has formed a committee to revise '*B.Sc. Fourth Year Project Work (PRO 406) Guideline*' under the convener-ship of **Prof. Dr. Daman Raj Gautam** (Amrit Campus) on 2078/01/15. The members of the committee were **Mr. Iswar Koirala** (Tri-Chandra Campus) and **Dr. Binod Baniya** (Patan Multiple College). The report was submitted to the Dean Office on 2078/02/14. Dean Office has tabled the report in the Full Faculty Board Meeting (virtual) on 2078/03/11. This '*B.Sc. Fourth Year Project Work (PRO 406) Guideline 2078*' has been approved by the faculty Board (Full) meeting on 2078/03/11.

Dissertation

Code No.: MDS699

Course Title: Dissertation **Full Marks:** 150

Nature: Dissertation **Credit:** 6

Course Description:

Dissertation is a formal piece of academic writing required for the completion of Master's degree in Data Science program. The final and central requirement for awarding the degree is the completion of substantial and original independent dissertation research in the data science field. Dissertation is a research paper of full marks 150 offered in 4^{th} semester of the program. It represents the culmination of a student's research and scholarly work in a particular field of data science. The purpose of this course is to contribute new knowledge, insights, or perspectives to the academic community and is expected to present original research and in-depth analysis of the chosen topic.

Course Objective:

The main objective of this course is to familiarize students with the skills needed to conduct in-depth study in the data science field to conduct an original research and contribute new knowledge to the data science community.

Learning Outcomes:

Upon successful completion of this course, students will be able to:

1. design and conduct an original research in the data science field,
2. contribute new knowledge to the academic community in the relevant field,
3. apply different theoretical concepts taught in the class in the chosen topic, and
4. conduct in-dept analysis of the chosen topic and enhance their research skills.

Phases:

The overall dissertation work is divided into three phases, proposal defense, pre-defense, and final defense.

1. **Proposal Defense**

   Each student must prepare a document in the prescribed proposal format proposing a specific plan for her or his dissertation research. This document is expected to make a convincing case that the proposed research is likely to make an original contribution. Students must present the research proposal in the research committee. Once accepted from the research committee, students can start their work under the supervision of a supervisor assigned from the research committee.

2. **Pre-Defense**

   Each student must prepare draft of the dissertation report and present this report in the research committee before final defense. Once approved from the research committee, students will be allowed to participate in the final defense. Each member of the committee members can advise the student about major revisions and additions to the tasks of research.

3. **Final Defense**

   During final defense, each student must prepare a final report in the prescribed format and present this final report. Students are expected to explain the significance of the dissertation research, justify the methods employed, and defend the conclusions reached. The overall dissertation work will be evaluated during final defense by the school director, an external examiner, the supervisor, and an internal examiner. The external examiner will be appointed from Institute of Science and Technology and the internal examiner will be appointed by the school director.

Activities:

The different activities and steps involved in the dissertation research are:

- Select the research topic
- Prepare and present research proposal
- Do the research and draw conclusion
- Prepare and present draft report
- Prepare and present final report

Proposal Structure:

The dissertation proposal document generally follows the following structure:

- Title Page
- Introduction
- Problem Statement
- Objectives
- Rational of the Study
- Preliminary Literature Review
- Methodology
- Expected Outcomes
- Working Schedule
- References

Final Report Structure:

The final report of the dissertation generally follows the following structure:

- Title Page
- Student's Declaration
- Supervisor's Recommendation
- Approval Sheet
- Acknowledgement
- Abstract
- Table of Contents
- List of Figures
- List of Tables
- List of Abbreviations / Acronyms
- Introduction (Chapter 1)
- Literature Review (Chapter 2)
- Methodology (Chapter 3)
- Result and Discussion (Chapter 4)
- Conclusion and Recommendation (Chapter 5)

- References
- Appendices

Needs of Scaling

Scales are such which can be used in quantifying every measurable property of objects or the variables. To measure the physical phenomena different kinds of scales are to be needed. The method of scaling is the technique of turning a series of qualitative facts into a quantitative series. The main needs of scaling techniques are:

(1) **For attaining scientific maturity**: The fundamental form of the movement in the direction of the greater precision is measuring graduation of the objects for a scientific study. Hence, the scaling technique is for the scientific maturity.

(2) **For objective measurement**: The scaling techniques are very useful in technical and social studies and the reliable inference about the technical/social phenomenon can be drawn by the use of the objective measurement.

(3) **For the improvement of more precise measuring device**: The existing measuring instrument and techniques can be improved by the use of different scales. More precise measuring devices are developed through the scientific use and practice of the existing scales.

Characteristics of a Scale

The essential characteristics of a good scale are:

a**) Continuum** **b) Reliability** **c) Validity** **d) Practicability**

Continuum

It is the characteristics of scale that it should be in the form of continuous series and the factors to be measured interrelated. The continuum to be defined depends upon the nature of the phenomenon and the nature of the factors to be defined.

Reliability

To obtain consistent result the measuring instrument should be steadfast. The reliability of the measuring scale must be stable, consistent and the error function should be correctly defined. It means the stability, consistency, dependability, predictability and accuracy of the scale used. According to Ebil 'The term reliability means the consistency with which set of test scores measure whatever they do measure'.

Definition

a) If we get the same measuring result for the same object / observation in many times then the measure (scale) may be considered as reliable measure (scale).

b) The absence of measurement error in measuring instrument is the reliability of the measure.

Validity

The most critical criterion of the scaling technique is the validity. A scale is said to be valid when it measures correctly what is expected to be measure. In other words, validity is the extent (degree) to which differences found with a measuring instrument reflect true difference among those being tested.

In experimentation, **reliability** is the extent to which the measurements resulting from a test reflect characteristics of the subject of measurement. An experiment is reliable if we are getting consistent results from the same measure. It is unreliable if repeat measurements of the same thing give different results.

In statistics a valid measure is one which is measuring what it is supposed to measure. **Validity** implies reliability (accuracy). A valid measure must be reliable, but a reliable measure may not be valid.

Practicability

It is the characteristics of the measure that must be practicable to use. It should be reasonable economically, conveniently and interpretably. It should be easy to administer. The scales used must be supplemented by i) detailed instruction of handling ii) scoring techniques (keys) iii) guides for utilize and iv) evidence about reliability.

Methods of Estimating Reliability (Tests of Reliability)

To obtain the reliability of the different scores, the following four method of computing reliability, coefficient are used.

a) Test- retests Method

b) Parallel/Alternate/Equivalent forms Method

c) Split Half Method

d) Rational Equivalence Method (Kuder Richardson Method)

(a) **Test-retest Method**

In this method the same set of objects/ items is measured (tested) again and again by using the same or the comparable measuring instrument. The results so obtain are compared by computing correlation coefficient between the scores of the different tests (measures). If it is impossible to use such method due to the long space of time, it is considered whether the effects of causative factor in the period of two tests are present or not. To find the result related to this problem technique of control group (a team checking by trained and motivated persons) is applied.

(b) **Parallel Forms Method**

In this method two analogous forms of test-scales are constructed and alternatively applied to the same samples/items selected/objects selected. The analogous forms mean the alternate or parallel forms of the tests having of the same kind difficulty category and design. To obtain the reliability coefficient the correlation coefficient between the test-results is computed. If the results are in high degree of connection then the scale may be said to be reliable. The correlation of the forms is called self-correlation and it becomes an index of equivalence of two sets. The parallel forms are mostly useful for the standard psychological and educational achievement tests.

(c) Split half Method

In this method the scores are divided in two equal parts randomly. For example, the scores on odd no. of test-set as a first half and the scores on even no. of test-set as the other half. Considering a part as complete, scaling procedure is applied for these two half-parts. If there exists a high degree of correlation between the scores of these halves, then the scaling is considered to be reliable. The split half method is generally used when it is difficult to construct the parallel form test. The coefficient of internal consistency or the self-correlation coefficient of the whole test is called Stepped up reliability and estimated by using Spearman-Brown formula. The general formula is

$$\text{Rw} = \frac{n * r_p}{1+(n-1)r_p}$$

Where, R_w is stepped up reliability coefficient; n the number of parts

r_p = the correlation coefficient between two parts

Spearman- Brown formula for computing test reliability having two halves is

$$R_{xy} = \frac{2 \times r_{xy}}{1+r_{xy}}$$

Where,

R_{xy} = Stepped up reliability coefficient of first and second half

2 is the number of parts and

r_{xy} = The correlation coefficient between two parts X and Y.

If the score are expressed in the ranks then, correlation coefficient is calculated by

$r_{xy} = 1 - \frac{6\Sigma d^2}{n(n^2 - 1)}$, Which is called Spearman's Rank correlation Coefficient?

If the scores are in the numeric scale then, correlation coefficient is calculated by,

$$r_{xy} = \frac{n\Sigma XY - \Sigma X \times \Sigma Y}{\sqrt{nY^2 - (\Sigma Y)^2}\sqrt{n\Sigma X^2 - (\Sigma X)^2}}$$

Which is called Karl Pearson's coefficient of correlation, where, X represent the scores of the first half and Y the scores on the second set.

Example

A test-score is divided in two halves as the scores on the odd numbered questions and the scores on the even numbered questions. The correlation coefficient between them is obtained as 0.72, what is the reliability coefficient of the whole test.

Solution

Here, Correlation coefficient (r_{xy}) = 0.72

n = 2

Reliability coefficient, $R_{xy} = \frac{2 \times r_{xy}}{1 + r_{xy}} = \frac{2 \times 0.72}{1 + 0.72}$ = 0.8272

The reliability coefficient is 82.72%; the dependability of the whole score seems to be very good.

d) Rational Equivalence Method (Kuder-Richardson Method)

Two forms of a test are defined as equivalence when corresponding items are interchangeable and inter item correlation is same for both forms. Kuder-Richardson method is the method of obtaining reliability by using the internal consistency between the measures (questions) of the same scaling (test). The reliability coefficient for this method is obtained by the following two formulae. Kuder-Richardson's first formula for reliability is denoted by KR_1, is computed as

$KR_1 = R_w = \frac{n}{n-1}\left[1 - \frac{\Sigma pq}{\sigma^2}\right]$

Where, R_w = The reliability coefficient of the whole test

n - The number of items in the test

σ -Standard deviation of the test score

p-the proportion of the answering test item correctly

q = (1 - p)

Note 1: If the values of p for each test is equal then Σpq = npq

2: If the values of p for 'n' tests are $p_1, p_2 \ldots\ldots p_n$, then $\Sigma pq = p_1q_1 + p_2q_2 + \ldots\ldots\ldots\ldots + p_nq_n$

Example

In a test there are 60 questions. The proportion of answering each question correctly is 70%, if the standard deviation is 10 what is the reliability coefficient?

Solution

Number of questions (n) = 60,

Proportion of correct answers (p) = 0.7 q = 1 - p = 1 - 0.7 = 0.3

$\Sigma pq = npq$

S.D. (s) = 10, therefore, the reliability coefficient is given by

$KR_1 = R_w = \frac{n}{n-1}\left[1 - \frac{\Sigma pq}{\sigma^2}\right]$

$KR_1 = \frac{60}{60-1}\left[1 - \frac{60 \times 0.7 \times 0.3}{10 * 10}\right]$

Hence reliability coefficient is 88.88%

Validity

Introduction

A scale possesses validity when it actually measures what it claims to measure. In other words, a scale is said to be valid if it measures what is expected to measure.

Interpretation of test scores ultimately involves predictions about a subject's behavior in a specified situation. If a test is an accurate predictor, it is said to have good validity.

Types of validity:

1. **Content Validity**

Content validity is the representativeness or adequacy of the unit selected of the content such as the substances, the matter, the topic of the measuring instrument etc. Content Validity is also known as logical validity. A test has content validity if the sample of items in the test is representative of all the relevant items that might have been used.

Let, U be the universe of the item; S is the subset of U i.e., $S \subset U$ and x be the item such that x is the element in U then it must be an element of S, i.e., $x \in U \Rightarrow x \in S$

The standardized achievement test is used for the content validity measure.

Content validity is related to face validity, although content validity requires more rigorous statistical tests than face validity, which only requires an intuitive judgment. Content validity is most often addressed in academic and vocational testing, where test items need to reflect the knowledge actually required for a given topic area or job skill. In clinical settings, content validity refers to the correspondence between test items and the symptom content of a syndrome.

2. **Criterion-related Validity**

A common approach, called criterion related validity is to correlate measures with a criterion measure known to be valid. For example, an art-aptitude test has predictive validity if high scores are achieved by those who later do well in art school. The concurrent validity of a new intelligence test may be demonstrated if its scores correlate closely with those of an already well-established test.

The criterion related validity is based on the four decisive factors: (i) An external criterion (ii) regular and future behavior (iii) Logical analysis and (iv)Empirical method.

• It is used to predict the criterion on the basis of some measure.

• It reflects the success of measures for empirical estimating process

In this type of validity, the proposed criterion must possess the following quality:

- Freedom from bias (criterion should be given each subject/matter an equal opportunity to score)

- Reliable (criterion should be stable and reproducible)

- Relevance (criterion should be defined in terms of proper measure). Availability (information specified by the criterion must be available)

The Criterion- related Validity broadly classified as: (a) Predictive validity and (b) Concurrent Validity

(a) Predictive validity:

It refers to the usefulness of the test in prediction some future performances on the criterion. It is concerned with how well the scale can forecast a future criterion. When the criterion measure is collected later the goal is to establish it is called the predictive validity.

(b) Concurrent Validity:

It is concerned with the performances that how it can describe a present criterion. Concurrent Validity is demonstrated where a test correlates well with a measure that has previously been validated. For example, if a test measuring job satisfaction gives similar results to those gathered using a job satisfaction which has been validated in past investigations the new measurement has concurrent validity.

