**Engineering Research Methodology**

**UNIT I**

**Do we need Research?**

"All progress is born of inquiry. Doubt is often better than over confidence, for it leads to inquiry, and inquiry leads to invention" - *Hudson Maxim*

**Meaning of Research:**

* A search for knowledge - A scientific and systematic search for significant information on a specific topic.
* A careful investigation through search for new facts in any branch of knowledge.
* Systematic gathering of data and information and its analysis for advancement of knowledge in any subject.
* Research attempts to find answer to intellectual and practical questions through application of systematic methods.
* Research is a form of investigation designed to discover a solution to a problem.
* It is the gathering of information about a given topic, usually with the idea of learning (like "what is research?").
* Research is originated from the root word *“search”* meaning facts and information already exist and the prefix *“re”* to find it but it requires systematic procedures.
* Research is defining and redefining problems, formulating hypothesis or suggested solutions; collecting, organizing and evaluating data; making deductions and reaching conclusions; and finally testing the conclusions carefully to determine whether they fit the hypothesis formulated.
* Broadly speaking, 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 solution to the concerned problem or in certain generalizations for some theoretical formulation.

**Objectives in Research**

1. To gain familiarity with a phenomenon or to achieve new insights into it (known as exploratory or formulative research studies);
2. To determine the frequency with which something occurs or with which it is associated with something else (known as diagnostic research studies);
3. To test a hypothesis of a causal relationship between variables (known as hypothesis-testing research studies).

**Other Objectives**

* To portray accurately the characteristics of a particular individual situation or group.
* To discover the truth and fact.
* To understand social life and gain a control over social behavior.
* To know old conclusions with new data.
* To find new conclusions with old data.
* To reach more conclusions from available data.
* To put forward an entirely new theory
* To study and resolve contradiction in the area of a study.

**Motivations in Research**

* Aspire to get a research degree along with career benefits;
* Aspire to take up the challenge in solving the unsolved problems;
* Desire to get intellectual joy of doing a creative work;
* Aspire to do research to serve the society;
* Seek to get recognition and respect;
* Many others such as directives of government, employment conditions, curiosity about new things, social thinking and awakening, and the like may as well motivate or compel people to do research.

**Types of Research**

Research can be classified in many different ways. Some major ways of classifying research include:

* Descriptive versus Analytical Research
* Applied versus Fundamental Research
* Qualitative versus Quantitative Research
* Conceptual versus Empirical Research

**Descriptive Research vs. Analytical Research**

**Descriptive research** includes surveys and fact-finding enquiries of different kinds. The major purpose of descriptive research is description of the state of affairs as it exists at present. This approach is suitable for social sciences and business and management studies for descriptive research studies. The main characteristic of this method is that the researcher has no control over the variables; She/he can only report what has happened or what is happening. Most research projects of this nature are used for descriptive studies in which the researcher seeks to measure factors like frequency of shopping, brand preference of people, most popular media programme etc. Survey methods of all kinds fall under descriptive research, including comparative and correlation techniques.

In contrast, **analytical research** is concerned with determining validity of hypothesis based on analysis of facts collected. Researcher makes a critical evaluation of the material by analyzing facts and information already available.

**Applied versus Fundamental Research**

**Applied research** is carried out to find answers to practical problems facing by a society or an industrial / business organization. It helps in decision making in different areas including product design, process design and policy making. The goal of applied research is to improve the human condition. It focus on analysis and solving social and real life problems.

According to hunt, “applied research is an investigation for ways of using scientific knowledge to solve practical problems” for example:- improve agriculture crop production, treat or cure a specific disease, improve the energy efficiency etc. Applied research can be further classified as problem oriented research (addressing a common problem) and problem solving research (addressing a specific problem).

Fundamental or Pure Research is mainly concerned with generalizations and concentrates on the formulation of a theory. "Gathering knowledge for the sake of knowledge” is termed 'Pure' or 'Basic' or ‘Fundamental’ research.

Examples of fundamental research are: research concerning some natural phenomenon or related to pure mathematics; research studies aimed at studying and making generalizations about human behavior.

