How to choose a sampling technique and determine sample size for research: A simplified guide for researchers

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How to choose a sampling technique and determine sample size for research: A simplified guide for researchers

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ABSTRACT

An appropriate sampling technique with the exact determination of sample size involves a very vigorous selection process, which is actually vital for any empirical research. It is obvious that these methodological decisions would greatly affect the internal and external validity and the overall generalizability of the study findings. This paper has comprehensively updated the guidelines on sampling methods and sample size calculation, hence giving enough evidence that will be beneficial in assisting researchers to advance the credibility and statistical power of their research work. The differences between probability sampling techniques, including simple random sampling, stratified sampling, and cluster sampling, and non-probability methods, such as convenience sampling, purposive sampling, and snowball sampling, have been fully explained. Probability is the only that can ensure the generalizability, while non-probability sampling is useful in exploratory situations. Another significant process is the determination of an optimal sample size, which, among other things, has to take into account the total population size, effect size, statistical power, confidence level, and margin of error. The paper contributes both theoretical guidance and practical tools that researchers need in choosing appropriate strategies for sampling and validating methodologically appropriate sample size calculations. In sum, such a paper sets the standard for best practice in research methodology that will drive reliability, validity, and empirical rigor across diverse studies.

1. Introduction

The empirical study will be accurate and valid when the proper sample technique will be cautiously selected. Sampling technique involve the selection of a subset from the larger population and are core to research, since through sampling, the nature and generalizability of findings depend on it [1]. The success of any study would depend upon the appropriateness of the sampling method.

The rationale for sampling methodologies is the capability of such procedures to infer characteristics about populations without the unrealistic expectation inherent in evaluating an entire group. This is very important and necessary in cases where complete enumeration becomes impossible for a given population due to such operational issues as time, resources, or access restrictions. A properly chosen sample would capture and enhance the external validity and generalizability of the findings [2].

It is generally divided into two: probability and non-probability sampling [1,3]. Probability sampling includes basic random sampling, stratified sampling, and cluster sampling, where methods of selection depend on the randomization process as a strengthening process to reduce selection bias. These methods boast of sound statistical tenets and are usually adopted when generalization is intended. Non-probability sampling methods include convenience and purposive sampling whenever random selection is not feasible or practical. These may be convenient for practical purposes, but they will rapidly lead to biases in the sample that then will affect the generalization of results [4].

The selection of the sampling method is intrinsically identified with a few specific research goals, some demographic features of the target population, and some methodological limitations of the study. Proper selection of sampling technique bears great relevance to the validity and generalization of the study outcomes. This calls for wide-ranging acquaintance with different sampling procedures and their consequences on the part of the researcher who intends to be methodologically correct.

The article tried to discuss various approaches to sampling in

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research methodology, and determine the most appropriate sample size calculations so that the researcher may choose the best fit for a particular research situation. This paper will attempt to give a close look at the pros and cons of the different procedures of sampling in promoting best practices of research and enhancing empirical validity.

2. Sampling process in research

The sampling process is one of the most important parts of the research methodology, through which accuracy and validity of findings from a study are guaranteed [5]. This process starts with the identification of a target population, which could be a total group of persons or entities relating to the research question. Defining clearly and properly what constitutes a population is highly important to make sure that the sample describes the group under study. Population means the definition that should reflect such an attribute like demographic variables, geographic location, and every other feature which could be relevant for research.

Having defined the population, the next process is the choice of a suitable sampling method. In view of research goals and resources and a need for generalization, researchers have to choose between probability and non-probability sampling methods. The justification for preference, if the objective is to make inferences about the population, normally includes the following probability sampling methods: simple random sampling, stratified sampling, cluster sampling, and systematic sampling. Convenience sampling, purposive sampling, and snowball sampling are some of the methods generally adopted in non-probability methods for exploratory studies or when the population is not accessible.