The validity coefficient is measured in terms of the correlation coefficient (r) of the scores of the different tests. We say, for $0.9 \leq$ r ≤ 1 there is very high validity; for $0.8 \leq r \leq$ 0.9 a high validity; for $0.6 \leq r \leq$ 0.8 a satisfactory validity: for $0.4 \leq r \leq 0.6$ a moderate validity; for $0.0 \leq r \leq 0.4$ a poor validity; and for r < 0.0 a negative validity

C. Construct Validity

It is the validity, which is most complex and abstract because of the complexity of the social parameter. It is based on psychological trait and quality. Construct validity is generally determined by investigating what psychological traits or qualities a test measures; that is, by demonstrating that certain patterns of human behavior account to some degree for performance on the test.

Construct validity can be evaluated by statistical methods that show whether or not a common factor can be shown to exist underlying several measurements using different observable indicators. For determining construct validity, we associate a set of other proposition with the result received from the use of our measuring instrument. If measurements on our devised scale correlated (associated) in a predicted way with the other propositions, we can conclude that there is construct validity.

Scaling

Scores and Scales

Scores

The number of points somebody gets for correct answers in a test is said to be scores. In other words the value of parameter in the observed phenomenon is termed as score. From an experiment or from a test what we obtained as the observation is called the raw score. The raw score is the simple numerical count of responses such as the number of correct answers on an intelligence test. The usefulness of the raw score is limited however, because it does not convey how well someone does in comparison with others taking the same test. Suppose, one attempts to answer 20 IQs having 1 point each and answered 16 correctly then the raw score is 16.

Scale

Scale is a predefined sequence of scores in ascending values that can map an item to it. Scale is a set of all the different levels of symbols or numerals or something so constructed, from the lowest to highest, that these can be assigned by rule to objects or to items or to the individuals or to their behavior to whom it is applied. In general concept, scale is also known as a quantifying appliance used to indicate the systematized numerals of the measuring instrument.

Scaling of the Scores

From a set of scores of the test we can construct a sequence of levels of the values that can be used as an extent for the test of that phenomena, this method of leveling is said to be scaling. For the purpose of scaling it is always desired to make the scores in an array. After that the scores are converted to the percentile points and then to a scale of required form.

The raw scores obtained in test can be converted to different auxiliary scores in relation to the distribution of the raw scores or according to the distribution of parent population. Such scores which are modified/improved/developed from the raw scores are called derived scores. From the derived scores of the same form in sequence can be used to create a continuous structure of the numerals which is the scale required to be constructed.

There are different types of derived scores widely used in the measurement of the phenomenon or the attitudes. The percentile scores, s-score (z-score) and T-score are such derived scores and are used to compare the strength and credibility of the measures. From these scores we can construct the standard scales namely percentile scale, sigma scale (z-scale) and T scale, respectively by arranging the scores lowest to highest.

Difficulties in scaling

In social phenomenon, following are the reasons that create difficulties of scaling in social sciences.

- Abstractness (nonfigurative) of the social phenomena
- Heterogeneity of the social values, customs and norms.
- Changing nature of human behavior Absence of universal measuring of social values
- Laboratory method cannot be applied in social phenomena.

Scales used in Social and Physical sciences

The main scales used in the measure of social/physical characteristics are:

(i) Point scale
(ii) Social distance scale
(iii) Rating scale
(iv) Ranking scale
(v) Thurstone scale

(i) Point scale

In this type of scale words or situations representing the criteria are selected and one point (marks or number) is given for each criteria. Attitude of a person can determined by the use of all the three following method effectively.

Method 1: The respondent is asked to tick one that is representing or favorable to him /her. The scores are counted and result is derived**.**

Method 2: In the second method the respondent is asked to cross the one point or situation which is not favorable to him /her. A point is given to each and every word that has not been crossed. The attitude of the respondent is then determined by counting no of points.

Method 3: In the third method of point scale the respondent is asked to cross, on which points he /she is agree or not.

(ii) Social distance scale

The social distance scale is developed by Emary S. Borgadus to measure the social distances (it is commonly known as Borgadus scale). The social distance may be defined as the proximity and favoritism; for example the cultural distance from one race to the other, custom from one ethnic group to the other etc. To measure a person's (respondent's) attitude how far from the given cause situation the Borgadus scale can be used. Borgadus developed a scale to measure the nearness of liking between two social groups using several items or statements which show the varying

relationship of social distance of Americans with other races as English, Korean, Swedish and poles.

(iii) ***Rating scale***

When the character to be measured is not dichotomous in this case the rating scale is used. Rating scale consists of a set of figures that can match to the individual or items to be measured. The response or the opinions of the respondent's attitude is rated in three to six points in continuum (range). The intensity of the attitude is measured by using equal or unequal type intervals. An example of three point rating scale is:

Very good .....satisfactory.....poor

A five points rating scale is

Strongly-Agree.....Agree .....Not-Decided. .....Dis-agree.....Strongly-Disagree

(iv) Ranking scale

The ranking scale is similar to rating scale applied to a set of objects or individuals with the preference or liking. In this scale the situations are placed in such a way that, everybody who inspects it knows that one likes the one better than the other. Ranking scales is determined in comparison to a few cases known as stimuli. The item obtaining first preference scores 1, the second as 2, third as 3 and so on. 'The smaller the score the greater the preferences' is the principle of ranking scale.

(v) Thurstone scale

American psychologist Louis L. Thurstone proposed that intelligence was not one general factor but a small set of independent factors of equal importance. He called these factors primary mental abilities. To identify these abilities, he developed a plan to conduct study amongst 250 college students, identified factors and developed a scale of measuring aptitude using factor analysis. The scale so developed is known as Thurstone scale. In educational and psychological experiments, it is used as a main type of scale used to measure the attitude. The statements are collected and arranged in continuum from most favorable to least favorable with neutral point (zero). It is one type of point scale having neutrality point at the central location.

Most- Favored.....neutral .....Least— Favored

Sampling

Introduction

Sampling is an essential part of any research investigation. Almost all research studies involve sampling. It is, therefore, essential that we understand the main concepts of sampling and are familiar with the sampling methods.

Research studies assume that the people selected for studies are representative of a large group about whom generalizations are to be made. We normally cannot survey everyone in the population; but through sampling techniques, we can be confident that only a small part of the total population can fairly represent the total population. Sampling, then, is a technique that saves the time and trouble of questioning 100 percent of the population.

What is Sample?

A sample is a collection of items or elements from a population or universe. Hence, a sample is only a portion or subset of the universe or population. It comprises some observations selected from the population. For instance, if 50 students are drawn from a population of 500 students of a college, these 50 students form the sample for the study.

Population or universe refers to the entire group of people, events, or things of interest that the researcher wishes to investigate. For example, if you are interested in investigating the smoking habits of employees in a chemical factory, then all employees in that factory will form the population.

Sometimes, the entire population will be sufficiently small, and you can include the entire population in your study. If the total items are studied, that is called a census study. However, it is not always possible to study every items or elements in a universe. Usually, the population is too large. Hence, a small, but carefully chosen sample can be used to represent the population. The sample thus selected reflects the characteristics of the population from which it is drawn. For thesis or project work to be undertaken by us, the study of the total population is neither possible nor necessary. Making a census study of the entire universes is not possible on account of limitations of time and money. Hence, sampling becomes inevitable.

Population may be finite or infinite. A finite population is one containing a fixed number of elements. An infinite population is one without limits of any kind and is therefore indeterminate.

Sample Design and Related Terminologies

Sampling design or strategy is the way in which you design your sample plan and select your samples from the population. In designing a sample, you must consider three things: sampling frame, selection of sampling items, and sample size. These terminologies can be explained as follows.

■ Sampling frame is the list identifying each unit in the study population. All the elements in a sampling population constitute its sampling frame. Thus, it may be all the students at university Campus, Kirtipur, all names in the telephone directory, or all persons having their bank accounts with the Nepal Bank Limited. After determining the sampling frame, the researcher will decide how sample will be selected.

■ *Sampling item or unit* is an element (person, institution, etc) of your study that becomes

the basis for selecting your sample.

■ The *size of the sample* must be determined. What should be the sample size? Should fifty or eighty employees be interviewed? Though accuracy is greater with large samples, so are costs.

■ *Sample statistics* are the information obtained from the respondents selected for your study. Your sample statistics become the basis of estimating the prevalence of the characteristics in the study population.

■ *Population parameters* or population mean are the characteristics of the population estimated from the sample statistics. If you measure the entire population and calculate a value like a mean or average, this is called a population parameter.

Thus, the basic components of a sample design are: (a) choosing the sample units (who are to be surveyed), (b) choosing the sample size (how many to be surveyed), (c) choosing the sampling procedure (how to ensure that those who are to be interviewed are included in the sample), and (d) choosing the media (how to reach respondents in the sample? - through mail survey, personal interview, or telephone interview).

THE PRINCIPAL STEPS IN A SAMPLE SURVEY

The main steps involved in the planning and execution of a sample survey may be grouped somewhat arbitrarily under the following heads.

1. **Objectives of the Survey**.
   The first step is to define in clear and concrete terms, the objectives of the survey. It is generally found that even the sponsoring agency is not quite clear in mind as to what it wants and how it is going to use the results. The sponsors of the survey should take care that these objectives are commensurate with the available resources in terms of money, manpower and the time limit required for the availability of the results of the survey.
2. **Defining the Population to be sampled**. The population, i.e., the aggregate of objects (animate or in-animate) from which sample is chosen should be defined in clear and unambiguous terms. For example, in sampling of farms clear-cut rules must be framed to define a farm regarding shape, size., etc., keeping in mind the border-line cases so as to enable the investigator to decide in the field without much hesitation whether or not to include a given farm in the population.

3. **The Frame and Sampling Units**.

The population must be capable of division into what are called sampling units for purposes of sample selection. The sampling units must cover the entire population and they must be distinct, unambiguous and non-overlapping in the sense that every element of the population belongs to one and only one sampling unit. For example, in socio-economic survey for selecting people in a town, the sampling unit might be an individual person, a family, a household or a block in a locality. In order to cover the population decided upon, there should be some list, map or other acceptable material, called the frame, which serves as a guide to the population to be covered. Only good experience person helps to construct a good frame.

4. Data to be collected.

The data should be collected keeping in view the objectives of the survey. The tendency should not be to collect too many data some of which are never subsequently examined and analyzed. A practical method is to chalk out an outline of the tables that the survey should produce. This would help in eliminating the collection of irrelevant information and ensure that no essential data are omitted.

5. The Questionnaire or Schedule. Having decided about the type of the data to be collected, the next important part of the sample survey is the construction of the questionnaire (to be filled in by the respondent) or schedule of enquiry (to be completed by the interviewer) which requires skill, special technique as well as familiarity with the subject-matter under study. The questions should be clear, brief, non-offending, courteous in tone, unambiguous and to the point so that not much scope of guessing is left on the part of the respondent or interviewer. Suitable and detailed instructions for filling up the questionnaire or schedule should also be prepared.

6. Method of collecting information

The two methods commonly employed for collecting data for human populations are : (i) Interview Method. In this method, the investigator goes from house to house and interviews the individuals personally. He asks the questions one by one and fills up the schedule on the basis of the information supplied by the individuals. (ii) Mailed Questionnaire Method. In this method, the questionnaire is mailed to the individuals who are required to fill it up and returns it duly completed. Whether the data should be collected by interview method or mail questionnaire method or by physical observation has to be decided keeping in view the costs involved and the accuracy aimed at. Although mail surveys are less costly, there is scope for considerable non-response. Moreover mail method is practicable only among the educated people who are really interested in the particular survey being conducted. On the other hand, interview method costs more and there are interviewer errors also but without investigators the data collected may be worthless.

7. Non-respondents.

Quite often (due to practical difficulties), the data cannot be collected for all the sampled units. For example, the selected respondent may not be available at his place when the investigator goes there or he may fail or even refuse to give certain information when contacted. This incompleteness, called non-response, obviously tends to change the results. Such cases of non-response should be handled with caution in order to draw unbiased and valid conclusions. Procedures will have to be devised to deal with those who do not furnish information. The reasons for non-response should be recorded by the investigator.

8. Selection of Proper Sampling Design.

The size of the sample (n), the procedure of selection and the estimation of the population parameters along with their margins of uncertainty are some of the important statistical problems that should receive the most careful attention. A number of designs (plans) for the selection of a sample are available and a judicious selection will guarantee good and reliable estimates. For each sampling plan, rough estimates of sample size n can be obtained for a desired degree of precision. The relative costs and time involved should also be considered before making a final selection of the sampling plan.

9. Organization of Field Work. It is absolutely essential that the personnel should be thoroughly trained in locating the sample units, recording the measurements, the methods of collection of required data before starting the field work. The success of a survey to a great extent depends upon the reliable field work. It is very necessary to make provisions for adequate supervisory staff for inspection after field work. From practical point of view a small pretest, (i.e., trying out the questionnaire and field methods on a small scale) has been found to be immensely useful. It always helps to decide upon effective method of asking questions and results in the improvement of the questionnaire. Moreover, it might disclose certain problems and troubles that will otherwise be quite serious on a large-scale survey such as "the cost and the time may far exceed the available money and stipulated period."

10 Summary and Analysis of the Data. The analysis of the data may be broadly classified into the following heads:

a) Scrutiny and editing of the data: An initial quality check should be carried out.by the supervisory staffs while the investigators are in the field. Accordingly, the schedule should be thoroughly scrutinized to examine the plausibility and consistency of the data obtained.

(b) Tabulation of data: Before carrying out the tabulation of the data, we must decide about the procedure for tabulation of the data which are incomplete due to non-response to certain items in the questionnaire and where certain questions are deleted in editing process. The method of tabulation, viz., hand tabulation or machine tabulation, will depend upon the quantity of the data. For large-scale survey, machine tabulation will obviously be much quicker and economical. For

a large-scale sample survey, the use of code numbers for qualitative variables is essential for machine tabulation. With simple questionnaire, the answers can sometimes be pre-coded, i.e., entered in a manner in which they can be conveniently or routinely transferred to mechanical equipment such as personal computers, etc. Finally, the tables that lead to the estimates are prepared.