Fundamental researchis carried out as more to satisfy intellectual curiosity, than with the intention of using the research findings for any immediate practical application. It is done for knowledge enhancement and does not have immediate commercial potential. The research is done for human welfare, animal welfare and plant welfare. The main motivation is to expand man's knowledge, not to create or invent something.

**Qualitative versus Quantitative Research**

Qualitative research is concerned with qualitative phenomenon. It is collecting, analyzing and interpreting data by observing what people do and say. Qualitative research is much more subjective and uses very different methods of collecting information mainly individual, in-depth interviews and focus groups. Qualitative research is especially important in the behavioral sciences where the aim is to discover the underlying motives of human behavior. For instance, when we are interested in investigating the reasons for human behavior, we quite often talk of 'Motivation Research', an important type of qualitative research. Ex. Small number of people are interviewed in depth and or a relatively small number of focus groups are conducted.

Quantitative research is applicable to phenomena that can be expressed in terms of quantity. It is based on numeric figures or numbers. Quantitative research aims to measure the quantity or amount and compares it with past records and tries to project for future period. The objective of quantitative research is to develop and employ mathematical models, theories or hypothesis pertaining to phenomena. Itmakes substantial use of measurements and quantitative analysis techniques. Quantitative research involving the use of structured questions, where the response options have been Pre-determined and large number of respondents is involved.

eg:-total sales of soap industry in terms of rupees cores and or quantity in terms of lakhs tones for particular year, say 2018, could be researched, compared with past 5 years and then projection for 2019 could be made.

**Conceptual vs. Experimental (or Empirical)**

Conceptual research involves investigation of thoughts and ideas and developing new ideas or interpreting the old ones based on logical reasoning. In contrast, empirical research is based on firm verifiable data collected by either observation of facts under natural condition or obtained through experimentation. It relies on conclusions coming up by experiment or observation alone, often without due regard for system and theory. In such a research it is necessary to get at facts firsthand, at their source, and actively to go about doing certain things to stimulate the production of desired information.

In such a research, the researcher must first provide himself with a working hypothesis or guess as to the probable results. He then works to get enough facts (data) to prove or disprove his hypothesis.

Empirical research is appropriate when proof is sought that certain variables affect other variables in some way. Evidence gathered through experiments or empirical studies is today considered to be the most powerful support possible for a given hypothesis.

**Other type of classification of research**

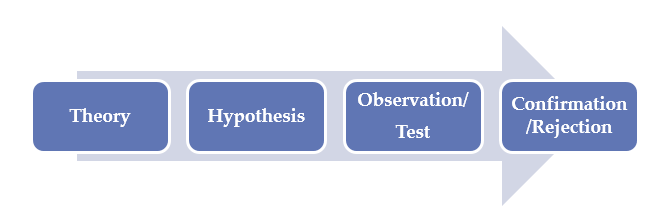
Descriptive research ; Analytical research ;Fundamental research ;Conceptual research ; Empirical research ;One time research or longitudinal research ;Field-setting research or laboratory research or simulation research ;Clinical or diagnostic research ;Exploratory research ; Historical research ;Conclusion oriented research ;Case study research; short term research

**Research Approach**

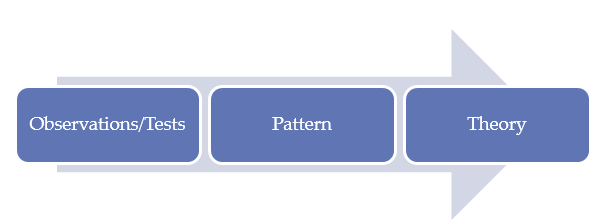
Research approach can be divided into two groups: Deductive and Inductive. The relevance of hypotheses to the study is the main distinctive point between these two approaches. Deductive approach tests the validity of assumptions (or theories/hypotheses) in hand, where as inductive approach contributes to the emergence of new theories and generalizations. Main distinction between inductive and deductive research approach relates to the existence and placement of hypotheses and theories.

Specifically, if the researcher adopts a range of hypotheses the research is aimed to explore, then it will be deductive research. On the other hand, if hypotheses are absent at the start of the research then it will be the case of inductive research.