Once the selection of a sampling plan is effected, the size of this sample has to be determined by the researcher, and this is taken as vital for the reliability of the results. In calculating sample size, several factors may be important: the size of the population, the effect size one expects, the confidence level, and the margin of error. This can be achieved with the help of statistical techniques or tools in order not to have too small a sample that would yield untrustworthy results, or too large in which case resources will be wasted.

Sampling selection refers to the stage where the chosen sampling method will decide who or which units in the population should constitute a study. This could be done through random number generation or systematic selection methods in the case of probability sampling. In non-probability sampling, it could be related to accessible or particular cases that are relevant to the study at hand.

Finally, the researcher must analyze the data obtained from the sample, taking into consideration that no conclusion can be made if the sampling procedure is not considered. In other words, it is to have in mind how biased the sample can be, or where the limitation is and whether generalization to the whole population is feasible. A formal sampling plan will enable the researcher to enhance the validity and reliability of the results and, therefore the accuracy and meaningfulness of his conclusions. Steps of Sampling process are presented in Fig. 1.

3. Sampling techniques

Differentiating between the two, probability sampling and non-probability sampling are mainly two different strategies adopted in research for the selection of participants [6]. Each has its own advantages and disadvantages. Probability sampling assures that every subject from the population carries a known, nonzero possibility of selection. The randomization in this design reduces selection bias and makes the sample representative of the population as a whole. Probability sampling provides the researcher with the chance to make generalizations from the sample to the population and estimate the sampling error with a measure of confidence. Examples of techniques falling under this category include simple random sampling, stratified sampling, and cluster sampling. While probability sampling is accurate, it tends to be

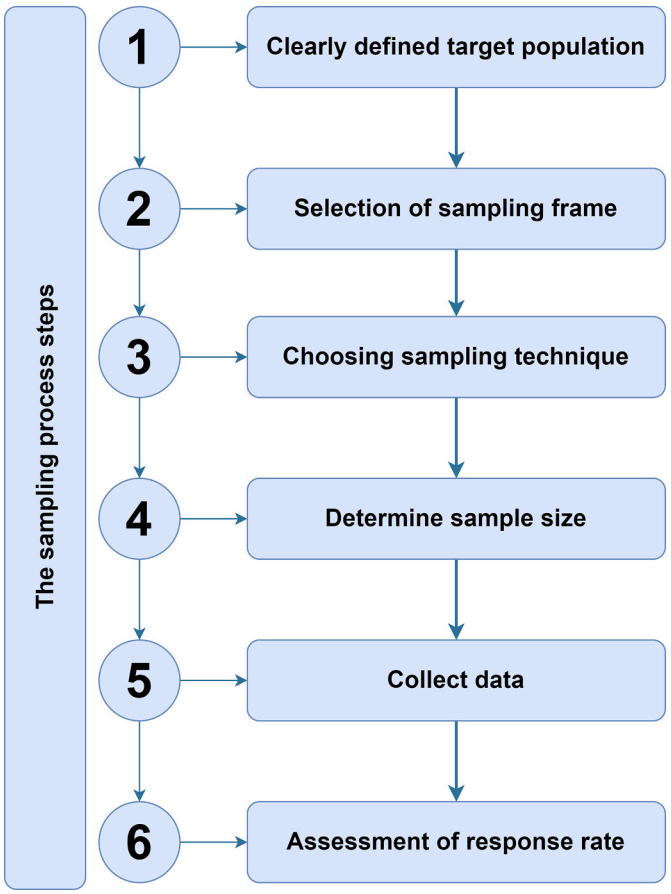

Fig. 1. Sampling process steps.

cumbersome and requires much time and resources, especially when the base of the population being targeted is very large or scattered since it is based on a detailed listing of the population and selections must be done using a complex procedure.