(c) Statistical analysis. After the data has been properly scrutinized, edited and tabulated, a very careful statistical analysis is to be made. Different methods of estimation may be available for the same data. Appropriate formulae should then be used to provide final estimates of the required information. Efforts should be made to keep the procedure free from errors.

(d) Reporting and conclusions. Finally, a report incorporating detailed statement of the different stages of the survey should be prepared. In the presentation of the results, it is good practice to report the technical aspect of the design, viz., the types of the estimators used along with the amount of error to be expected in the most important estimate.

11. Information gained for Future Surveys. Any completed survey is helpful in providing a note of caution and taking lessons from it for designing future surveys. The information gained from any completed sample in the form of the data regarding the means, standard deviations and the nature of the variability of the principal measurements tougher with the cost involved in obtaining the data serves as a potential guide for improved together sampling.

PARAMETER AND STATISTIC

In order to avoid verbal confusion with the statistical constants of the population, viz., mean, variance, etc., of the population which are usually referred to as parameters, statistical measures computed from the sample observations alone, e.g., mean, variance, etc., of the sample have been termed as statistic.

In practice parameter values are not known and their estimates based on the sample values are generally used. Thus statistic which may be regarded as an estimate of the parameter, obtained from the sample, is a function of the sample values only. It may be pointed out that a statistic, as it is based on sample values and as there are multiple choices of the samples that can be drawn from a population, varies from sample to sample. The determination or the characterization of the variation (in the values of the statistic obtains from different samples) that may be attributed to chance or fluctuations of sampling is one of the fundamental problems of the sampling theory.

S**ampling Distribution**

The number of possible samples of size n that can be drawn from a finite population of size N is NCn. (If N is large or infinite, then we can draw a large number of such samples.) For each of these samples we can compute a statistic, say 't' ....e.g., mean, variance, etc., which will obviously vary from sample to sample. The aggregate of the various values of the statistic under consideration so obtained (one from each sample), may be grouped into a frequency distribution which is known as the sampling distribution of the statistic. Thus, we can have the sampling distribution of the sample mean $\bar{x}$, the sample variance, etc.

Standard Error.

The standard deviation of the sampling distribution of a statistic is known as its Standard Error. The standard errors (S.E.) of some of the well-known statistics are given in Table, where n is the sample size, σ^2 the population variance, P the population proportion and Q = 1- P.

SAMPLING AND NON-SAMPLING ERRORS

The errors involved in the collection, processing and analysis of a data may be broadly classified under the following two heads:

(**i) Sampling Errors** **(ii) Non-sampling Errors**.

(i) Sampling Errors.

Sampling errors have their origin in sampling and arise due to the fact that only a part of the population (i.e., sample) has been used to estimate population parameters and draw inferences about the population. As such the sampling errors are absent in a complete enumeration survey. Sampling biases are primarily due to the following reasons:

1. Faulty selection of the sample. Some of the bias is introduced by the use of defective sampling technique for the selection of a sample, e.g., purposive or judgment sampling in which the investigator deliberately selects a representative sample to obtain certain results. This bias can select a representative sample to obtain certain results. This bias can be overcome by strictly adhering to a simple random sample or by selecting a sample at random subject to restrictions which while improving the accuracy are of such nature that they do not introduce bias in the results.

2. Substitution.

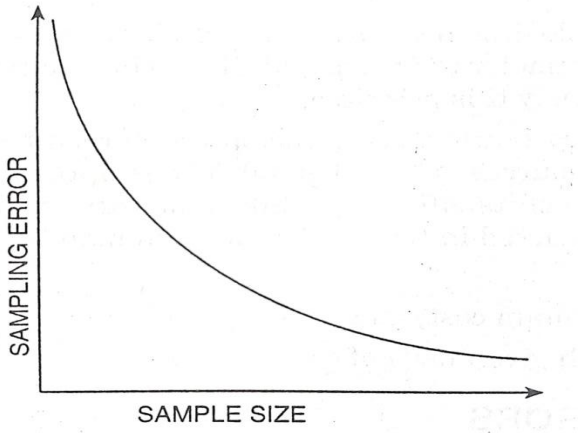
If difficulties arise in enumerating a particular sampling unit included in the random sample, the investigators usually substitute a convenient member of the population. This obviously leads to some bias since the characteristics processed by the substituted unit will usually be different from those possessed by the unit originally included in the sample.

3. Faulty demarcation of sampling units.

Bias due to defective demarcation of sampling units is particularly significant in area surveys such as agricultural experiments in the field or crop cutting survey, etc. In such surveys, while dealing with border line cases, it depends more or less on the discretion of the investigator whether to include them in the sample or not,

4. Constant error due to improper choice of the statistic for estimating the population Parameters.

For example, if $x_1, x_2, \ldots\ldots\ldots, x_n$ is a sample of independent observations, then the sample variance $s^2 = \sum_{i=1}^{n} (x_i - \overline{x})^2 / n$ as an estimate of the population variance σ^2 is biased whereas the statistic $\frac{1}{n}\sum_{i=1}^{n}(x - \bar{x})^2$, is an unbiased estimate of σ^2.



Remark: Increase in the sample size (i.e., the number of units in the sample) usually results in the decrease in sampling error.

. **(ii) Non-sampling Errors**. As distinct from sampling errors which are due to the inductive process of inferring about the population on the basis of a sample, the non-sampling errors primarily arise at the stages of observation, ascertainment and processing of the data and are thus present in both the complete enumeration survey and the sample survey. Thus, *the data obtained in a complete census, although free from sampling errors, would still be subject to non-sampling errors whereas data obtained in a sample survey should be subject to both sampling and non-sampling errors.*

Non-sampling errors can occur at every stage of the planning or execution of census or sample survey. The preparation of an exhaustive list of all the sources of non-sampling errors is a very difficult task. However, a careful examination of the major phases of a survey (complete or sample) indicates that some of the more important non-sampling errors arise from the following factors.

1. The planning of a survey consists in explicitly stating the objectives of the survey. These objectives are then translated into (i) a set of definitions of the characteristics for which data are to be collected, and (ii) into a set of specifications for collecting, processing and publishing. Here the non-sampling errors can be due to:

(a) Data specification being inadequate and inconsistent with respect to the objectives of the survey.

(b) Error due to location of the units and actual measurement of the characteristics, errors in recording the measurements, errors due to ill-designed questionnaire, etc.

(c) Lack of trained and qualified investigators and lack of adequate supervisory staff.

2. Response Errors

These errors are introduced as a result of the responses furnished by the respondents and may be due to any of the following reasons:

(i) Response errors may be accidental

For example, the respondent may misunderstand a particular question and accordingly furnish improper information un-intentionally.

(ii) Prestige bias

An appeal to the pride or prestige of person interviewed may introduce yet another kind of bias, called prestige bias by virtue of which he may upgrade his education, intelligence quotient, occupation, income, etc., or downgrade his age, thus resulting in wrong answers.

(iii) Self-interest

Quite often, in order to safeguard one's self-interest, one may give incorrect information, e.g., a person may give an underestimate of his salary or production and an over-statement of his expenses or requirements, etc.

(iv) Bias due to interviewer

Sometimes the interviewer may affect the accuracy of the response by the way he asks questions or records them. The information obtained on suggestions from the interviewer is very likely to be influenced by interviewer's beliefs and prejudices.

(v) Failure of respondent's memory

One source of error which is common to most of the methods of collecting information is that of 'recall'. Many of the questions in surveys refer to happenings or conditions in the past and there is a problem both of remembering the event and associating it with the correct time period.

3. Non-response Biases.

Non-response biases occur if full information is not obtained on all the sampling units. In house-to-house survey, non-response usually results if the respondent is not found at home even after repeated calls, or if he/she is unable to furnish the information on all the questions or if he/she refuses to answer certain questions. Therefore, some bias is introduced as a consequence of the exclusion of a section of the population with certain peculiar characteristics, due to non-response.

4. Errors in Coverage.

If the objectives of the survey are not precisely stated in clear cut terms, this may result in

(i) the inclusion in the survey of certain units which are not to be included, or

(ii) The exclusion of certain units which were to be included in the survey under the objectives. For example, in a census to determine the number of individuals in the age group, say, 20 years to 50 years, more or less serious errors may occur in deciding whom to enumerate unless particular community or area is not specified and also the time at which the age is to be specified.

5. Compiling Errors.

Various operations of data processing such as editing and coding of the responses, tabulation and summarizing the original observations made in the survey are a potential source of error. Compilation errors are subject to control though verification, consistency check, etc.

6. Publication Errors.

Publication errors, i.e., the errors committed during presentation and printings of tabulated results are basically due to two sources. The first refers to the mechanics of publication—the proofing error and the like. The other, which is of more serious nature, lies in the failure of the survey organization to point out the limitations of the statistics.

Sample Size

The size of the sample is an important factor. It has direct bearing on the accuracy, estimation, cost and administration of the survey. Large sample has low sampling error where as small sample have higher sampling error. To avoid unnecessary cost small sample should be selected. Hence optimum sample size should be selected to fulfill the requirement of efficiency, representativeness, reliability and flexibility. Some of the factors affecting the sample size are nature of study, nature of reaction of respondent towards the subject under study, nature of population i.e. composition of population under study, number of classes in the population, types of sampling used during study etc.

Factors affecting Sample Size

Size of sample depends upon different factors. These are

i. Nature of population
ii. Number of classes
iii. Nature of the study
iv. Types of sampling used
v. Degree of accuracy

Nature of population

If the population under study is homogeneous then small sample size is sufficient, but in case of heterogeneous population large sample size is required to make sample size representative of the population.

Number of classes

For the classification with large number of classes, large sample size is required.

Nature of study

If the study takes long time then small sample size is better from the financial and analysis point of view.

Types of sampling used

The sample size depends upon the type of sampling used. For simple random sampling large sample size is required but for the case of stratified sampling small sample size is sufficient.

Degree of accuracy

If the greater degree of accuracy is required then large sample should be selected.

Testing Reliability of the Sample

If the selected sample is representative of the population then sample is called reliable. The selected sample is reliable or not can be tested using following methods;

i. Drawing parallel sample.
ii. Comparing sample with population.
iii. Drawing sub sample from main sample.

Drawing parallel sample

Draw sample parallel to the drawn sample from the population and compare various measures such as average, dispersion, skewness, kurtosis etc. between the samples. If the comparison measures are alike then the sample is reliable otherwise unreliable.

Comparing sample with population

Different measures computed from samples are compared with that of population. If the measures are identical then the selected sample is reliable.

Drawing sub sample from main sample

The different measures computed from sub sample arc compared with main sample. It cannot be used to find the sample is representative of population or nut but can be used to find if any error occurred due to faulty selection of sample.

Method of Estimating Sample Size

Estimation of sample size by using mean

Let $\bar{x}$ be the sample mean from a random sample of size n drawn from population with mean E($\bar{x}$) and standard deviation σ.

Now,

$$Z = \frac{\bar{x} - E(\bar{x})}{SE(\bar{x})} = \frac{\bar{x} - \mu}{\frac{\sigma}{\sqrt{n}}}$$

at α level of significance and $(1 - \alpha)$ confidence limit is

$$P\left(\left|\frac{\bar{x}-\mu}{\frac{\sigma}{\sqrt{n}}}\right| \leq Z_{\alpha/2}\right) = 1 - \alpha$$

$P(|\bar{x} - \mu| \leq {}^{\sigma}/_{\sqrt{n}}) Z_{(}\alpha/2) = 1 - \alpha$

Now, x - μ = d (margin of error) then

$d = \frac{\sigma}{\sqrt{n}} Z\ \alpha/2$

$\sqrt{n} = \frac{\sigma}{d} Z\alpha/2$

$n = \frac{\sigma^2\ {Z_{\alpha/_2}}^2}{d^2}$

In case of σ is not known take $\sigma = s$

For the finite population of Size N, sample size = $\frac{\sigma^2\ {Z_{\alpha_2}}^2}{d^2\ + \frac{\sigma^2\ {Z_{\alpha_2}}^2}{N}} = \frac{n}{1+\frac{n}{N}}$

Estimation of sample size by using proportion

Let p be sample proportion from random sample of size n drawn from population with proportion P

Now,

$Z = \frac{p-E(p)}{SE(p)} = \frac{p-P}{\sqrt{\frac{PQ}{n}}}$

At α level of significance (1 - α) confidence limit is

$P\left(\left|\frac{p-P}{\sqrt{\frac{PQ}{n}}}\right| \leq Z_{\alpha/_2}\right) = 1 - \alpha$

or $P\ (|p - P| \leq \sqrt{\frac{PQ}{n}}\ Z_{\alpha/_2} = 1 - \alpha$

Now, p - P = d (margin of error) then

$d = \sqrt{\frac{PQ}{n}}\ Z_{\alpha/_2}$

$\sqrt{n} = \frac{Z_{\alpha/2}\sqrt{PQ}}{d}$

$n = \frac{PQ\, Z_{\alpha/2}^{\,2}}{d^2}$

In case of P is not known take P = p.

For the finite population of size N, sample size $= \frac{PQ\, Z_{\alpha/2}^{\,2}}{d^2 + \frac{PQ\, Z_{\alpha/2}^{\,2}}{N}} = \frac{n}{1+\frac{n}{N}}$

Example 1

Determine the minimum sample size required so that the sample estimate lies within 10% of the true value with 95% level of confidence when coefficient of variation is 60%.