**Deductive Approach**



**Inductive Approach**



**The Significance of Research**

“All progress is born of inquiry. Doubt is often better than overconfidence, for it leads to inquiry, and inquiry leads to invention”

-Hudson Maxim

Increased amounts of research make progress possible. Research inculcates scientific and inductive thinking and it promotes the development of logical habits of thinking and organization.The role of research in several fields of applied economics, whether related to business or to the economy as a whole, has greatly increased in modern times. Research provides the basis for nearly all government policies in our economic system. For instance, government’s budgets rest in part on an analysis of the needs and desires of the people and on the availability of revenues to meet these needs.

*Research has its special significance in solving various operational and planning problems of business and industry. Operations research and market research, along with motivational research,* are considered crucial and their results assist, in more than one way, in taking business decisions.

*Research is equally important for social scientists in studying social relationships and in seeking answers to various social problems.*

In addition, the significance of research can also be understood keeping in view the following from different persons’ perspective:

* To master's or Ph.D students, research may mean careerism or a way to attain a high position in the social structure;
* To professionals in research methodology, research may mean a source of livelihood;
* To philosophers and thinkers, research may mean the outlet for new ideas and insights;
* To literary men and women, research may mean the development of new styles and creative work;
* To analysts and intellectuals, research may mean the generalizations of new theories.

**Difference between Research Methods and Research Methodology**

Research methods may be understood as all those methods/techniques that are used for conducting research. They aim at finding solutions to research problems. These are mainly used to gather information so that the researcher can find answers to his research problem. They involve surveys, interviews, case studies, observation, experiments, etc.

Research methods can be put into the following three groups:

1. Methods which are concerned with the collection/ acquisition of data; these methods will be used where the data already available are not sufficient to arrive at the required solution;
2. Mathematical/statistical techniques which are used for establishing relationships between the data and the unknowns;
3. Methods used to evaluate the accuracy of the results obtained.

Research methodology is a way to systematically solve the research problem. It is considered as a science of studying how research is done scientifically. Research methodology involves the theoretical frameworks and learning of the various techniques that can be used in the conduct of research and the conduct of tests, experiments, surveys and critical studies. It involves formulation of the various steps that are to be 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. The researcher has to design his 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. 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?

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 of research methodology concerning a research problem or study.

**Research Process**

Research process consists of the following series of actions or steps necessary to effectively carry out research.

1. Formulating the research problem
2. Extensive literature survey
3. Development of working hypotheses
4. Preparing the research design
5. Determining sample design
6. Collecting the data
7. Execution of the project
8. Analysis of data
9. Hypotheses testing
10. Generalizations and interpretation
11. Preparation of the report or the thesis

**1. Formulating the research problem**

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

Essentially two steps are involved in formulating the research problem, viz., understanding the problem thoroughly, and rephrasing the same into meaningful terms from an analytical point of view. The best way of understanding the problem is to discuss it with one’s own colleagues or with those having some expertise in the matter. In an academic institution the researcher can seek the help from a guide who is usually an experienced man and has several research problems in mind. Often, the guide puts forth the problem in general terms and it is up to the researcher to narrow it down and phrase the problem in operational terms.

In private business units or in governmental organizations, the problem is usually earmarked by the administrative agencies with whom the researcher can discuss as to how the problem originally came about and what considerations are involved in its possible solutions. The researcher must at the same time examine all available literature to get himself acquainted with the selected problem. He may review two types of literature—the conceptual literature concerning the concepts and theories, and the empirical literature consisting of studies made earlier which are similar to the one proposed.

The basic outcome of this review will be the knowledge as to what data and other materials are available for operational purposes which will enable the researcher to specify his own research problem in a meaningful context. After this the researcher rephrases the problem into analytical or operational terms i.e., to put the problem in as specific terms as possible. This task of formulating, or defining, a research problem is a step of greatest importance in the entire research process. The problem to be investigated must be defined unambiguously for that will help discriminating relevant data from irrelevant ones. The researcher must at the same time examine all available literature to get himself acquainted with the selected problem. He may review two types of literature—the conceptual literature concerning the concepts and theories, and the empirical literature consisting of studies made earlier which are similar to the one proposed.

