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Determining an Applicable Sample Size in Research Studies

DR. LOK RAJ SHARMA | TEKNATH BHATTARAI

*Author affiliations can be found in the back matter of this article

CORRESPONDING AUTHOR
Dr. Lok Raj Sharma
Makawanpur Multiple Campus, Hetauda
lokraj043i@gmail.com

KEYWORDS

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ABSTRACT

Determining a proper sample size is a critical aspect of research design as it influences the reliability and validity of study findings. The key objective of writing this article is to suggest some rudimentary formulae, easy software tools and a general sample size table to determine an applicable sample size to be used in research studies. To attain this objective, relevant books and journal articles have been taken as the sources of secondary data. After a comprehensive overview of the literature regarding the sample size, this article concludes that the confidence level, the margin of error, the population size, and the population proportion statistically determine the sample size in quantitative research studies. Similarly, the nature of population, and types of research studies are the vital factors that confer us the basic idea about the sample size before computing the ideal or required sample size that homogeneous population and qualitative research studies generally require a smaller sample size, whereas heterogeneous population and quantitative research studies necessitate a larger sample size. Researchers, practitioners, and students will find this article valuable in guiding their decisions on sample size determination for robust and meaningful research outcomes.

1. INTRODUCTION

The determination of an appropriate sample size is a pivotal component in the design (Rao, 2012; Kaur, 2017) and execution of research studies as it significantly influences the credibility and generalizability regarding the findings of research studies. An exact sample size is an important part of research design (Charan & Biswas, 2013).

As researchers strive to produce robust and meaningful outcomes, the consideration of sample size becomes a critical methodological decision that necessitates a thorough understanding of various factors and methodologies. When conducting research, one of the fundamental considerations is determining the appropriate sample size. This is crucial as it directly impacts the statistical power of the study. Researchers often face challenges in determining the optimal sample size due to various factors such as effect size and desired level of confidence. The smaller the sample size, the less the power of the study (Saxena, Yadav, & Kantharia, 2011; Button et al., 2013). Numerous articles in the existing literature detail methods for calculating sample size, yet a considerable confusion persists (Naduvilath, John, & Dandona, 2000; Shah, 2011; Patra, 2012).

This article provides a comprehensive overview of the sample size calculation formulae, software calculators, sample size tables and considerations involved in determining the appropriate sample size for research studies. It further deals with the sample size required in qualitative and quantitative research studies. It reveals that the sample should be determined by focusing on the nature of population. There are primarily two sorts of population: homogenous and heterogeneous. Furthermore, precision-based calculations, often guided by confidence intervals, play a crucial role in determining the width of estimation and the reliability of the study results (Portney & Watkins, 2009).

Several studies exhibit shortcomings in selecting a suitable sample size. Recognizing this, it becomes crucial to provide readers with comprehensive information from a single source regarding the determination of sample sizes. This paper aims to offer an overview of commonly employed formulae and software sample size calculators for calculating the sample sizes. Additionally, it delves into various methods for determining sample sizes.

2. LITERATURE REVIEW

Sample size primarily depends on the confidence level, the margin of error, the population size, and the population proportion. Literature review has been limited to these aspects.

2.1 SAMPLE AND SAMPLE SIZE

Sample is a collection of representative items or elements from the population. It is a representative subset of a population (Sharma, 2023). It is a small proportion of the population that is selected for observation and analysis (Best & Kahn, 2010). If a census is not needed, or not practical to carry out, a sample is the most appropriate (Kolb, 2011). It is a subset of a larger population (Zikmund et al., 2016). It is a subgroup of the target population that the researcher plans to study for the purpose of generalizing about the target population (Creswell, 2012). It involves people or units that a researcher includes in the study (Wrench et al., 2009). Sample size refers to the number or number of items which is to be selected from the population. Samples should be as large as a researcher can obtain with a reasonable expenditure of time and energy (Fraenkel & Wallen, 1990).

It is the number of individual subjects or observations included in a research study, representing a subset of the larger population, and is crucial for the reliability and generalizability of study findings. The sample size depends on five parameters like the effect of size, variability statistical power, significance criteria and type of statistical test (Singh & Masuku, 2014). The sample size should be determined through statistical analysis (Quinn& Keough, 2002; Wilson & Morgan, 2007; Van- Belle, 2008). It should also be based on the acceptable *P* value for statistical significance (Torwane et al., 2021). Sample size greatly influences statistical precision, determining how closely a calculated value approximates the true population value (Cohen, 1988). This precision is typically estimated by the standard error in two ways: descriptively and inferentially (Thompson, 2006).

2.2 CONFIDENCE LEVEL

A confidence level is a statistical measure that represents the degree of certainty or probability that a calculated interval, such as a confidence interval, contains the true population parameter. It is the level of confidence that the results found within a study are generalizable to the population and not due to the chance (Wrench et al., 2009). It is the range of values for some estimate that accounts for a specific percentage of possibility (Zikmund et al., 2016).