Solution

Here,

C.V. = 60% = 0.6

$P\ (|\bar{x} - \mu| \leq 0.1\,\mu\ ) = 0.95$

(i) Confidence level $(1 - \alpha) = 95\% = 0.95$ then $\alpha = 0.05$

Now,

$P\left(\left|\frac{\bar{x}-\mu}{\frac{\sigma}{\sqrt{n}}}\right| \leq Z_{\alpha/2}\right) = 1 - \alpha$

$P(|\bar{x} - \mu| \leq {}^{\sigma}/_{\sqrt{n}})\ Z_{(}\alpha/2) = 0.95$

$P(|\bar{x} - \mu| \leq 1.96 \times \frac{\sigma}{\sqrt{n}}) = 0.95$

From equation (i) and (ii)

$0.1\mu = 1.96 \times \frac{\sigma}{\sqrt{n}}$

$\sqrt{n} = \frac{1.96}{0.1} \times \frac{\sigma}{\sqrt{n}}$

$n = \left(\frac{1.96}{0.1} \times \frac{\sigma}{\sqrt{n}}\right)^2$

$n = 384.16 \times CV^2$

$n = 384.16 \times (0.6)^2$

or $n = 138.29 = 138$

Hence required sample size is 138.

Example 2 In measuring reactions time, a psychologist estimates that the standard deviation is 0.05 seconds. How large a sample of measurement must be taken in order to be 99% confident that the error of his estimate will not exceed 0.01 seconds?

Solution

Here,

Sample size (n) = ?

Standard deviation (s) = 0.05

Confidence interval $(1 - \alpha) = 99\% = 0.99$

or $\alpha = 0.01$ $Z_{\alpha/2} = 2.58$

Error (d) = 0.01

Here $\sigma = s$

$n = \frac{\sigma^2 \ {Z_{\alpha_2}}^2}{d^2} = \frac{(0.05)^2(1.96)^2}{(0.01)^2} = 166.4 \approx 167$

Hence required sample size is 167.

Example 3

A researcher wants to conduct a survey of disabled at Kathmandu valley. What should be the sample size of the prior estimate of population of disables if the population is 10% and the desired error of estimation is 2% and level of significance is 5%.

Solution

Sample size (n) = ?

Population proportion (p) = 10% = 0.1

q = 1 - p = 0.9

Error (d) = 2% = 0.02

Level of significance (α) = 5%

Here P = p

$$n = \frac{PQ\ Z_{\alpha/2}^{\ 2}}{d^2} = \frac{(1.96)^2 \times 0.1 \times 0.9}{(0.02)^2} = 864.36 \approx 865$$

Hence required sample size is 865**.**

Example 4

For p 0.2, d = 0.05 and z = 2 find n. Also find n if N = 1000.

Solution

Here P= p

Now

$$n = \frac{PQ\ Z_{\alpha/2}^{\ 2}}{d^2} = \frac{4 \times 0.2 \times (1-0.2)}{0.05^2} = 256$$

When N = 1000

$$\text{Sample size} = \frac{n}{1+\frac{n}{N}} = \frac{256}{1+\frac{256}{1000}} = 203.82 \approx 204$$

Example 5

The mean systolic blood pressure of a certain group of people was found to be 125 mm of Hg with standard deviation of 15 mm of Hg. Calculate sample size to verify the result at 5'y level of significance if error do not exceed 2. Also find sample size if sample is selected from population of size 500.

Solution

Standard deviation (s) = 15

Level of significance (α) = 5%

Sample size (n) = ?

Error (d) = 2 Here σ = s

Now,

n = $\frac{\sigma^2 \ {Z_{\alpha_2}}^2}{d^2} = \frac{(15)^2(1.96)^2}{(2)^2} = 216.09 \approx 216$

When N = 500

Sample size = $\frac{n}{1+\frac{n}{N}} = \frac{216}{1+\frac{216}{500}} = 150.83 \approx 151$

YAMANE FORMULA

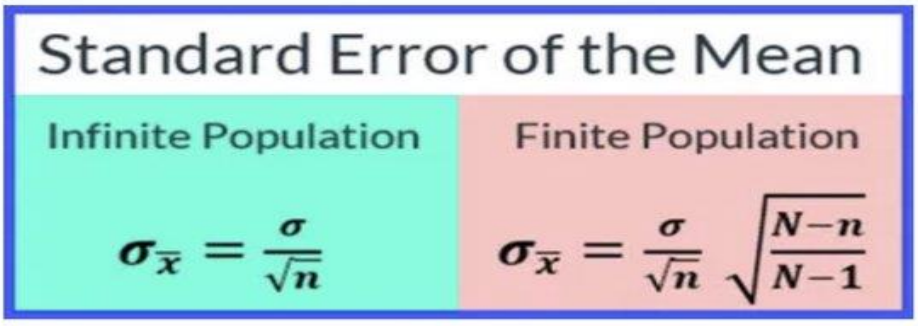
n=$\frac{N}{1+N\times e^2}$

Where n= the sample size

N= the population size

e= the acceptable sampling error

95% confidence level and p= 0.5 are assumed



Working with a finite population and if the population size is known, the **Yamane formula for determining the sample size is given by:**

$n=N/(1+N\ e^2)$

Where

n= corrected sample size, N = population size, and e = Margin of error (MoE), e = 0.05 based on the research condition.

Let's assume that the population is 10,000. At 5% MoE., the sample size would be: $10000/(1+10000(.05^2)$

$=10000/26$

$= 384.61 \sim 385$

In a finite population, when the original sample collected is more than 5% of the population size, the corrected sample size is determined by using the Yamane's formula.

In the example above, 5% of 10,000 is 500 and hence the corrected size is 385 although for research purposes, even 385 is a big number (for handling and collection point of view) and the researcher has to make a decision to collect even smaller number in order of ease of handling, costing but he has to ensure that the sample is representative.

Sampling Frame

The sampling frame (also known as the "sample frame" or "survey frame") is indeed the actual collection of units. A sample has now been taken from this. A basic random sample gives all units in it an equal probability of being drawn and appearing in the sample.

A complete list or collection from which our sample participants will be drawn in a predetermined manner. The list will be organized in some way. That is, each member of a population will have an individual identity and a contact mechanism. This allows you to categorize and code known information about segmentation features.

Collecting the sample indicates that we have a supply or list of all the individuals of the target population from which to take a sample, as well as a process for selecting the sample. Any resource that has the information needed to reach every individual in the targeted group qualifies as a source.

Characteristics of a Good Sampling Frame

Be assertive when selecting lists! Make sure the sample frame is large enough for our requirements. A decent sample frame for research on living conditions, for example, might include:

Everyone is in the target demographic.

Exclude everyone who isn't part of the target group.

A file containing factual information that may be used to reach specific people.

Other considerations:

Each member has a unique identification. This might be a short number code (e.g., from 1 to 3000).

Make sure the frame doesn't have any duplicates.

The list should be well organized. Sort them alphabetically for better access

Information should be up to date. This might need to be examined regularly (e.g., for address or contact number changes).

Examples of the Sampling Frame

The issue is that studying every individual in a population is not always practical or practicable.

Suppose we might be curious to learn about the opinions of Nepalese bankers about vehicle ownership, for example. Gathering data from every bank in the Nepal would be too time-

consuming and expensive. You can investigate a sample of the population in situations like these.

The process of picking a sample should be intentional, and you can utilize various sampling strategies based on the research's aim.

It would help if we first constructed a sampling frame, which would be a list of all the units in the population of interest before we can choose a sample. Our study findings can only benefit the population identified by the sample frame.

Conclusion

A sampling frame is a researcher's list or device to specify the population of interest. A basic random sample gives all units an equal probability of being drawn and appearing in the sample.

People, organizations, and existing records might all be considered units. It is critical to be as detailed as possible when describing the population.

Issues of choosing appropriate sampling technique(s) while selecting samples

Choosing a sampling strategy is an essential step in the capture phase of the data journey and will ensure that, data is reliable and reflects the characteristics of target group. In this blog, we'll take step by step through the process by outlining the ways in which primary data is collected using an example in which a survey on characteristics (tax, education levels, etc) is collected on residents in five towns. The towns are of different sizes and have a total of 3,200 households. These 3,200 households make up the target population for survey.

Step one: Define sample and target population

At times, the survey may require covering the entire target population, as is the case in mapping or population studies. That's usually referred to as a census survey. However, target populations are generally large and expensive to survey. In our example, it may not be feasible to visit all 3,200 households of the five towns. Instead, we want to choose a smaller sample that would be representative of the population and reflect its characteristics.

A survey that is done on a smaller number of the target population is referred to as a sample survey. We can infer our findings for the entire population based on this representative sample.

Step two: Define sample size

The first step in sampling exercise will be decided on an appropriate sample size. There are no strict rules for selecting a sample size. We can make a decision based on the objectives of the project, time available, budget, and the necessary degree of precision.

In order to select the appropriate sample size, we will need to determine the degree of accuracy that we want to achieve. For this, we'll need to establish the confidence interval and confidence level of our sample.

The confidence interval, also called the margin of error, is a plus or minus figure. It is the range within which the likelihood of a response occurs. The most commonly used confidence interval is +/- 5. If we wish to increase the precision level of our data, we would further reduce the error margin or confidence interval to a +/- 2. For example, if our survey question is "does the household pay tax?" and 65% of our sampled households say "yes," then using a confidence interval of +/- 5, we can state with confidence that if we are asked the question to all 3,200 households, between 60% (i.e. 65-5) and 70% (i.e. 65+5) would have also responded "yes."

The confidence level tells how sure we want to be and is expressed as a percentage. It represents how often the responses from our selected sample reflect the responses of the total population. Thus, a 95% confidence level means we can be 95% certain. The lower the confidence level, the less certain we will be.

Most surveys use the 95% confidence level and a +/- 5 confidence interval. When we put the confidence level and the confidence interval together, we can say that we are 95% sure that, if we had surveyed all (3,200) households, between 60% and 70% of the households of the target population would have answered "yes," to the question "does the household pay tax?".

The size of sample may be determined using any standard sample size calculator. Using a standard sample size calculator (as can be seen in table one below) for our example of 3,200 households in five towns, we can examine the difference in sample sizes based on different confidence levels and intervals.

Option A

If we decide on a 5% confidence interval and want to achieve a 95% confidence level, the sample size will be 345 households.

Option B

If we wish to have higher accuracy and increase the confidence level to 99%, the recommended sample size would be 551.

The quality of our findings are likely to only be marginally better than with option A or B, as the rate of improvement of accuracy gradually diminishes with the increase in sample size. The size of sample should therefore be decided by the objectives of the study and resources available.

Step three: Define sampling technique

Once we've chosen the sample size for survey, we need to define which sampling technique to select sample from the target population. The sampling technique that's right depends on the nature and objectives of project. Sampling techniques can be broadly divided into two types: random sampling and non-random sampling.

Random sampling

As the name suggests, random sampling literally means selection of the sample randomly from a population, without any specific conditions. This may be done by selecting the sample from a list, such as a directory, or physically at the location of the survey. If we want to ensure that a particular household does not get selected more than once, you can remove it from the list. This

type of sampling is called simple random sampling without replacement. If you choose not to remove duplicate households from the list, you would do a simple random sampling with replacement.

Systematic sampling is the most commonly used method of random sampling, whereby you divide the total population by the sample size and arrive at a figure which becomes the sampling interval for selection. For example, if you need to choose 20 samples from a total population of 100, your sampling interval would be five. Systematic sampling works best when the population is homogeneous, i.e. most people share the same characteristics. In our example, the sampling interval would be nine (3200/345= 9 for a 95% confidence level and 5% confidence interval). Thus we will select every ninth household in a town.

However, populations are generally mixed and heterogeneous. To ensure sufficient inclusion of all categories of the population, we need to identify the different strata or characteristics and their actual representation (i.e. proportion) in the population. In such cases, we can use the stratified random sampling technique, whereby we first calculate the proportion of each strata within the population and then select the sample in the same proportion, randomly or systematically, from all the strata.

If we take our earlier example of five towns, to calculate a stratified random sample, you will need to calculate the proportion of each town within the sample size of 345 as shown in table two below. Column three gives the proportion of each town of the total population (3,200). In column four, the sample size (345) is proportionately divided across the five towns. For example, town three, which is 25% of the total population, will select 86 households with a sampling interval of nine (i.e. 800/86) in the same manner as was done for systematic sampling.

Table 2: Calculate stratified random sample

Location	Population size	Proportion (%) of population	Stratified sample size
Town 1	1200	38%	129
Town 2	900	28%	97
Town 3	800	25%	86
Town 4	180	6%	19
Town 5	120	4%	13
Total	*3200*		*345*

Non-random sampling

In non-random sampling, the sample selection follows a particular set of conditions and is generally used in studies where the sample needs to be collected based on a specific characteristic of the population. For example, you may need to select only households which own a car, or have children less than six years of age. For this, you would consciously select only the 345 or 551 households that have those characteristics. Also termed purposive or subjective sampling, non-random sampling methods include convenience, judgment, quota and snowball sampling.

Step four: Minimize sampling error

It's normal to make mistakes during sample selection. Our efforts should always be to reduce the sampling error and make the chosen sample as representative of the population as possible. The robustness of sample depends on how we minimize the sampling error. The extents of errors during sampling vary according to the technique or method you choose for sample selection.

For samples selected randomly from a target population, the results are generally prefixed with the +/- sampling error, which is the degree to which the sample differs from the population. If our study requires to know the extent of sampling error that is acceptable for the survey, you can select a random sampling technique. In random sampling, you will be able to regulate the survey design to arrive at an acceptable level of error. In a non-random sample selection, the sampling error remains unknown.

Thus, when your sample survey needs to infer the proportion of a certain characteristics of the target population, you can select a random sampling method. But if you want to know the perceptions of residents regarding taxation laws or the school curriculum, you would want to capture as many perceptions as possible, and therefore select a non-random method in situations where sampling errors or sampling for proportionality are not of concern. Non-random sampling techniques can be very useful in situations when you need to reach a targeted sample with specified characteristics very quickly.