The basic outcome of this review will be the knowledge as to what data and other materials are available for operational purposes which will enable the researcher to specify his own research problem in a meaningful context. After this the researcher rephrases the problem into analytical or operational terms i.e., to put the problem in as specific terms as possible. This task of formulating, or defining, a research problem is a step of greatest importance in the entire research process. The problem to be investigated must be defined unambiguously for that will help discriminating relevant data from irrelevant ones. Care must, however, be taken to verify the objectivity and validity of the background facts concerning the problem.

Professor W.A. Neiswanger correctly states that the statement of the objective is of basic importance because it determines the data which are to be collected, the characteristics of the data which are relevant, relations which are to be explored, the choice of techniques to be used in these explorations and the form of the final report. If there are certain pertinent terms, the same should be clearly defined along with the task of formulating the problem. In fact, formulation of the problem often follows a sequential pattern where a number of formulations are set up, each formulation more specific than the preceding one, each one phrased in more analytical terms, and each more realistic in terms of the available data and resources.

**2. Extensive literature survey:**

Once the problem is formulated, a brief summary of it should be written down. It is compulsory for a research worker writing a thesis for a Ph.D. degree to write a synopsis of the topic and submit it to the necessary Committee or the Research Board for approval. At this juncture the researcher should undertake extensive literature survey connected with the problem. For this purpose, the abstracting and indexing journals and published or unpublished bibliographies are the first place to go to. Academic journals, conference proceedings, government reports, books etc., must be tapped depending on the nature of the problem. In this process, it should be remembered that one source will lead to another. The earlier studies, if any, which are similar to the study in hand should be carefully studied. A good library will be a great help to the researcher at this stage.

**3. Development of working hypotheses:**

After extensive literature survey, researcher should state in clear terms the working hypothesis or hypotheses. Working hypothesis is tentative assumption made in order to draw out and test its logical or empirical consequences. As such the manner in which research hypotheses are developed is particularly important since they provide the focal point for research. They also affect the manner in which tests must be conducted in the analysis of data and indirectly the quality of data which is required for the analysis. In most types of research, the development of working hypothesis plays an important role. Hypothesis should be very specific and limited to the piece of research in hand because it has to be tested. The role of the hypothesis is to guide the researcher by delimiting the area of research and to keep him on the right track. It sharpens his thinking and focuses attention on the more important facets of the problem. It also indicates the type of data required and the type of methods of data analysis to be used.

How does one go about developing working hypotheses? The answer is by using the following approach:

1. Discussions with colleagues and experts about the problem, its origin and the objectives in seeking a solution;
2. Examination of data and records, if available, concerning the problem for possible trends, peculiarities and other clues;
3. Review of similar studies in the area or of the studies on similar problems;
4. Exploratory personal investigation which involves original field interviews on a limited scale with interested parties and individuals with a view to secure greater insight into the practical aspects of the problem.

Thus, working hypotheses arise as a result of a-prior thinking about the subject, examination of the available data and material including related studies and the counsel of experts and interested parties. Working hypotheses are more useful when stated in precise and clearly defined terms. It may as well be remembered that occasionally we may encounter a problem where we do not need working hypotheses, especially in the case of exploratory or formulative researches which do not aim at testing the hypothesis. But as a general rule, specification of working hypotheses in another basic step of the research process in most research problems

**4. Preparing the research design:**

The research problem having been formulated in clear cut terms, the researcher will be required to prepare a research design, i.e., he will have to state the conceptual structure within which research would be conducted. The preparation of such a design facilitates research to be as efficient as possible yielding maximal information. In other words, the function of research design is to provide for the collection of relevant evidence with minimal expenditure of effort, time and money. But how all these can be achieved depends mainly on the research purpose.

Research purposes may be grouped into four categories, viz.,

1. Exploration,
2. Description,
3. Diagnosis, and
4. Experimentation.

A flexible research design which provides opportunity for considering many different aspects of a problem is considered appropriate if the purpose of the research study is that of exploration. But when the purpose happens to be an accurate description of a situation or of an association between variables, the suitable design will be one that minimises bias and maximises the reliability of the data collected and analysed. There are several research designs, such as, experimental and non-experimental hypothesis testing. Experimental designs can be either Informal designs such as

before-and-after without control,

after-only with control,

before-and-after with control)

or

Formal designs such as

completely randomized design,

randomized block design,

Latin square design,

simple and complex factorial designs,

Out of above the researcher must select one for his own project. The preparation of the research design, appropriate for a particular research problem, involves usually the consideration of the following:

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

**5. Determining sample design:**

All the items under consideration in any field of inquiry constitute a ‘universe’ or ‘population’. A complete enumeration of all the items in the ‘population’ is known as a census inquiry. It can be presumed that in such an inquiry when all the items are covered no element of chance is left and highest accuracy is obtained. But in practice this may not be true. Even the slightest element of bias in such an inquiry will get larger and larger as the number of observations increases. Moreover, there is no way of checking the element of bias or its extent except through a resurvey or use of sample checks. Besides, this type of inquiry involves a great deal of time, money and energy. Not only this, census inquiry is not possible in practice under many circumstances.

For instance, blood testing is done only on sample basis. Hence, quite often we select only a few items from the universe for our study purposes. The items so selected constitute what is technically called a sample. The researcher must decide the way of selecting a sample or what is popularly known as the sample design. In other words, a sample design is a definite plan determined before any data are actually collected for obtaining a sample from a given population. Thus, the plan to select 12 of a city’s 200 drugstores in a certain way constitutes a sample design.

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

A brief mention of the important sample designs is as follows:

1. ***Deliberate sampling: Deliberate sampling is also known as purposive or non-probability* sampling.**

This sampling method involves purposive or deliberate selection of particular units of the universe for constituting a sample which represents the universe. When population elements are selected for inclusion in the sample based on the ease of access, it can be called *convenience sampling. If a researcher wishes to secure data from, say, gasoline* buyers, he may select a fixed number of petrol stations and may conduct interviews at these stations. This would be an example of convenience sample of gasoline buyers. At times such a procedure may give very biased results particularly when the population is not homogeneous. On the other hand, in *judgment sampling the researcher’s judgment is* used for selecting items which he considers as representative of the population. For example, a judgment sample of college students might be taken to secure reactions to a new method of teaching. Judgment sampling is used quite frequently in qualitative research where the desire happens to be to develop hypotheses rather than to generalize to larger populations.

***(ii) Simple random sampling:***

*This type of sampling is also known as chance sampling or* probability sampling where each and every item in the population has an equal chance of inclusion in the sample and each one of the possible samples, in case of finite universe, has the same probability of being selected. For example, if we have to select a sample of 300 items from a universe of 15,000 items, then we can put the names or numbers of all the 15,000 items on slips of paper and conduct a lottery. Using the random number tables is another method of random sampling.

To select the sample, each item is assigned a number from 1 to 15,000. Then, 300 five digit random numbers are selected from the table. To do this we select some random starting point and then a systematic pattern is used in proceeding through the table. We might start in the 4th row, second column and proceed down the column to the bottom of the table and then move to the top of the next column to the right.

When a number exceeds the limit of the numbers in the frame, in our case over 15,000, it is simply passed over and the next number selected that does fall within the relevant range. Since the numbers were placed in the table in a completely random fashion, the resulting sample is random. This procedure gives each item an equal probability of being selected.

In case of infinite population, the selection of each item in a random sample is controlled by the same probability and that successive selections are independent of one another.

***(iii) Systematic sampling:***

*In some instances the most practical way of sampling is to select* every 15th name on a list, every 10th house on one side of a street and so on. Sampling of this type is known as systematic sampling. An element of randomness is usually introduced into this kind of sampling by using random numbers to pick up the unit with which to start. This procedure is useful when sampling frame is available in the form of a list. In such a design the selection process starts by picking some random point in the list and then every *nth element is selected until the desired number is secured.*

***(iv) Stratified sampling:***

*If the population from which a sample is to be drawn does not constitute* a homogeneous group, then stratified sampling technique is applied so as to obtain a representative sample. In this technique, the population is stratified into a number of non overlapping sub populations or strata and sample items are selected from each stratum. If the items selected from each stratum is based on simple random sampling the entire procedure, first stratification and then simple random sampling, is known as *stratified random sampling.*

***(v) Quota sampling:***

*In stratified sampling the cost of taking random samples from individual* strata is often so expensive that interviewers are simply given quota to be filled from different strata, the actual selection of items for sample being left to the interviewer’s judgment. This is called quota sampling. The size of the quota for each stratum is generally proportionate to the size of that stratum in the population. Quota sampling is thus an important form of non-probability sampling. Quota samples generally happen to be judgment samples rather than random samples.