2.3 MARGIN OF ERROR

The margin of error is a statistical measure indicating the range within which the true population parameter is likely to lie, typically expressed as a confidence interval, based on the variability observed in a sample. It is the degree of error in results received from random sampling surveys. The margin of error is a range of values above and below the actual results from a survey. For example, a 70% "yes" response with a margin of error of 5% means that between 65% and 75% of the general population think that the answer is "yes." It is computed by using the following formula:

Margin of Error = $\frac{z \times \sigma}{\sqrt{n}}$, where z= z-score value, n= sample size, and σ is population standard deviation.

2.4 POPULATION SIZE

In research, a population refers to the entire group of individuals, items, or events that meet specific criteria and are the subject of study, from which a sample is drawn to generalize or draw conclusions. Population or universe is the entire collection of all items, elements, persons, or units of the interest for the research. It is an entire set of objects, observations, or scores that have some characteristic in common (Wrench et al., 2009). The population is the entire group of interest in a study, while the sample is a subset of this group (Brown, 2006). It is any group of individuals that has one or more characteristics in common and that are of interest to the researcher (Best & Kahn, 2010). It refers to any complete group of entities that share some common set of characteristics (Zikmund et al., 2016). Choosing the population depends mostly on the researcher's interests on the basis of information about cases that are relevant to the study (Henry, 2009). The population size refers to the total number of individuals, things, organisms, or inhabitants under study at a given point in time.

2.5 POPULATION PROPORTION

A population proportion is *a fraction of the population that has a certain characteristic*. It is *a number representing a part of a population* and is therefore an example of a population parameter. It is determined by counting the whole population and then figuring out exactly how many in the population have a particular condition. Then the number with the condition is divided by the total population to arrive at the population proportion. The population proportion formula is:

$p = x/n$, where the x is the number of individuals in the group with a given characteristic and n is the total population size.

Other terms related to the sample size are sampling, sampling unit, sampling frame, and sampling error.

2.6 SAMPLING

Sampling is the procedure of picking out a subset of elements from a larger population to sort inferences or draw decisions about the complete population. It is a deliberate method of selecting subjects for observation (Best & Kahn, 2010). It is the method of electing people or units for inclusion in a research study (Wrench et al., 2009). It involves any procedure that draws conclusions based on measurements of a portion of the population (Zikmund et al., 2016). It is related with the selection of a subset of individuals from within a population to estimate the characteristics of whole population (Singh & Masuku, 2014). The two main advantages of sampling are the faster data collection and lower cost. (Kish, 1965; Robert, 2004). Oversampling can add costs to the survey but is often necessary (Fink, 1995). Sampling is typically done with a set of clear objectives in mind (Shafer & Zhang, 2012).

2.7 SAMPLING UNIT

A sampling unit is the individual element or entity chosen during the sampling process to represent and gather information about the larger population. It is each item from a sample. It is the unit that represents every character of population. It is a single or groups of elements subject to the selection in the sample (Zikmund et al., 2016).

2.8 SAMPLING FRAME

A sampling frame is a list or representation of all the elements in a population from which a sample is drawn, providing a basis for the sampling process. It refers to all members of the population accessible to the researcher (Wrench et al., 2009). Similarly, it is a list of elements from which a sample may be drawn (Zikmund et al., 2016). A sampling frame contains the names of all items of the population or universe. It is the list of elements from which the sample is drawn (Kumar, 2011). It is a complete listing of all the elements that make up a research population (Ruane, 2005).

2.9 SAMPLING ERROR

Sampling error is the discrepancy between a sample statistic and the true population parameter due to the inherent variability introduced by the process of selecting a subset rather than surveying the entire population. It is a statistical error that occurs when a researcher does not select a sample that represents the entire population. It is the difference between the sample estimate and the true population score (Cresswell, 2019). It is calculated using the formula:

$SE = S/\sqrt{n}$, where S is the standard deviation and n is the number of observations.

2.10 SAMPLE SIZE IN QUALITATIVE AND QUANTITATIVE RESEARCH STUDIES

In qualitative research, the focus is on depth rather than breadth, which often leads to smaller sample sizes. The primary aim is to gain a deep understanding of a phenomenon, behavior, or experience from the perspectives of the participants. Hence, qualitative researchers typically use non-probability sampling techniques, such as purposive or theoretical sampling, to select participants who are most likely to provide rich and relevant data (Creswell & Poth, 2018).

The adequacy of a sample in qualitative research is often judged by the concept of data saturation, which occurs when additional data no longer contribute new insights to the study. Guest, Bunce, and Johnson (2006) suggest that saturation often occurs within the first 12 interviews, although this number can vary depending on the complexity of the research question and the heterogeneity of the population. It is also noted that the variability in qualitative sample sizes reflects the flexibility inherent in qualitative research, allowing for adjustments as the study progresses (Mason, 2010).