On the contrary, non-probability sampling encompasses no randomization; therefore, not all subjects in the population carry an equal or known probability of selection. This is mainly used when it is not possible for the researchers to reach the entire population or when the resources and time are limited. Some of the non-probability sampling methods include convenience sampling, purposive sampling, and snowball sampling, in which the judgment of the researcher or the availability of participants is depended on. This latter method, while faster, inexpensive, and easier to carry out, has the liability of selection bias-that is, the sample chosen may eventually contain over-representation or underrepresentation of groups. Results from non-probability sampling therefore have limited generalizability to the population-at-large, and statistical inference cannot be carried out as confidently. It is, however, very useful in exploratory research, qualitative studies, and where the intention is to study some of those difficult-to-reach subgroups rather than to represent the whole population.

Where the research situation calls for a high degree of accuracy and generalization of results to the whole population, the preference is for probability sampling. Only in small-scale or exploratory studies can one resort to non-probability sampling when logistical constraints or focus groups turn out to be more important than representativeness. Both techniques have a place in research, but the choice of one or the other depends upon research objectives, resources, and needs regarding statistical reliability. Fig. 2 and Table 1 summarize probability and non-probability sampling techniques in detail, together with a number of advantages and disadvantages associated with each technique. This should be helpful in enabling the researcher to choose the most

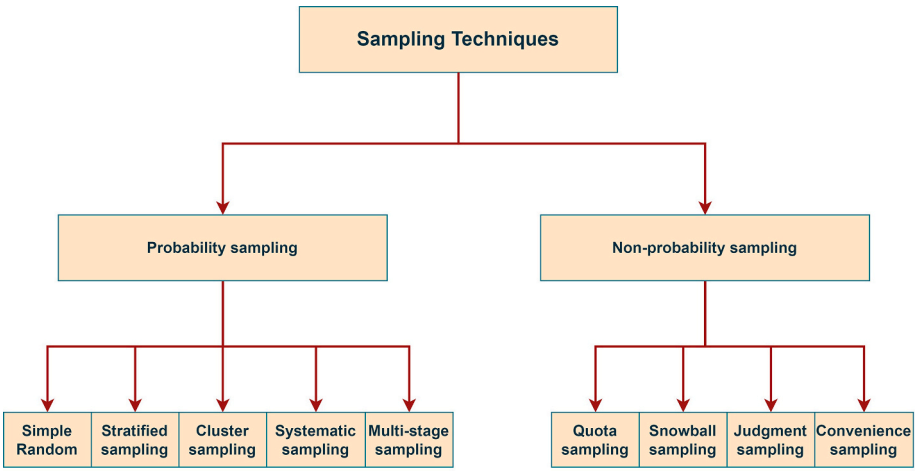

Fig. 2. Sampling techniques in research.

appropriate sampling method for their studies.

3.1. Probability sampling methods

3.1.1. Simple random sampling

The simple random sample, although very basic, is an effective method of ensuring that every single member of the population will have a chance of being selected. Following definition and compilation of a complete list of members constituting the population, the defining of the sample size, then the actual random selection using a random number generator or drawing of lots commences. This is highly valued because it reduces selection bias, although it might be very demanding in logistics, especially when the population is so big or dispersed.

3.1.2. Stratified sampling

In stratified sampling, the population would be divided into distinct groups, commonly known as strata, based on uniform categories such as age, sex, or education. Random samples would then be taken from each stratum to derive a sample representative of the entire range of categories. This will increase the accuracy of the estimates, given that every subgroup is well-represented, thereby making this method more suitable for populations where great variability in key characteristics exists. However, it is difficult to meaningfully form strata if detailed knowledge of the population does not exist.

3.1.3. Cluster sampling

Cluster sampling is a method of simplifying the process of data collection whereby a population is divided into clusters, which may be geographic locations or institutions, and a random selection is taken from these for study. All members in the selected clusters will then be included in the sample. It will be very useful in large-scale studies where compiling a complete list of the population would be highly impractical. Though cluster sampling is inexpensive, it might introduce biases if the selected clusters are not typical of the overall population.