***vi) Cluster sampling and area sampling:***

*Cluster sampling involves grouping the population* and then selecting the groups or the clusters rather than individual elements for inclusion in the sample. Suppose some departmental store wishes to sample its credit card holders. It has issued its cards to 15,000 customers. The sample size is to be kept say 450. For cluster sampling this list of 15,000 card holders could be formed into 100 clusters of 150 card holders each. Three clusters might then be selected for the sample randomly.

The sample size must often be larger than the simple random sample to ensure the same level of accuracy because is cluster sampling procedural potential for order bias and other sources of error is usually accentuated. The clustering approach can, however, make the sampling procedure relatively easier and increase the efficiency of field work, specially in the case of personal interviews. *Area sampling is quite close to cluster sampling and is often talked about when the total* geographical area of interest happens to be big one.

Under area sampling we first divide the total area into a number of smaller non-overlapping areas, generally called geographical clusters, then a number of these smaller areas are randomly selected, and all units in these small areas are included in the sample. Area sampling is specially helpful where we do not have the list of the population concerned. It also makes the field interviewing more efficient since interviewer can do many interviews at each location.

***(vii) Multi-stage sampling:***

*This is a further development of the idea of cluster sampling. This* technique is meant for big inquiries extending to a considerably large geographical area like an entire country. Under multi-stage sampling the first stage may be to select large primary sampling units such as states, then districts, then towns and finally certain families within towns. If the technique of random-sampling is applied at all stages, the sampling procedure is described as multi-stage random sampling.

***(viii) Sequential sampling:***

*This is somewhat a complex sample design where the ultimate size* of the sample is not fixed in advance but is determined according to mathematical decisions on the basis of information yielded as survey progresses. This design is usually adopted under acceptance sampling plan in the context of statistical quality control. In practice, several of the methods of sampling described above may well be used in the same study in which case it can be called mixed sampling. It may be pointed out here that normally one should resort to random sampling so that bias can be eliminated and sampling error can be estimated. But purposive sampling is considered desirable when the universe happens to be small and a known characteristic of it is to be studied intensively.

Also, there are conditions under which sample designs other than random sampling may be considered better for reasons like convenience and low costs. *The sample design to be used must be decided by the researcher taking into consideration the nature of the inquiry and other related factors.*

**6. Collecting the data:**

There are several ways of collecting the appropriate data which differ considerably in context of money costs, time and other resources at the disposal of the researcher. Primary data can be collected either through experiment or through survey. If the researcher conducts an experiment, he observes some quantitative measurements, or the data, with the help of which he examines the truth contained in his hypothesis. But in the case of a survey, data can be collected by any one or more of the following ways:

1. ***By observation:***

This method implies the collection of information by way of investigator’s own observation, without interviewing the respondents.

The information obtained relates to what is currently happening and is not complicated by either the past behaviour or future intentions or attitudes of respondents.

This method is no doubt an expensive method and the information provided by this method is also very limited. As such this method is not suitable in inquiries where large samples are concerned.

1. ***Through personal interview:***

The investigator follows a rigid procedure and seeks answers to a set of pre-conceived questions through personal interviews. This method of collecting data is usually carried out in a structured way where output depends upon the ability of the interviewer to a large extent.

**(iii) *Through telephone interviews:***

This method of collecting information involves contacting the respondents on telephone itself. This is not a very widely used method but it plays an important role in industrial surveys in developed regions, particularly, when the survey has to be accomplished in a very limited time.

***(iv) By mailing of questionnaires:***

Questionnaires are mailed to the respondents with a request to return after completing the same. It is the most extensively used method in various economic and business surveys. Before applying this method, usually a Pilot Study for testing the questionnaire is conduced which reveals the weaknesses, if any, of the questionnaire. Questionnaire to be used must be prepared very carefully so that it may prove to be effective in collecting the relevant information.

***(v) Through schedules:***

Under this method the enumerators are appointed and given training. They are provided with schedules containing relevant questions. These enumerators go to respondents with these schedules. Data are collected by filling up the schedules by enumerators on the basis of replies given by respondents. Much depends upon the capability of enumerators so far as this method is concerned. Some occasional field checks on the work of the enumerators may ensure sincere work.