If you don't have a sampling strategy in place, you may collect data which is biased or not representative, rendering your data invalid.

Statistical Analysis

Analysis means the categorizing, ordering, manipulating, and summarizing of data to obtain answers to research questions. The purpose of analysis is to reduce data to intelligible and interpretable form so that the relations of research problems can be studied and tested. A primary purpose of statistics, for example, is to manipulate and summarize numerical data and to compare the obtained results with chance expectations. A researcher hypothesizes that styles of leadership affect group-member participation in certain ways. He plans an experiment, executes the plan, and gathers data from his subjects. Then he must so order, break down, and manipulate the data that he can answer the question: How do styles of leadership affect group-member participation? It should be apparent that this view of analysis means that the categorizing, ordering, and summarizing of data should be planned early in the research. The researcher should lay out analysis paradigms or models even when working on problem and hypotheses.

Data Editing

Editing is the process of examining errors and omissions in the collected data and to make necessary corrections. Data should be edited after getting the filled up questionnaire or schedule and before entering in to the step of data processing. It is done to assure the data are accurate, consistent, uniformly entered, complete and well arranged. Editing is carried out in two stages:

(i) field editing
(ii) central editing

Field editing is the review of reporting forms by enumerator or investigator for completing what the signs and symbols have written in abbreviated form in the time of recording respondents' response. Central editing is editing obvious errors such as entry in wrong place, missing replies etc. by editor when all schedules or forms have been completed and returned to office.

Data Coding

It is process of assigning numerals or other symbols to answers so that response can be put into a limited number of class or categories. The quantitative data collected using questionnaire or schedule is numeric so that no need of coding. For the data which is qualitative in nature the numeric codes are to be used before the analysis. For the statistical treatments qualitative responses are to be converted into numerical figures which satisfy, all the rules of arithmetic operation. Different social scales are used on assigning numerical figures to the qualitative response. For example for male and female code 1 and 0 are used.

Classification of Data

The data contained in questionnaire or schedule will not enable us to see quickly all possible characteristics. In order to make data easily understandable the classification is adopted. Classification is the process of arranging the related facts or data into different groups or classes according to their similarities. Facts differ from class to class with re characteristics which is the basis of classification.

The classification should be

(i) according to research problem
(ii) exhaustive
(iii) mutually exclusive
(iv) independent

The main objectives of classification are

i) to condense mass of data
ii) to facilitate comparison
iii) to pinpoint feature of data at a glance
iv) to enable statistical treatment

Types of classification: Statistical data are classified in respect of their characteristics. Broadly there are four basic types of classification namely

a) Chronological classification
b) Geographical classification
c) Qualitative classification
d) Quantitative classification

a) **Chronological Classification**

In chronological classification the collected data are arranged according to the order of time expressed in years, months, weeks, etc.. The data is generally classified in ascending order of time. For example, the data related with population, sales of a firm, imports and exports of a country are always subjected to chronological classification. For example, The estimates of birth rates in Nepal during 1970 - 76 are

Year	1970	1971	1972	1973	1974	1975	1976
Birth rate	36.8	36.9	36.6	34.6	34.5	35.2	34.2

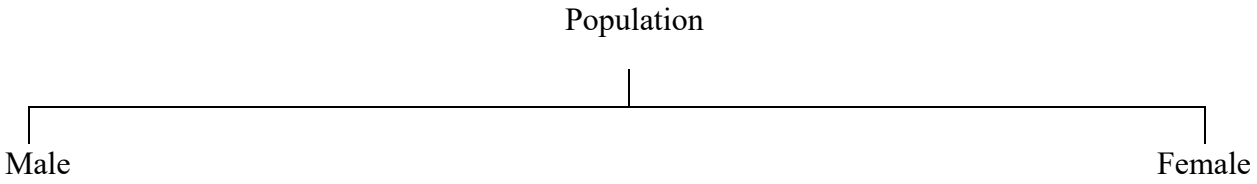
b) **Geographical Classification**

In this type of classification the data are classified according to geographical region or place. For instance, the production of wheat different countries etc.

Country	America	China	Denmark	France	Nepal
Yield of wheat kg/acre	1925	893	225	439	862

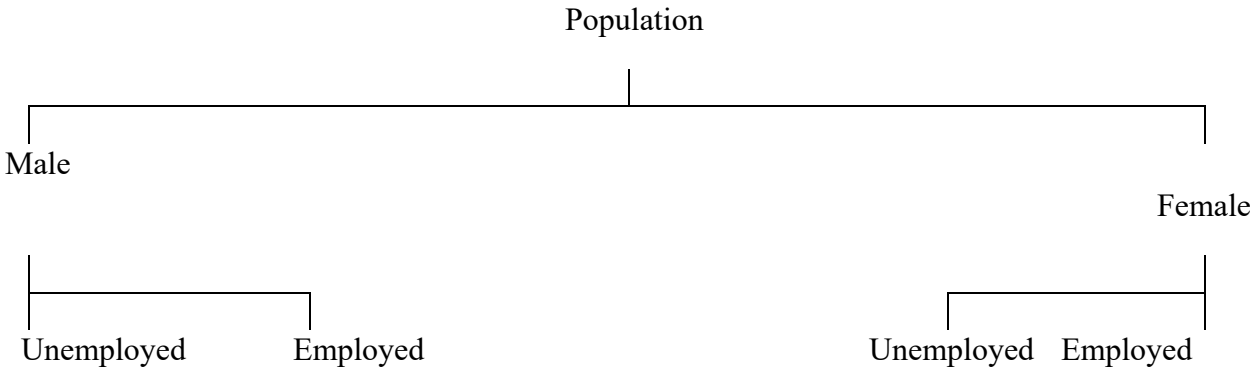
c) **Qualitative Classification:**

In this type of classification data are classified on the basis of some attributes or quality like: sex, literacy, religion, employment etc. Such attributes cannot be measured along with a scale.



(i) The classification, where two or more attributes are considered and several classes are formed, is called a manifold classification. For example, if we classify population simultaneously with respect to two attributes e.g., sex and employment then population are first classified with respect to 'sex' into 'males' and 'females'. Each of these classes may then be further classified into 'employment' and 'unemployment' on the basis of attribute 'employment' and as such population are classified into four classes namely. (i) Male employed (ii) Male unemployed (iii) Female employed ((iv) Female unemployed

Still the classification may be further extended by considering other attributes like marital status etc. This can be explained by the following chart



(d) Quantitative classification

Quantitative classification refers to the classification of data according to some characteristics that can be measured such as height, weight, etc.

Data Entering into Spreadsheet

A spreadsheet is an interactive computer application program for organization and analysis of data in tabular form. Spreadsheets developed as computerized simulations of paper accounting worksheets. The program operates on data represented as cells of an array organized in rows and columns. Each cell of the array is a model-view-controller element that can contain either numeric or text data or the results of formulas that automatically calculate and display a value based on the contents of other cells. The user of the spreadsheet can make changes in any stored value and observe the effects on calculated values. This makes the spreadsheet useful for "what-if" analysis since many cases can be rapidly investigated without tedious manual recalculation. Modern spreadsheet software can have multiple interacting sheets and can display data either as text and numerals or in graphical form.

Management of Missing and Inconsistent Information

Generally, in data management activity of research work a researcher faces the threats of

i) Missing data
ii) Impossible values
iii) Inconsistencies and
iv) Transcription errors.

Missing and inconsistent data (information) are a part of almost all research and all the researcher have to deal with it from time to time. There are various alternative ways of dealing with missing data. To get data with less missing and inconsistent information attention should be given from the designing questionnaire to data entry. Most of the

missing are arisen in the survey field because of the imperfection of the field workers and the less skill of the person who involved in data entry work.

There are a number of strategies for handling missing and inconsistent data and common will be described here. These methods can be accomplished with standard statistical software packages (SAS, SPSS).

List wise deletion

In this method, cases with any missing values are deleted from an analysis. This method is sometimes called *complete case analysis* because only cases with complete data are retained. This is the default procedure for many statistical programs but it is generally not an advisable method.

Pairwise deletion

In this method, the maximum amount of available data is retained and so this method is sometimes referred to as *available case analysi*s. Cases are excluded from only operations in missing which data are missing on a variable that is required. In a correlation matrix, for example a case that was data on one variable would not be used to calculate the correlation coefficient between that variable and another but would be included in all other correlations.

Ways of managing Missing and Inconsistent data

The quality of the data can be kept up by careful and systematic method of data cleaning. The following are the steps by using which we can reduce the inconsistent observation and problems of missing data.

- Develop a plan for data management
- Make a an intensive training before data entry
- Make strategy of getting quality data
- Maintain the question that can cross check the responses
- Adopt checking system of impossible values
- Record the variables and if possible create composite variables
- Preferably do not make a change in raw data set, if changed logically it should be documented
- Coding system should be preferably used to reduce such errors
- Use standard methods of data cleaning using software
- Use the method of labeling the values and merge cells if possible
- Once the data set is cleaned, the next step is to format it for analysis
- Data formatting should be done using code
- Maintain a master dataset that is distributed to everyone conducting analyses

Descriptive Statistical measure

Types of average

I. Arithmetic Mean
II. Geometric mean
III. Harmonic mean
IV. Median
V. Mode

Measure of Dispersion

Absolute and relative measure of dispersion

Types of dispersion

Range

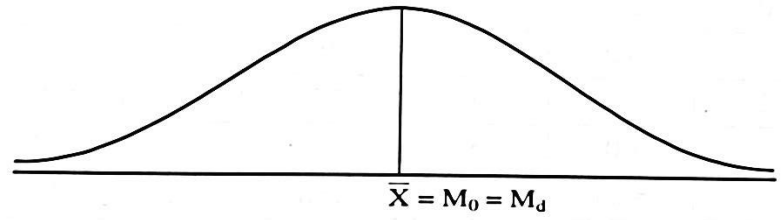
Quartile deviation

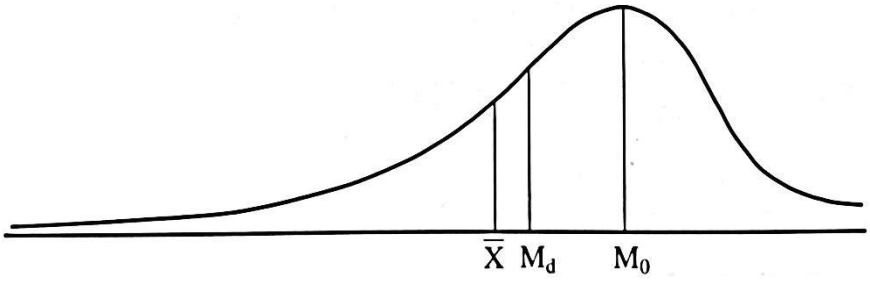
Mean deviation

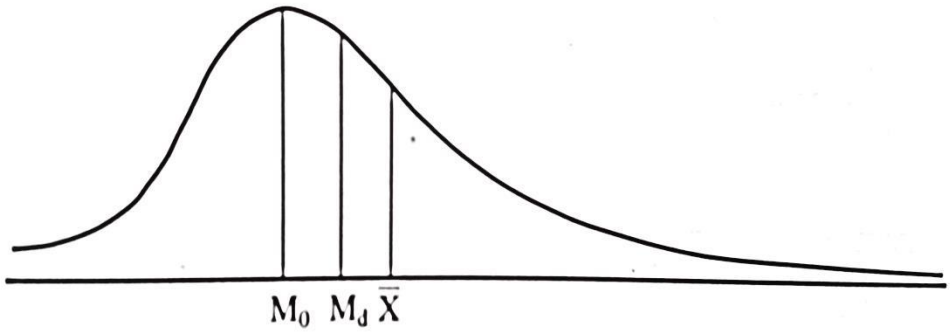
Standard deviation

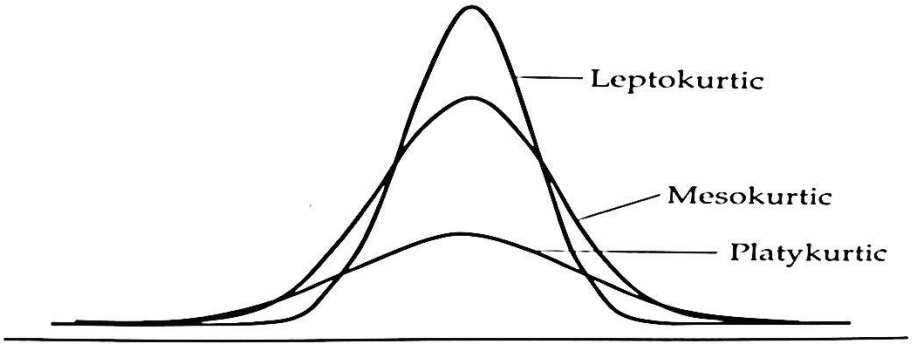
(Coefficient of Variation)

Skewness **kurtosis** $\mathbf{K=\frac{Q_3 - Q_1}{2(P_{90-P_{10}}}}$ **K=0.263**









Correlation and Regression

Inferential statistics

Testing of Hypothesis

Z test

It is important parametric test based upon the normality assumption. Traditionally Z test is used, when the samples are selected from population of known parameter with sample size more than 30. We consider that if sample size is more than 30 then sample selected from non normal population is also approximately normal distributed.

Z test is defined as the ratio of difference between t and E(t) to the S.E.(t)

$$Z = \frac{t - E(t)}{SE.(t)} \sim N(0, 1),$$

where t = statistic, E(t) = Expected value of statistic and S.E.(t) = Standard error of the statistic.

Z test is used to test

- Significance of single mean.

- Significance of difference between two means.

- Significance of single proportion.