3.1.4. Systematic sampling

In systematic sampling, every K^{th} individual is chosen in a continuous manner from a population list, starting from a random point. It is efficient and quite easy to conduct because it is based on a regular sampling interval. Systematic sampling may be biased, however, if there is an inherent pattern in the population that coincides with the sampling interval.

3.1.5. Multi-stage sampling

In multi-stage sampling, a population is divided into a number of stages or levels. For example, in cluster sampling - a complicated form of multi-stage sampling - populations are divided into large clusters (for instance, regions or institutions), from which further random samples are drawn in successive stages. Once geographic areas are selected, for example, a random sample of individuals within each area could be selected. The stepwise stratification is useful in large-scale studies to systematically reduce the sample size by narrowing down through vast or dispersed populations. While this may save costs and time, there is a risk of increased sampling error at each stage in the selection process, if the sampling at each level is not representative.

3.2. Non-probability sampling methods

3.2.1. Convenience sampling

Of the various methods of data collection, convenience sampling involves drawing samples from that portion of the population which the researcher finds most accessible [2]. This is a fast and cheap method of collecting data when either time or resources are in short supply. However, in most instances, this method introduces bias, since the sample may not be representative and thus generalization of the findings to the rest of the population will not be possible.

3.2.2. Purposive sampling

In purposive sampling, also known as judgmental or expert sampling, the participants are selected based on the judgment of the researcher who decides who will be most useful for the data required [2]. This is normally used in research requiring certain people with some specific characteristics or expertise. Though the method can result in very profound insights, it carries a very high risk of bias on the part of the researcher and may not represent the whole population.

3.2.3. Snowball sampling

Snowball sampling is utilized when one is studying hidden or hard-to-reach populations. In this case, participants are required to refer those that also fit the criteria for study participants, making a network of referrals. This technique is useful in exploratory research. However, it has been criticized to lead to biased samples because samples get homogeneous over time due to social networks.

3.2.4. Quota sampling

Quota sampling refers to the process whereby the population is divided into mutually exclusive subgroups from which participants are selected, ensuring that certain quotas within each subgroup are filled. Quotas ensure that certain characteristics of the population exist within the sample; however, the actual selection within the subgroup remains non-random, hence biased and a less representative sample.

Table 1
Pros and Cons of Probability and Non-Probability Sampling techniques.