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

**7. Execution of the project:**

Execution of the project is a very important step in the research process. If the execution of the project proceeds on correct lines, the data to be collected would be adequate and dependable. The researcher should see that the project is executed in a systematic manner and in time. If the survey is to be conducted by means of structured questionnaires, data can be readily machine-processed. In such a situation, questions as well as the possible answers may be coded. If the data are to be collected through interviewers, arrangements should be made for proper selection and training of the interviewers. The training may be given with the help of instruction manuals which explain clearly the job of the interviewers at each step. Occasional field checks should be made to ensure that the interviewers are doing their assigned job sincerely and efficiently. A careful watch should be kept for unanticipated factors in order to keep the survey as much realistic as possible. This, in other words, means that steps should be taken to ensure that the survey is under statistical control so that the collected information is in accordance with the pre-defined standard of accuracy.

If some of the respondents do not cooperate, some suitable methods should be designed to tackle this problem. One method of dealing with the non-response problem is to make a list of the non-respondents and take a small sub-sample of them, and then with the help of experts vigorous efforts can be made for securing response.

**8. Analysis of data:**

The analysis of data requires a number of closely related operations such as establishment of categories, the application of these categories to raw data through coding, tabulation and then drawing statistical inferences. The unwieldy data should necessarily be condensed into a few manageable groups and tables for further analysis. Thus, researcher should classify the raw data into some purposeful and usable categories.

*Coding operation is usually done at this stage through which the* categories of data are transformed into symbols that may be tabulated and counted.

*Editing is the* procedure that improves the quality of the data for coding.

With coding the stage is ready for tabulation. *Tabulation is a part of the technical procedure wherein the classified data are put in the form of* tables.

Analysis work after tabulation is generally based on the computation of various percentages, coefficients, etc., by applying various well defined statistical formulae. In the process of analysis, relationships or differences supporting or conflicting with original or new hypotheses should be subjected to tests of significance to determine with what validity data can be said to indicate any conclusion(s).

For instance, if there are two samples of weekly wages, each sample being drawn from factories in different parts of the same city, giving two different mean values, then our problem may be whether the two mean values are significantly different or the difference is just a matter of chance. Through the use of statistical tests we can establish whether such a difference is a real one or is the result of random fluctuations. If the difference happens to be real, the inference will be that the two samples come from different universes and if the difference is due to chance, the conclusion would be that the two samples belong to the same universe. Similarly, the technique of analysis of variance can help us in analyzing whether three or more varieties of seeds grown on certain fields yield significantly different results or not. In brief, the researcher can analyse the collected data with the help of various statistical measures.

**9. Hypothesis-testing:**

After analysing the data as stated above, the researcher is in a position to test the hypotheses, if any, he had formulated earlier. Do the facts support the hypotheses or they happen to be contrary? This is the usual question which should be answered while testing hypotheses.

Various tests, such as Chi square test, *t-test, F-test, have been developed by statisticians for the* purpose. The hypotheses may be tested through the use of one or more of such tests, depending upon the nature and object of research inquiry. Hypothesis-testing will result in either accepting the hypothesis or in rejecting it. If the researcher had no hypotheses to start with, generalizations established on the basis of data may be stated as hypotheses to be tested by subsequent researches in times to come.

**10. Generalisations and interpretation:**

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

**11. Preparation of the report or the thesis:**

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

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

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

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

1. ***Introduction:*** *It should contain a clear statement of the objective of the research and* an explanation of the methodology adopted in accomplishing the research. The scope of the study along with various limitations should as well be stated in this part.

**(b) *Summary of findings:*** *After introduction there would appear a statement of findings* and recommendations in non-technical language. If the findings are extensive, they should be summarised.

***(c) Main report:*** *The main body of the report should be presented in logical sequence and* broken-down into readily identifiable sections.

**(d) *Conclusion:*** *Towards the end of the main text, researcher should again put down the* results of his research clearly and precisely. In fact, it is the final summing up.

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

**2**. Report should be written in a concise and objective style in simple language avoiding vague expressions such as ‘it seems,’ ‘there may be’, and the like.