Significance of difference between two proportions

- Significance of difference between sample correlation and population correlation.

- Significance of difference between independent sample correlations

Test of significance of a single mean

Let us consider sample of size n (n > 30) has been drawn from the normal population N (μ, σ^2) then the sample mean $\bar{x} \sim N\ (\mu, \sigma^2)$.

Different steps in the test are;

Problem to test

Ho:$\mu = \mu_0$ (sample is drawn from population with mean μ_0)

H1: $\mu \neq \mu_0$ (Two tailed test)

or H1: $\mu > \mu_0$ (One tailed right)

or H1: $\mu < \mu_0$ (One tailed left)

Test statistic

For the sample selected from the population of unknown size

$Z = \frac{\bar{X} - E(\bar{X})}{SE.(\bar{X})} = \frac{\bar{X} - \mu}{\frac{\sigma}{\sqrt{n}}}$ for known variance

$\frac{\bar{X} - \mu}{\frac{S}{\sqrt{n}}}$ for unknown variance(for large sample size($\hat{\sigma} = s$)

For the sample selected from the population of known size

$Z = \frac{\bar{X} - E(\bar{X})}{SE.(\bar{X})} = \frac{\bar{X} - \mu}{\frac{\sigma}{\sqrt{n}}\sqrt{\frac{N-n}{N-1}}}$ for known variance

$\frac{\bar{X} - \mu}{\frac{s}{\sqrt{n}}\sqrt{\frac{N-n}{N-1}}}$ for unknown variance

Where $\bar{X}$ = sample mean, μ = population mean, σ = population s.d. s = sample s.d.,

N = population size, n = sample size

Level of significance

Let α be the level of significance. Usually we take α = 0.05 unless we are given.

Critical value

Critical or tabulated value of Z is obtained from table according to the level of significance and alternative hypothesis.

Decision

Reject Ho at α level of significance if I z I > $Z_{tabulated}$, accept otherwise.

Example

A sample of 400 students is found to have mean height of 170 cm. Can it be reasonably regarded as a sample from a large population with mean height 169.5 cm and standard deviation 3.5 cm?

Solution

Here,

Sample size (n) = 400

Sample mean ($\bar{X}$) = 170

Population mean (μ) = 169.5

Population S.D. (σ) = 3.5

Problem to test

Ho : Mean height of students is 169.5 cm (μ = 169.5)

H_1 = Mean height of student is not 169.5 cm ($\mu \neq 169.5$) (Two tailed)

Test statistic

$$Z = \frac{\bar{X} - \mu}{\frac{\sigma}{\sqrt{n}}} = \frac{170 - 169.5}{\frac{3.5}{\sqrt{400}}} \quad \frac{0.5 \times 20}{3.5} = 2.857$$

Critical value

Let 5% be the level of significance then critical value is Ztab = $Z\alpha/2$ = 1.96 Decision Here Z= 2.857 > Z_{tab} = 1.96, reject Ho at 5% level of significance.

Conclusion

The sample of 400 students cannot be regarded as sample from large population with mean height 169.5 cm and standard deviation 3.5 cm.

Test of significance difference between two means

Let us consider two independent samples of size n_1 and n_2 be drawn from population having means means μ_1 and μ_2 and variances σ_1^2 and σ_2^2 respectively. Let $\bar{X}_1$ and $\bar{X}_2$ be the sample means.

For large n_1 and n_2.

$$\bar{X}_1 \sim N(\mu_1, \frac{\sigma_1^2}{n_1}$$

$$\bar{X}_2 \sim N(\mu_2, \frac{\sigma_2^2}{n_2}$$

$$\bar{X}_1 - \bar{X}_2 \sim N(\mu_1 - \mu_2, \frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2})$$

Different steps in the test are

Problem to test

Ho: $\mu_1 = \mu_2$ There is no significant difference between two population mean.

H1: $\mu_1 \neq \mu_2$ (two tailed)

or H1 : $\mu_1 < \mu_2$ (one tailed left)

or H1 : $\mu_1 > \mu_2$ (one tailed right)

Test statistic

$$\boldsymbol{Z} = \frac{\bar{X}_1 - \bar{X}_2 - E(\bar{X}_1 - \bar{X}_2)}{\boldsymbol{S.E.}(\bar{X}_1 - \bar{X}_2)}$$

$$\boldsymbol{Z} = \frac{(\bar{X}_1 - \bar{X}_2) - (\mu_1 - \mu_2)}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}}$$

When population means and variances are known

$$\boldsymbol{Z} = \frac{(\bar{X}_1 - \bar{X}_2)}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}}$$

When population variances are known

$$\boldsymbol{Z} = \frac{(\bar{X}_1 - \bar{X}_2)}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

When population variances are unknown

for large sample size $\widehat{\sigma_1^2} = S_1^2$ and $\widehat{\sigma_2^2} = S_2^2$

$\bar{X}_1$ = sample mean of size n_1,

$\bar{X}_2$ = sample mean of size n_2

σ_1^2 = population variance of first population

σ_2^2 = population variance of second Population

S_1^2 = sample variance of first sample

S_2^2 = sample variance of second sample.

Level of significance

Let a α be the level of significance. Usually we take α = .05 unless we are given.

Critical value

Critical or tabulated value of Z is obtained from table according to the level of significance and alternative hypothesis.

Decision

Reject Ho at a level of significance if I z I > $_{Ztabulated}$, accept otherwise.

Example

In a random sample of 500 the mean is found to be 20. In another independent sample of 400 the mean is 15. Could the samples have been drawn from the same population with S.D. 4? Solution Here,

Sample size of first sample (n_1) = 500

Sample mean of first sample ($\bar{X}_1$) = 20

Sample size of second sample (n_2) = 400

Sample mean of second sample ($\bar{X}_2$) = 15

Population S.D. of first (σ_1) = 4

Population S.D. of second (σ_2) = 4

Problem to test

Ho : $\mu_1 = \mu_2$ (both the populations are same)

H1: $\mu_1 \neq \mu_2$ (population are different)

Test statistic

$$\boldsymbol{Z} = \frac{(\bar{X}_1 - \bar{X}_2)}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}}$$

$$\boldsymbol{Z = \frac{(20-15)}{\sqrt{\frac{16}{500}+\frac{16}{400}}} = 18.51}$$

Critical value

Let α = 5 % be the level of significance the critical value is $_{Ztabulated}$ = Z α /2 = 1.96. .

Decision

Z =18.51 > Ztabulated = 1.96, reject Ho at 5% level of significance.

Conclusion

We cannot conclude that the samples have been drawn from the same population.

Test of significance difference between two proportions:

Let P_1 and P_2 be the two population proportions possessing a certain characteristic. Let two independent samples of sizes n_1 and n_2 be drawn from the two population. Also p_1 and p_2 be the proportion of units possessing certain characteristic in the two samples.

For large sample size

$p_1 \sim N(p_1 , \frac{P_1Q_1}{n_1})$

$p_2 \sim N(p_2 , \frac{P_2Q_2}{n_2})$

Then

$p_1 - p_2 \sim (p_1 - p_2 , \frac{P_1Q_1}{n_1} + \frac{P_2Q_2}{n_2})$

Different steps in the test are;

Problem to test

$H_0 : P_1 = P_2$

$H_1 : P_1 \neq P_2$ (Two tail test)

$H_1 : P_1 > P_2$ (One tail right)

$H_1 : P_1 < P_2$ (One tail left)

Test statistic

$$\boldsymbol{Z} = \frac{(p_1 - p_2) - E((p_1 - p_2)}{\boldsymbol{S.E.}((p_1 - p_2)}$$

$$= \frac{(p_1 - p_2 - (P1 - P2)}{\sqrt{\frac{P_1Q_1}{n_1} + \frac{P_2Q_2}{n_2}}}$$

$$= \frac{(P1 - P2)}{\sqrt{\frac{P_1Q_1}{n_1} + \frac{P_2Q_2}{n_2}}}$$

If population proportion are given

$$= \frac{(p_1 - p_2}{\sqrt{\boldsymbol{PQ}(\frac{1}{n_1} + \frac{1}{n_2})}}$$

If population proportion are not given

Where P_1 = population proportion of first population

P_2 = population proportion of second population

p_1 = sample proportion of first sample of size n_1

p_2 = sample proportion of second sample of size n_2

Level of significance

Let α be the level of significance. Usually we take α = .05 unless we are given.

Critical value Critical or tabulated value of Z is obtained from table according to the level of significance and alternative hypothesis.

Decision

Reject Ho at a level of significance if I z I > $z_{tabulated}$, accept otherwise.

Example

A machine puts out 21 defective articles in a sample of 500 articles. Another machine gives 3 defective articles in a sample of 100 are the two machines significantly different in their performance? Use p value method at 1% level of significance.

Solution

Here Defective articles by a machine (x_1) = 21

Number of articles by a machine (n_1) = 500

Defective articles by another machine (x_2) = 3

Number of articles by another machine (n_2) = 100

Sample proportion of defective article by a machine (p_1) = $\frac{x1}{n1} = \frac{21}{500}$ = 0.042

Sample proportion of defective article by another machine (p_2) = $\frac{x2}{n2} = \frac{3}{100}$ =0.03

Let

P_1 = Population proportion of defective from a machine

P2 = Population proportion of defective from another machine

P = $\frac{n_1p_1+n_2p_2}{n_1+n_2} = \frac{500\times0.042+100\times0.03}{500+100} = \frac{24}{100} = 0.04$

Level of significance (α) = 1%

Problem to test

Ho : $P_1 = P_2$ (There is no significance difference in performance of machines)

H_1 : $P_1 \neq P_2$ (There is significance difference in performance of machines)

Test statistic

Z= $\frac{(p_1 - p_2}{\sqrt{PQ(\frac{1}{n_1}+\frac{1}{n_2})}}$

$\frac{0,042-0.03}{\sqrt{0.04\times0.96(\frac{1}{500}+\frac{1}{100})}}$ = 0.571

Now prob(Z≥ Zcalculated) $= \text{prob}(Z \geq 0.571) = 0.5 - \text{prob}(0 \leq Z \leq 0.571)$

$$= 0.5 - 0.2175 = 0.284$$

For two tailed test, p value = 2 Prob ($Z \geq Z_{calculated}$) = 2 x 0.284 = 0.568

Here α = 1% = 0.01

Decision P value = 0.568 > α = 0.01, accept H_0 at 1% level of significance.

Conclusion

There is no significant difference in performance of two machines.

t test

When the sample size is small (traditionally it is assumed less than or equal to 30), then the sampling distribution of the sample mean is assumed to follow student's t distribution. The t distribution is also similar to normal distribution having shape as in normal distribution but little bit flatter. As the sample size increases the shape of t distribution is more likely to normal curve. Whatever be the sample size the statistical software uses the t test for all sample size instead of Z test, since it can compute the tail area of the curve (p value) or to compare with the pre-assigned value of a.

t test is based upon the assumption that

- Sample size small
- Sample is selected from normal population.
- Population standard deviation is not known.
- Samples are independent.

It is used to test

- **Significance of single mean**.
- **Significance of difference between means.**
- **Significance of correlation coefficient.**
- **Significance of regression coefficient**.

Some other test

(i)Chi- square test

ii) ANOVA (Analysis of Variance)

iii) Run test

iv) Sign test

v) Mann Whitney U test

vi) The Kruskal- Wallis test

CHAPTER 5

Preparation of Research Report

Research Report

A report is simply a statement or description of things that have already occurred. It is concise, clear communication of the important findings of the research work. Reports communicate information which has been compiled as a result of research and analysis of data and of issues. Reports focus on transmitting information with a clear purpose, to a specific audience. Good reports are documents that are accurate, objective and complete. They should be well-written, clearly structured and expressed in a way that holds the reader's attention and meets their expectations.

A research report has a special feature in that it conveys information to the evaluator about the entire activities you had undertaken during the research process. It is the only truly effective way in which you can communicate with your examiners or evaluators about the interesting findings of your work and the new knowledge you have generated.

Purpose and Importance of Research Reports

■ It is a means whereby the data, analysis and conclusions are placed in an organized form. These information can be used both for academic and application purposes.

■ Your research work will be judged mainly by the quality of the report. The examining committee may not see your effort while at field. Your research report is the "only tangible product" of hundreds of hours of work. Therefore, you should show your performance, skills, and thoughts in your report, as these are vital to its assessment and grading.

■ The effectiveness of the report may be judged by its use. The organizations, professors, researchers and students are using good reports for different purposes. Report writing may benefit you in any of the following ways, although the relative importance of each will change as the program of work progresses:

■ To see whether you are on target with your work, so that any problems can be spotted in time to be attended to.

■ To provide an opportunity for you to reflect on progress, consolidate arguments and identify any gaps in knowledge, data or methodology.