Sampling techniques	Pros	Cons
Simple Random Sampling	1 It makes the process fair for every person to have an equal opportunity to be selected without any bias. 2 It is easy to perform statistical tests on because of its random nature. 3 Selection bias would be less likely to occur, with more reliable and generalizable findings.	1 It requires a full and accurate count of the population, which sometimes is hard to obtain, especially in large or mixed populations. 2 It can become resource-intensive and time-consuming, especially in the case of large populations. 3 Unless the sample size is sufficiently large, randomness will not capture rare subgroups.
Systematic Sampling	1 The method is easier to apply than simple random sampling in large populations. 2 The selection is done in an orderly manner, which helps the organization. 3 Generally, more effective than simple random sampling in terms of time and resources.	1 May bring bias if the periodic pattern in the population list coincides with the interval used for sampling, resulting in over- or under-representation of particular characteristics. 2 Less random than simple random sampling, thus it can reduce the diversity of the sample.
Stratified Sampling	1 Ensuring representation of key subgroups, or strata, leads to more precise and relevant estimates. 2 It ensures statistical efficiency is increased and variability within strata reduced, hence increasing its reliability. 3 Could enhance comparability between different strata to allow focused insight.	1 In the formation of strata, there is a need for detailed knowledge of population characteristics, which may not be available. 2 More complex to carry out and interpret than straightforward methods, and demands more advance thinking
Cluster Sampling	1 Inexpensive and effective for the geographically dispersed population to reduce costs associated with traveling. 2 Saves resources and time to collect data; hence, making big studies viable. 3 Useful in cases where the complete list of the population is not available and when only cluster information is needed.	1 Clusters may not be homogenous, and this could increase the variability of the clusters and distort the results. 2 Analysis can be difficult where clusters are poorly defined or differ significantly.
Convenience Sampling	1 Data collection is fast and cheap; hence, one can get results in a very short period. 2 Useful in preliminary studies or as a pilot test when time/resources are scant. 3 Relatively easy to conduct, especially in familiar settings such as hospitals or community centers.	1 There is a high risk of selection bias, which will mean the results cannot be generalized across the whole population because of poor external validity. 2 It may reflect only the experiences or views of a particular group and hence give biased results.
Purposive Sampling	1 One can study issues and populations particularly relevant to the research question in greater depth. 2 Appropriate for qualitative research, especially in cases when certain information about experiences or expertise is needed. 3 It allows data collection focusing on specific people with rare knowledge or experiences.	1 They may be subject to the biases of the researcher himself; this is because the samples may not represent the overall population highly, which can develop an over-inclination of the particular point of view. 2 The finding is hard to generalize due to limitation on application to the wider population.
Snowball Sampling	1 The study design is especially useful for reaching those hidden or hard-to-reach populations, such as marginalized groups. 2 The trust in populations is the other elementary outcome; it will lead to participation rates by increasing a person's willingness to share experiences. 3 It is ideal to carry out exploratory research when one has little knowledge about the population under study.	1 A homogenous sample may result, whereby diversity will be reduced; hence, results will not be biased. 2 Initial participants' networks are unrepresentative of wider populations.
Quota Sampling	1 Assures that specific subgroups are present in the sample, which is a prime requisite in research concerned with such groups. 2 It is helpful in conducting market research and opinion polls by grasping several opinions simultaneously. 3 Can be implemented relatively fast, thus allowing for timely data collection.	1 Selection is not random; therefore, the selection may introduce bias because participants would be selected in an 'available' basis rather than randomly, which will create biased outcomes. 2 This impinges on the general applicability of the study itself because it cannot generalize such findings to the larger population. 3 If the quotas are not well-set, then the selection process might get arbitrary, which could compromise data quality.

4. Sample size determination in research

The sample size determination is vital in research for valid and reliable results [7,8]. In the estimation of population means or proportions, applying the correct formula ensures that the sample taken represents the population and minimizes error [9].

4.1. Formula for estimating population proportions

Among all formulas used in research, perhaps the most common is for estimating a population proportion [10]. A commonly used formula is:

$$n = \frac{Z^2.p.(1-p)}{E^2}$$

Where.

- **n** = required sample size,
- **Z** = z-value associated with the desired confidence level (e.g., 1.96 for 95 % confidence),
- **p** = estimated population proportion (use **p = 0.5** if unknown to maximize variability),
- **E** = margin of error or desired precision.

This formula is applied when a researcher is interested in the proportion of a population with a particular attribute, such as the percentage of smokers or voters. A larger sample size reduces the margin of error E and hence provides an estimate closer to actuality.

4.2. Formula for estimating population means

The formula for sample size in studies designed to estimate a population mean, such as average income or height, is given by:

$$n = \frac{Z^2 \times \sigma^2}{E^2}$$

Where.

- **n** = required sample size,
- **Z** = z-value corresponding to the confidence level (e.g., 1.96 for 95 % confidence),
- **σ** = estimated population standard deviation,
- **E** = margin of error or allowable difference between the sample mean and the population mean.

This is an important formula when one is working with continuous variables. The greater the dispersion in the population, σ, the larger the sample that will be needed in order to have an accurate estimate. Similarly, the smaller the margin of error, or the higher confidence level, the greater the sample size needed.

4.3. Cochran's sample size formula

Cochran's formula is normally used when the population is large or infinite and applies to both proportions and means [11]. The general formula for the calculation:

$$n_0 = \frac{Z^2.p.(1-p)}{E^2}$$

Where.