**3**. Charts and illustrations in the main report should be used only if they present the information more clearly and forcibly.

**4**. Calculated ‘confidence limits’ must be mentioned and the various constraints experienced in conducting research operations may as well be stated

**Criteria of Good Research**

Whatever may be the types of research works and studies, one thing that is important is that they all meet on the common ground of scientific method employed by them. One expects scientific research to satisfy the following criteria:

1. The purpose of the research should be clearly defined and common concepts be used.
2. The research procedure used should be described in sufficient detail to permit another researcher to repeat the research for further advancement, keeping the continuity of what has already been attained.
3. The procedural design of the research should be carefully planned to yield results that are as objective as possible.
4. The researcher should report with complete frankness, flaws in procedural design and estimate their effects upon the findings.
5. The analysis of data should be sufficiently adequate to reveal its significance and the methods of analysis used should be appropriate. The validity and reliability of the data should be checked carefully.
6. Conclusions should be confined to those justified by the data of the research and limited to those for which the data provide an adequate basis.
7. Greater confidence in research is warranted if the researcher is experienced, has a good reputation in research and is a person of integrity.

In other words, we can state the qualities of a good research12 as under:

1. **Good research is systematic**: It means that research is structured with specified steps to be taken in a specified sequence in accordance with the well defined set of rules. Systematic characteristic of the research does not rule out creative thinking but it certainly does reject the use of guessing and intuition in arriving at conclusions.

2. **Good research is logical:** This implies that research is guided by the rules of logical reasoning and the logical process of induction and deduction are of great value in carrying out research. Induction is the process of reasoning from a part to the whole whereas deduction is the process of reasoning from some premise to a conclusion which follows from that very premise. In fact, logical reasoning makes research more meaningful in the context of decision making.

3. **Good research is empirical:** It implies that research is related basically to one or more aspects of a real situation and deals with concrete data that provides a basis for external validity to research results.

4. **Good research is replicable:** This characteristic allows research results to be verified by replicating the study and thereby building a sound basis for decisions.

**Problems Encountered by Researchers in India**

***Lack of Scientific Training:***

The research methodology is not systematic. Many researchers undertake research work without having actual knowledge of the research methods. They just look for similar studies and copy the methodologies listed in it. Even the research guides do not have a thorough knowledge of the various methodologies. This scenario warrants the need for some sort of short-term training to be imparted to researchers prior to undertaking research activities.

***Insufficient Interaction:***

There is no proper interaction between researchers and the business establishments, government institutions, etc. This leads to a great deal of data going untapped. Interaction programs should be organized between researchers and other institutions on a regular basis. This will highlight what issues need to be researched, what data is required for conducting research, and how the study will be useful.

***Lack of Confidence:***

Most of the business establishments are of the opinion that, researchers can misuse the data provided by them. As such, they are reluctant to divulge details of their company. This affects the research studies for which that particular data may be of utmost importance. Thus, confidence-building measures should be adopted, which will convince the business units that their data will be put to productive purposes, and will not be misused in any manner by the researcher.

***Lack of Code of Conduct:***

No specific code of conduct exists for the researchers, which leads to inter-departmental and inter-university rivalries.

***Inadequate Assistance:***

Researchers in India have to cope with the non-availability of adequate and timely secretarial assistance, which affects the schedule of their research study.

***High Cost of Publishing:***

Once their research is completed, the researchers have to look for a means to publish it. Publishing in international journals is highly expensive. This discourages most of the researchers from taking up research work.

***Improper Library Management:***

The libraries are not managed systematically. Much of the precious time of the researchers is spent in looking for books, reports, newspapers, etc. rather than searching relevant information from them.

*There is also the problem that many of our libraries are not able to get copies of old and new Acts/Rules, reports and other government publications in time. This problem* is felt more in libraries which are away in places from Delhi and/or the state capitals. Thus, efforts should be made for the regular and speedy supply of all governmental publications to reach our libraries.

*There is also the difficulty of timely availability of published data from various* government and other agencies doing this job in our country. Researcher also faces the problem on account of the fact that the published data vary quite significantly because of differences in coverage by the concerning agencies.

There may, at times, take place *the problem of conceptualization and also problems* relating to the process of data collection and related things.