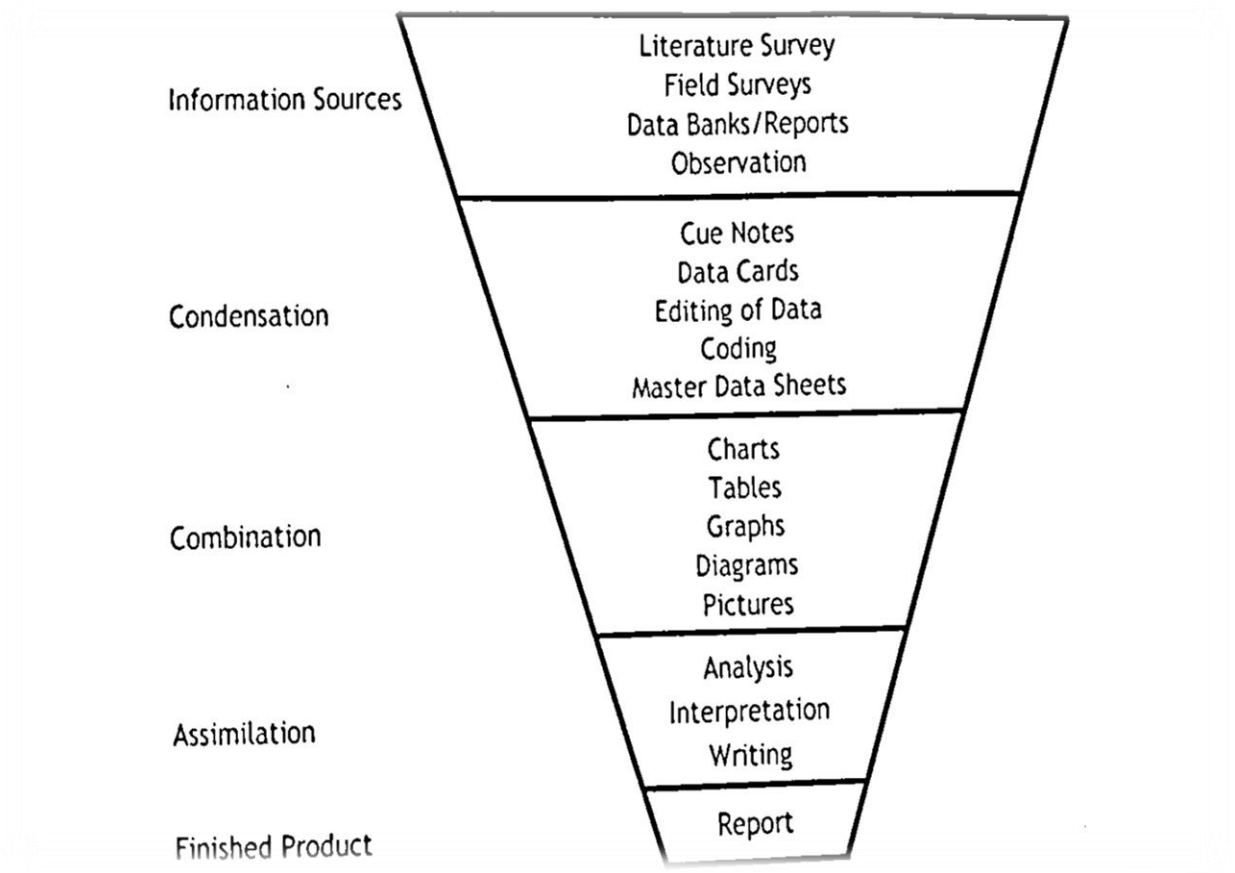
■ To help you to develop an appreciation of standards and hence to learn to monitor your own progress.

■ To provide practice in academic report writing and academic discourse, so that any additional training which may be necessary in this report can be supplied at an early stage.

■ To form a basis, in due course, for your project work and possibly a journal article.

Research Report Process

There are five steps in the research reporting process. At the top, we have raw data collected from different sources. The data is then passed through different stages of compression. Given figure highlights this report process.



Types of Research Reports

i) Descriptive Reports

Descriptive reports are description of facts, trends or opinions gathered by you in course of your investigation. The presentation and analysis of facts in an organized way may be of real value in properly understanding the situation. These reports indicate the current situation and the nature of the problems facing the organization under study and also indicate the reforms required to overcome the problems.

ii) Analytical Reports

Analytical reports go one step further than descriptive reports. These reports, in addition to presenting facts and statistics, interpret this information in relation to the problem under consideration. Focused on a single or limited area of the problem, these reports follow the process of scientific investigation and reporting. These reports also recommend the actions to be taken for improvements in the situation. You may choose any one of these types of reports. The choice of the types would depend on the nature of your investigation..

Procedures for Report Writing

There are no set rules for writing a research report. A procedure that works well for one person may not work so well for another.

Analyze the Task

You may find the following questions useful when analyzing the task:

I. What is the purpose of the report?
II. What should I look up?
III. Who will read my report?
IV. What is the word limit?
V. What is the expected format of the report?

Prepare Outline

In view of your task analysis and the data that you have collected, you can draw an outline of reporting prior to actually starting the write up. An outline is a roadmap to keep you from getting lost when you start to write. This will help you in arranging ideas in a better way. This will also enable you to see broadly which information you want to communicate and how the various points are related to one another. Thus, for effective report writing, it is essential to plan its contents well.

Plan Your Time

The campus/college decides the date of report submission. Therefore, you may not have enough time to work at ease. As you have to meet the time schedule, it is always better for you to plan the available time accordingly. Delays in submission of the research report may cause problems for the student as well as the campus/college.

Arrange Data

You may have collected the data from different sources. The raw data need to be processed and tabulated first. After some editing work is done, the data would be somewhat revealing. You then have to arrange the data in some sequential order for meaningful presentation. The better you organize and arrange the data, the better the data will be revealing.

Start Writing

In writing, the beginning is often difficult. You may begin with the introduction and proceed through to the conclusion. But it is always better to start writing the sections, which appear to be especially easy. This would increase the enthusiasm for the task and enhance your level of confidence.

Prepare the First Draft

You should never expect to produce the excellent report in the first attempt. This may not even be possible for experienced writers. Therefore, it is better-to prepare the draft first. Then you can rewrite where necessary.

Put the Report aside for a Day or Two

After preparing the first draft, you can keep the report aside for a day or two and can do some other work. Forgetting about the report for a day or two can be very beneficial. Then you review the report afresh, almost as objectively as another person. If you find weaknesses, you can remove or correct them.

Review and Rewrite

In any report, there is always some scope for improvement. You must review your work in terms of the format and style of reporting. You must ensure that you have followed the format and style prescribed by your campus/college. You should also review your work to identify any errors in grammar, spelling, punctuation, sentence structure, etc. Revision or editing is not the same as re-writing the whole thing from scratch. What you are doing is taking a close and careful look at each word, sentence, and paragraph to make sure you have made the best choices.

Style of Report Writing

Write Clearly

The sentence must be as simple as possible. Two or three relatively simple sentences may convey an idea more clearly than one complicated sentence. Similarly, you should not write long paragraphs. You should divide the material into separate paragraphs and use sub-headings, if necessary, to highlight important separate points. The words used must express precisely what you want to say. Finally, you must make sure that the report has uniform style and format.

Adhere to the Study Objectives

You should focus on the research problem. The main purpose of the research investigation is to answer the questions that derive from the statement of objectives. The findings or a simple piece of writing without reference to the objective may be a futile exercise.

Be Careful of Terminology, Grammar and Spelling

The fundamental medium of communicating one's findings is words. Therefore, you should give adequate attention to the correct use of grammar and to the correct spellings of all word. Similarly, appropriate punctuation marks must also be used according to the standard rules and not arbitrarily.

Be Selective

Research reports cannot include everything known on the given subject. If an attempt is made to include too much, there is always danger that the important points will be lost in the detail. Unnecessary accumulation of materials may distort the focus. Hence, you should make good judgment as to what materials to include in the report and what to exclude.

Be Objective

Objectivity is an important determinant of the quality of a research report. Hence, objectivity should be maintained in your research methods and interpretations. You must at all times retain your objectivity. In other words, facts should determine conclusions. Objectivity is essential because it is necessary that others be able to understand and replicate a finding before it is considered dependable. Hence, extra caution should be taken to keep the research reporting process bias-free.

Draw Conclusions

Students often confuse conclusions with research findings. Findings state facts. Conclusions represent inferences drawn from the findings. Findings are just like threads in a handloom. These threads need to be woven, intermixed and converted into a finished product called conclusion..

Conventions of Academic Writing

Make Direct and Positive Sentences

You should not use unessential words and phrases. You should avoid unnecessarily long, technical, or unusual words or phrases. Thus, well-constructed sentences are a mark of skill in writing. In writing a report, you should write naturally and directly using familiar words, short sentences with simple constructions.

Presentation

Charts, sections, sub-sections, tables etc. should be labeled adequately. The system of headings and subheadings should be kept simple. The report must be a coherent whole; it must be a tightly woven fabric of facts and ideas - of sections, subsections, paragraphs and sentences. The sequence of the sections and subsections should be logical and clear. The introduction, data analysis and findings are to be in the past tense; conclusion in the tense; and recommendations in the future tense.

Use of the First Person

The report is to be written in the third person. The pronouns such as I, my, mine, our, ours, We, us and me should be eliminated from the report. If required to refer to yourself, you use the Words "the writer" or "the investigator".

Use Gender-neutral Language

When writing a research report, it is very important to select terminology which treats both genders equally. You should not make assumptions about one gender as opposed to the other. When reporting empirical data in a project work, however, there may often be instances where it is necessary to refer to the gender of a respondent. In such instances, the use of the relevant pronoun, he or she, may be appropriate and even necessary for the reporting of the research.

Avoid Emotional Terms

Instead of writing "Sales increased tremendously", "The increase was fantastic" or "The amazing increase was attributed to... ", simply state the percentage of increase in sales. By so doing, you are neither passing judgment nor trying to make the reader pass judgment.

Label Opinions

Generally, facts are strongly preferred over opinions. Sometimes, however, opinions add conviction. The opinions of specialists may be available when facts from research are not available. When presenting opinions, you can reveal the background and identity of the person presenting the opinion. Sometimes, data are such that no solid conclusion can be drawn, or a variety of explanations could exist. In such cases, opinions can strongly substantiate your explanations and conclusions.

Use of Notes and Footnotes

It is sometimes necessary to include in a project report additional material which it is felt to be inappropriate to place in the main text. This kind of material may be information which is supplementary to the principal arguments of the text. Such material may be included in footnotes at the bottom of the relevant page, or in notes at the end of each chapter.

Non-English Terms and Expressions

Non-English terms are sometimes used in project research reports. The terms which are used regularly in English should not be italicized. However, an expression such as *chakka jam* would probably be italicized. When using an expression from another language, it is worth considering whether it is likely to be understood by most readers.

English and American Spellings

The issue which occurs most commonly in academic writing is the selection of the form of verbs which can end in either Ise' or `ize'. In English academic writing, the latter form is the norm. Examples of such regularly used words in research include hypothesize, synthesize, and socialize. However, both these formats are equally acceptable. You should use one spelling format consistently.

Abbreviations

Abbreviations should be used sparingly. When inserted in the text to any great extent, they have the effect of breaking up the text, and making it more difficult to read. The reader may forget the meaning of some of the abbreviations and need to turn back regularly to consult the glossary. When the abbreviation is used for the first time, then the full form of the term should be given first, followed by the abbreviation in brackets afterwards. From that point onwards, the abbreviation may be used on its own.

Confidentiality and Anonymity

As far as possible, you should try to maintain confidentiality and anonymity. If the research involves any type of case study, then it is possible to use fictional names. The main advantage in this is that it gives the report an air of reality.

Consistency

While writing, consistency in the spellings, abbreviations, style, etc. should be maintained. It is therefore to make a choice of format, and then to abide by that choice throughout the report. Even slight variations in practice, can be an irritant for the evaluators of your thesis.

Typing the Research Report

Paper

For the purpose of typing white Xerox paper may be used. The size of the paper should be 8.6 by 11 inches. Only one side of the paper is to be used.

Chapter Page

The chapter number is centered about two inches from the top of the page. Following to spaces below should be the title of the chapter in capital letters. The first line of the text should begin four spaces below that title.

Margins

Margins indicate the boundaries of the text. APA specifies 1-inch margins all around (top, bottom, left, and right).

Spacing

The text of the report should be double-spaced. Indented, quotations and footnotes should be single-spaced. Same style and size of font should be used throughout the report.

Page Number

Page number should come at the top right hand corner of the page, one inch from the top edge and one inch from the right-hand edge of the page. The first line of the text should be two spaces below the page number.

Pagination

Pages should be numbered consecutively in Arabic numerals from the first page of the text to the end of the manuscript (including the appendices). The pages in the introductory sections (preface, table of contents etc.) should be numbered with small Roman numerals i, ii, iii, iv, v, etc., one inch from the bottom of the page. All page numbers should stand alone without periods, hyphens or. dashes.

Proofreading

The manuscript should be read critically, searching for inaccurate statements, wrong entries' omissions and inconsistencies. After verifying and locating errors in quotations, footnotes, tables, figures, paragraphing, sentence structure, headings, spellings, style, bibliography, mark the copy to provide the typist with necessary directions for providing a satisfactory transcript.

LAYOUT OF THE RESEARCH REPORT

Anybody, who is reading the research report, must necessarily be conveyed enough about the study so that he can place it in its general scientific context, judge the adequacy of its methods and thus form an opinion of how seriously the findings are to be taken. For this purpose there is the need of proper layout of the report means as to what the research report should contain. A comprehensive layout of the research report should comprise (a) preliminary pages; (b) main text; and(c) the end matter.

(a) Preliminary Pages

In its preliminary pages the report should carry a title and date, followed by acknowledgements in the form of 'preface' or 'foreword'. Then there should be a table of contents followed by List of tables and illustrations.

(b) Main Text

The main text provides the complete outline of the research report along with all details. Title of the research study is repeated at the top of the first page of the main text and then follows the other details on pages numbered consecutively, beginning with the second page. Each main section of the report should begin on a new page. The main text of the report should have the following sections: (i) Introduction; (ii) Statement of findings and recommendations; (iii) The results; (iv) The implications drawn from the results; and (v) The summary.

(i) Introduction

The purpose of introduction is to introduce the research project to the readers It should contain a clear statement of the objectives of research i.e., enough background should be given to make clear to the reader why the problem was considered worth investigating. A brief summary of other relevant research may also be stated so that the present study can be seen in that context. The hypotheses of study, if any, and the definitions of the major concepts employed in the study should be explicitly stated in the introduction of the report.