- $\mathbf{n_0}$ = initial sample size for large populations (before any adjustments for finite populations),
- **Z** = z-value (e.g., 1.96 for 95 % confidence),
- **p** = estimated population proportion (use 0.5 if unknown),
- **E** = margin of error.

Cochran's formula is widely applied when a survey or a cross-sectional study is used, in which the researcher expects the population to be large.

If the size of the population is small-that is, finite-the sample size has to be adjusted by the finite population correction. This is done in the following manner:

$$n_{adj} = \frac{n_0}{1 + \frac{n_0 - 1}{N}}$$

Where.

- $\mathbf{n}_{adj}$ = adjusted sample size,
- $\mathbf{n_0}$ = initial sample size from Cochran's formula or the other formulas,
- **N** = total population size.

This will adjust the sample size, especially when the population is small, to retain precision of results without over-sampling.

4.4. Formula for stratified sampling

Stratified sampling is used when a population can be divided into distinct subgroups, or strata, such as age group, gender, or level of education. The sample size for each stratum can be determined by the use of proportional allocation:

$$n_h = \frac{N_h}{N} \times n$$

Where.

- $\mathbf{n_h}$ = sample size for stratum h,
- $\mathbf{N_h}$ = population size for stratum h,
- **N** = total population size,
- **n** = overall sample size.

This would ensure that the sample is representative of all subgroups in the population of interest. Stratified random sampling is useful in a situation where the subgroups are very different from one another.

4.5. Yamane's formula

Yamane's formula, 1967, is one of the common methods in survey research used to estimate an appropriate sample size for any given population with concern for precision and practicality [12]. This formula approximates the sample size based on the total size of a population and desired margin of error. For using this method, 95 % confidence levels are considered; although it can be modified using other confidence levels.

The formula for Yamane's sample size calculation is:

$$n = \frac{N}{1 + N\,(e^2)}$$

Where.

- n = sample size
- N = population size
- e = margin of error

4.6. The role of tables in sample size determination

One common means of easing the computational burden in determining sample size is through the use of precalculated tables. These tables generally provide sample size estimates for precalculated values of the margin of error, E; confidence level, Z; and estimated proportion, p. Such tables provide quick reference points for researchers who may want to estimate a required sample size for a certain accuracy without necessarily having to compute complicated formulae (Tables 2 and 3).

4.7. Factors affecting sample size

The sample size of any study is determined by a number of factors. First, there is the size of the population from which the sample is to be drawn; larger populations may require a different approach than smaller ones. Second, the desired confidence level significantly influences sample size; the higher the confidence level-95 percent compared to 90 percent, for example-the larger the sample size must be. Other important considerations include margin of error-smaller margins are associated with larger sample sizes to ensure findings indicative of true parameters in a population. The variability within the population might also affect sample size; the larger the variability, the more participants, generally speaking, one will have to capture the range in. It is equally important to look at the effect size and statistical power: with smaller effect sizes and high levels of power, larger samples are needed to detect meaningful differences. Any study design-cross-sectional, longitudinal, or experimental-will further stipulate sample size requirements. Lastly, the expected attrition rate-for example, the number of dropouts or non-responses-may be the reason for an adjustment of the initial sample size to ensure a sufficient number of participants complete the study. The said factors, if considered with due deliberation, will lead a researcher to such a sample size that is sufficient not only to support the

Table 2
Required sample sizes for various population sizes at 95 % confidence level with different margins of error (5 %, 3 %, and 1 %).

- Variance of the population P = 50 %
- Confidence Level = 95 %

Popultion size	Required sample size (Margin of Error = 5 %)	Required sample size (Margin of Error = 3 %)	Required sample size (Margin of Error = 1 %)
50	44	48	50
75	63	70	74
100	79	91	99
150	108	132	148
200	132	168	196
250	151	203	244
300	168	234	291
400	196	291	384
500	217	340	475
600	234	384	565
700	246	423	652
800	260	457	738
1000	278	516	906
1500	306	624	1297
2000	322	696	1655
3000	341	787	2286
5000	357	879	3288
10,000	370	964	4899
25,000	378	1023	6939
50,000	381	1045	8057
100,000	383	1056	8762
250,000	384	1063	9249
500,000	384	1065	9423
1,000,000	384	1066	9513

Source (Gill et al., 2010) [13].

Table 3
Required sample sizes for various population sizes at 99 % confidence level with different margins of error (5 %, 3 %, and 1 %).

- Variance of the population P = 50 %
- Confidence Level = 99 %

Population size	Required sample size (Margin of Error = 5 %)	Required sample size (Margin of Error = 3 %)	Required sample size (Margin of Error = 1 %)
50	46	49	50
75	67	72	75
100	87	95	99
150	122	139	149
200	154	180	198
250	181	220	246
300	206	258	295
400	249	328	391
500	285	393	485
600	314	452	579
700	340	507	672
800	362	557	763
1000	398	647	943
1500	459	825	1375
2000	497	957	1784
3000	541	1138	2539
5000	583	1142	3838
10,000	620	1550	6228
25,000	643	1709	9944
50,000	652	1770	12,413
100,000	656	1802	14,172
250,000	659	1821	15,489
500,000	660	1828	15,984
1,000,000	660	1831	16,244

Source (Gill et al., 2010) [13].

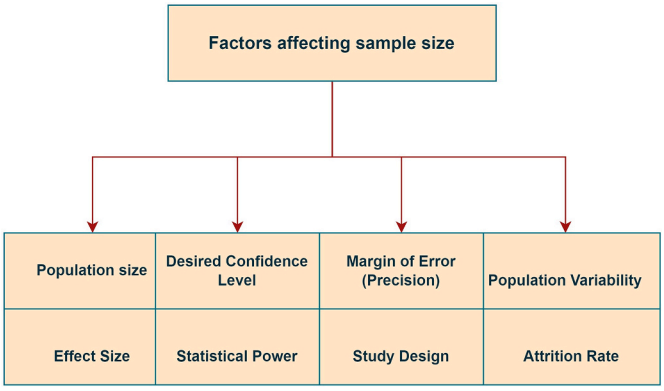

Fig. 3. Factors affecting sample size.

objectives of the study but also produce results which are statistically significant. The factors affecting sample size are illustrated in Fig. 3.

5. Conclusion

The precision of methodology in research depends on the selection of proper sampling techniques and calculation of an adequately powered sample size. Probability sampling, for example, stratified and cluster sampling, is thus fundamental in those studies that tend to make statistically significant inferences about the wider population. By contrast, non-probability sampling methods offer pragmatic ways when one conducts exploratory research or where full population access cannot be made. Precise calculation of sample size is a very important step in any research project. This factor has a great bearing on the statistical power and the precision of conclusions that may be drawn from any study. Undersized samples cannot yield conclusive results, whereas samples that are too big are wasteful because they will add nothing to the validity of the study. Confidence level, margin of error, and size of effects remain some of the key determinants that help researchers ensure their research designs facilitate strong findings. In that respect, the methodological guidelines include ways a researcher can contribute to the advance of scientific knowledge by setting up works that other researchers will refer to as foundational many years to come. This guide hopefully sets a benchmark with regard to research methodology and thus serves as a reference point for scholars committed to the production of work of the highest empirical and theoretical standards, with an ultimate aim of globally increasing the impact and citation potential of the research.

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Data availability

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CRediT authorship contribution statement

Sirwan Khalid Ahmed: Conceptualization, Data curation, Supervision, Writing – original draft.

Declaration of competing interest

The authors declare that they have no known competing financial

interests or personal relationships that could have appeared to influence the work reported in this paper.

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