The methodology adopted in conducting the study must be fully explained. The scientific reader would like to know in detail about such thing: How was the study carried out? What was its basic design? If the study was an experimental one, then what were the experimental manipulations? If the data were collected by means of questionnaires or interviews, then exactly what questions were asked (The questionnaire or interview schedule is usually given in an appendix).If measurements were based on observation, then what instructions were given to the observers? Regarding the sample used in the study the reader should be told:

Who were the subjects? How many were there? How were they selected? All these questions are crucial for estimating the probable limits of generalizability of the findings.

The statistical analysis adopted must also be clearly stated. In addition to all this, the scope of the study should be stated and the boundary lines be demarcated. The various limitations, under which the research project was completed, must also be narrated.

(ii) Statement of findings and recommendations

After introduction, the research report must contain a statement of findings and recommendations in non-technical language so that it can be easily understood by all concerned. If the findings happen to be extensive, at this point they should be put in the summarized form.

(iii)Results

A detailed presentation of the findings of the study, with supporting data in the form of tables and charts together with a validation of results, is the next step in writing the main text of the report. This generally comprises the main body of the report, extending over several chapters. The result section of the report should contain statistical summaries and reductions of the data rather than the raw data. All the results should be presented in logical sequence and splitted into readily identifiable sections. All relevant results must find a place in the report. But how one is to decide about what is relevant is the basic question. Quite often guidance comes primarily from the research problem and from the hypotheses if any, with which the study was concerned. But ultimately the researcher must rely on his own judgement in deciding the outline of his report.

(***iv)Implications of the results*** Toward the end of the main text, the researcher should again put down the results of his research clearly and precisely. He should, state the implications that flow from the results of the study, for the general reader is interested in the implications for understanding the human behaviour. Such implications may have three aspects as stated below:

(a) A statement of the inferences drawn from the present study which may be expected to apply in similar circumstances.

(b) The conditions of the present study which may limit the extent of legitimate generalizations of the inferences drawn from the study.

(c) The relevant questions that still remain unanswered or new questions raised by the study along with suggestions for the kind of research that would provide answers for them.

It is considered a good practice to finish the report with a short conclusion which summarises and recapitulates the main points of the study. The conclusion drawn from the study should be

clearly related to the hypotheses that were stated in the introductory section. At the same time, a forecast of the probable future of the subject and an indication of the kind of research which needs to be done in that particular field is useful and desirable.

(*v*) *Summary:* It has become customary to conclude the research report with a very brief summary, resting in brief the research problem, the methodology, the major findings and the major conclusions drawn from the research results.

(c) End Matter

At the end of the report, appendices should be enlisted in respect of all technical data such as questionnaires, sample information, mathematical derivations and the like ones. Bibliography of sources consulted should also be given. Index (an alphabetical listing of names, places and topics along with the numbers of the pages in a book or report on which they are mentioned or discussed) should invariably be given at the end of the report. The value of index lies in the fact that it works as a guide to the reader for the contents in the report.

Research Proposal

In a research proposal, the goal is to present the author's plan for the research they intend to conduct. In some cases, part of this goal is to secure funding for said research. In other words it is approved by the author's supervisor or department so they can move forward with it. In some cases, a research proposal is a required part of a graduate school application. In every one of these circumstances, research proposals follow the same structure.

In a research proposal, the author demonstrates how and why their research is relevant to their field. They demonstrate that the work is necessary for the following:

- Filling a gap in the existing body of research on their subject
- Underscoring existing research on their subject, and/or
- Adding new, original knowledge to the academic community's existing understanding of their subject

A research proposal also demonstrates that the author is capable of conducting this research and contributing to the current state of their field in a meaningful way. To do this, the research proposal needs to discuss your academic background and credentials as well as demonstrate that your proposed ideas have academic merit.

But demonstrating your research's validity and your personal capability to carry it out isn't enough to get your research proposal approved. **Your research proposal also has to cover these things**:

a. The research methodology you plan to use

b. The tools and procedures you will use to collect, analyze, and interpret the data you collect
c. An explanation of how your research fits the budget and other constraints that come with conducting it through your institution, department, or academic program

If you've already read our post on literature reviews, you may be thinking that a research proposal sounds pretty similar. They're more than just similar, though—a literature review is part of a research proposal. It's the section that covers which sources you're using, how you're using them, and why they're relevant. Think of a literature review as a mini-research proposal that fits into your larger, main proposal.

Length of Proposal

Generally, research proposals for bachelor's and master's theses are a few pages long. Research proposals for Ph.D. dissertations and funding requests, are often longer and far more detailed. A research proposal's goal is to clearly outline exactly what your research will entail and accomplish, so including the proposal's word count or page count isn't nearly as important as it is to ensure that all the necessary elements and content are present.

Research proposal structure

A research proposal follows a fairly straightforward structure. In order to achieve the goals described in the previous section, nearly all research proposals include the following sections:

Introduction

Your introduction achieves a few goals:

- Introduces your topic
- States your problem statement and the questions your research aims to answer
- Provides context for your research

In a research proposal, an introduction can be a few paragraphs long. It should be concise, but don't feel like you need to cram all of your information into one paragraph.

In some cases, you need to include an abstract and/or a table of contents in your research proposal. These are included just before the introduction.

Background significance

This is where you explain why your research is necessary and how it relates to established research in your field. Your work might complement existing research, strengthen it, or even challenge it—no matter how your work will "play with" other researchers' work, you need to express it in detail in your research proposal.

This is also the section where you clearly define the existing problems your research will address. By doing this, you're explaining why your work is necessary.

In your background section, you'll also outline how you'll conduct your research. If necessary, note which related questions and issues you won't be covering in your research.

Literature review

In your literature review, you introduce all the sources you plan to use in your research. This includes landmark studies and their data, books, and scholarly articles. A literature review isn't merely a list of sources (that's what your bibliography is for); a literature review delves into the collection of sources you chose and explains how you're using them in your research.

Research design, methods, and schedule

In this section, make sure you cover these aspects:

- The type of research you will do. Are you conducting qualitative or quantitative research? Are you collecting original data or working with data collected by other researchers?
- Whether you're doing experimental, correlational, or descriptive research
- The data you're working with. For example, if you're conducting research in the social sciences, you'll need to describe the population you're studying. You'll also need to cover how you'll select your subjects and how you'll collect data from them.

The tools you'll use to collect data.

- Sampling frame
- Sampling method
- Use of descriptive statistics and inferential statistics
- Will you be running experiments?
- Conducting surveys?
- Observing phenomena?

Note all data collection methods here along with why they're effective methods for your specific research.

Beyond a comprehensive look at your research itself, you'll also need to include:

- Your research timeline
- Your research budget
- Any potential obstacles you foresee and your plan for handling them

Suppositions and implications

Although you can't know your research's results until you've actually done the work, you should be going into the project with a clear idea of how your work will contribute to your field. This section is perhaps the most critical to your research proposal's argument because it expresses exactly why your research is necessary.

In this section, make sure you cover the following:

- Any ways your work can challenge existing theories and assumptions in your field
- Your work will create the foundation for future research
- The practical value of your findings will provide to practitioners, educators, and other academics in your field
- The problems your work can potentially help to fix
- Policies that could be impacted by your findings
- How your findings can be implemented in academia or other settings and how this will improve or otherwise transform these settings

In other words, this section isn't about stating the specific results you expect. Rather, it's where you state how your findings will be valuable.

Conclusion

This is where you wrap it all up. Your conclusion section, just like your conclusion paragraph for an essay, briefly summarizes your research proposal and reinforces your research's stated purpose.

Bibliography

Yes, you need to write a bibliography in addition to your literature review. Unlike your literature review, where you explained the relevance of the sources you chose and in some cases, challenged them, your bibliography simply lists your sources and their authors.

The way you write a citation depends on the style guide you're using. The three most common style guides for academics are MLA, APA, and Chicago, and each has its own particular rules and requirements. Keep in mind that each formatting style has specific guidelines for citing just about any kind of source, including photos, websites, speeches, and YouTube videos.

Sometimes, a full bibliography is not needed. When this is the case, you can include a references list, which is simply a scaled-down list of all the sources you cited in your work. If you're not sure which to write, ask your supervisor.

How to write a research proposal

Research proposals, like all other kinds of academic writing, are written in a formal, objective tone. Keep in mind that being concise is a key component of academic writing; formal does not mean flowery.

Adhere to the structure outlined above. Your reader knows how a research proposal is supposed to read and expects it to fit this template. It's crucial that you present your research proposal in a clear, logical way. Every question the reader has while reading your proposal should be answered by the final section.

Common mistakes to avoid when writing a research proposal

When you're writing a research proposal, avoid these common pitfalls:

Being too wordy

You should aim to keep your writing as brief and to-the-point as possible. The more economically you can express your purpose and goal, the better.

Failing to cite relevant sources

When you're conducting research, you're adding to the existing body of knowledge on the subject you're covering. Your research proposal should reference one or more of the landmark research pieces in your field and connect your work to these works in some way. This doesn't just communicate your work's relevance—it also demonstrates your familiarity with the field.

Focusing too much on minor issues

Including too many questions and issues in your research proposal can detract from your central purpose, weakening the proposal. Save the minor issues for your research paper itself and cover only the major, key issues you aim to tackle in your proposal.

Failing to make a strong argument for your research

This is perhaps the easiest way to undermine your proposal because it's far more subjective than the others. A research proposal is, in essence, a piece of persuasive writing. That means that although you're presenting your proposal in an objective, academic way, the goal is to get the reader to say "yes" to your work.

This is true in every case, whether your reader is your supervisor, your department head, a graduate school admissions board, a private or government-backed funding provider, or the editor at a journal in which you'd like to publish your work.

Polish your writing into a stellar proposal

When you're asking for approval to conduct research, especially when there's funding involved, you need to be nothing less than 100 percent confident in your proposal. If your research proposal has spelling or grammatical mistakes, an inconsistent or inappropriate tone, or even just awkward phrasing, those will undermine your credibility.

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In this section, make sure you cover these aspects:

- The type of research you will do. Are you conducting qualitative or quantitative research? Are you collecting original data or working with data collected by other researchers?
- Whether you're doing experimental, correlational, or descriptive research
- The data you're working with. For example, if you're conducting research in the social sciences, you'll need to describe the population you're studying. You'll also need to cover how you'll select your subjects and how you'll collect data from them.

The tools you'll use to collect data.

- Sampling frame
- Sampling method
- Use of descriptive statistics and inferential statistics
- Will you be running experiments?
- Conducting surveys?
- Observing phenomena?

Note all data collection methods here along with why they're effective methods for your specific research.

Beyond a comprehensive look at your research itself, you'll also need to include:

- Your research timeline
- Your research budget
- Any potential obstacles you foresee and your plan for handling them

Suppositions and implications

Although you can't know your research's results until you've actually done the work, you should be going into the project with a clear idea of how your work will contribute to your field. This section is perhaps the most critical to your research proposal's argument because it expresses exactly why your research is necessary.

In this section, make sure you cover the following:

- Any ways your work can challenge existing theories and assumptions in your field
- Your work will create the foundation for future research

- The practical value of your findings will provide to practitioners, educators, and other academics in your field
- The problems your work can potentially help to fix
- Policies that could be impacted by your findings
- How your findings can be implemented in academia or other settings and how this will improve or otherwise transform these settings

In other words, this section isn't about stating the specific results you expect. Rather, it's where you state how your findings will be valuable.

Conclusion

This is where you wrap it all up. Your conclusion section, just like your conclusion paragraph for an essay, briefly summarizes your research proposal and reinforces your research's stated purpose.

Bibliography

Yes, you need to write a bibliography in addition to your literature review. Unlike your literature review, where you explained the relevance of the sources you chose and in some cases, challenged them, your bibliography simply lists your sources and their authors.

The way you write a citation depends on the style guide you're using. The three most common style guides for academics are APA,I EEE and Chicago, and each has its own particular rules and requirements. Keep in mind that each formatting style has specific guidelines for citing just about any kind of source, including photos, websites, speeches, and YouTube videos.

Sometimes, a full bibliography is not needed. When this is the case, you can include a references list, which is simply a scaled-down list of all the sources you cited in your work. If you're not sure which to write, ask your supervisor.

How to write a research proposal

Research proposals, like all other kinds of academic writing, are written in a formal, objective tone. Keep in mind that being concise is a key component of academic writing; formal does not mean flowery.

Adhere to the structure outlined above. Your reader knows how a research proposal is supposed to read and expects it to fit this template. It's crucial that you present your research proposal in a clear, logical way. Every question the reader has while reading your proposal should be answered by the final section.

Common mistakes to avoid when writing a research proposal

When you're writing a research proposal, avoid these common pitfalls:

Being too wordy

You should aim to keep your writing as brief and to-the-point as possible. The more economically you can express your purpose and goal, the better.

Failing to cite relevant sources

When you're conducting research, you're adding to the existing body of knowledge on the subject you're covering. Your research proposal should reference one or more of the landmark research pieces in your field and connect your work to these works in some way. This doesn't just communicate your work's relevance—it also demonstrates your familiarity with the field.

Focusing too much on minor issues

Including too many questions and issues in your research proposal can detract from your central purpose, weakening the proposal. Save the minor issues for your research paper itself and cover only the major, key issues you aim to tackle in your proposal.

Failing to make a strong argument for your research

This is perhaps the easiest way to undermine your proposal because it's far more subjective than the others. A research proposal is, in essence, a piece of persuasive writing. That means that although you're presenting your proposal in an objective, academic way, the goal is to get the reader to say "yes" to your work.

This is true in every case, whether your reader is your supervisor, your department head, a graduate school admissions board, a private or government-backed funding provider, or the editor at a journal in which you'd like to publish your work.

Polish your writing into a stellar proposal

When you're asking for approval to conduct research, especially when there's funding involved, you need to be nothing less than 100 percent confident in your proposal. If your research proposal has spelling or grammatical mistakes, an inconsistent or inappropriate tone, or even just awkward phrasing, those will undermine your credibility.