Quantitative research, in contrast, typically requires larger sample sizes to ensure statistical power and the generalizability of the findings. Probability sampling methods, such as simple random sampling or stratified sampling, are often employed to select a representative sample from the population (Bryman, 2016). The determination of sample size in quantitative studies is influenced by several factors, including the desired level of confidence, the margin of error, the population size, and the expected effect size (Cochran, 1977).

Power analysis is a commonly used method for determining sample size in quantitative research. It involves calculating the minimum sample size required to detect an effect of a given size with a specified level of confidence and power (Cohen, 1992). A general guideline suggests that larger sample sizes are needed for studies aiming to detect smaller effects, as well as for those involving complex analyses, such as multiple regression or structural equation modeling (Field, 2018).

While qualitative research values the richness and context-specific nature of data, quantitative research emphasizes statistical representativeness and precision. Therefore, the sample size considerations differ fundamentally between the two approaches. In qualitative research, the guiding principle is the depth of information, while in quantitative research, it is the breadth and the ability to generalize findings to a broader population (Patton, 2015).

One of the real advantages of quantitative methods is their ability to use smaller groups of people as a sample to make inferences about larger groups that would be prohibitively expensive to study. Selecting the sample size for a study requires compromise between balancing the need for statistical power, economy and timeliness (Ahmad & Halim, 2017).

2.11 SAMPLE SIZE WITH HOMOGENOUS AND HETEROGENEOUS POPULATION

In homogeneous populations, where members share similar characteristics or traits, smaller sample sizes are generally sufficient. This is because there is less variability within the population, and thus, a smaller sample can adequately represent the population. For instance, a study focusing on a specific age group with similar socio-economic backgrounds may require fewer participants to capture the essential characteristics accurately (Krejcie & Morgan, 1970). According to Roscoe (1975), in homogeneous populations, a sample size of 10% of the population is often considered sufficient.

Conversely, heterogeneous populations contain diverse members with varying characteristics. In such cases, a larger sample size is required to ensure that all subgroups within the population are adequately represented (Cochran, 1977). This helps capture the full range of variability within the population, reducing the risk of sampling bias. For example, studies involving diverse populations such as multi-ethnic groups, or those spanning different socio-economic statuses, need larger samples to accurately reflect the population's diversity (Israel, 1992).

2.12 DETERMINING THE IDEAL SAMPLE SIZE

Sample size determination is an important and often difficult step in planning an empirical study (Dattalo, 2008). Both a higher population and a higher desired level of confidence normally require a larger sample, however a smaller margin of error necessitates a larger sample size. Similarly, a smaller sample size may be sufficient for the homogeneous population, whereas a larger sample size is usually required if the population is heterogeneous
In quantitative research, the sample size is typically determined using statistical calculations to ensure that the findings are representative of the larger population. The goal is often to generalize the results to a broader population. Time, budget, and accessibility of participants can limit the achievable sample size. The sample sizes increase with the increase in the population variability, degree of confidence and the precision level required of the estimate (Malhotra, 2010). Sudman (1976) suggested that a minimum of 100 elements were required for each major group or subgroup in the sample and for each minor subgroup, a sample of 20 to 50 elements was necessary. According to Kish (1965), 30 to 200 elements are sufficient when the attribute is present 20 to 80 percent of the time if the distribution approaches normality. A small sample yields inaccurate findings, conversely a large sample is an unnecessary mobilization of extra resources. Therefore, determining optimum sample size is a crucial exercise in research studies.

2.13 SAMPLE SIZE FOR FINITE/KNOWN POPULATION

The sample size formulae are determined by considering a population proportion set at 50% (.5). Three formulas for determining the sample size from the finite or known population have been mentioned in this article:

1. First Formula

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

Where,
n = Ideal sample size
N= Population size
e = Margin of error
Confidence level = 95%
(Source: Yamane, 1967, p.886)
Suppose the population is 100, the margin of error is .05, and the confidence level is 95%. Determine the ideal sample size.

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

$$n = \frac{100}{1+100\times(.05)^2} = = \frac{100}{1+0.25} = \frac{100}{1.25} = 80.$$

If we decrease the margin of error, the sample size will increase. If we take 2%

(.02) and 1% (.01) margins of error, the sample sizes will be 96 and 99 respectively.
The alpha level used in determining sample size in most management or educational research studies is either .05 or .01 (Ary, Jacobs, & Razavieh, 1996). The general rule relative to acceptable margins of error in educational, management and social research is as follows: for categorical data, the acceptable margin of error is 5% and, for continuous data, 3% margin of error is acceptable (Krejcie & Morgan, 1970).

2. Second Formula

$$n = N \times \frac{\frac{Z^2 \times p\,(1-p)}{e^2}}{\left[N-1+\frac{Z^2 \times p\,(1-p)}{e^2}\right]}$$

Where,
N= Population size
N= Ideal sample size
p = Sample proportion = .5
e = Margin of error
z = Critical value of normal distribution at the required confidence level
By simplifying the formula, we get:

$$n = N \times \frac{Z^2 \times 0.25}{e^2\,(N-1) + z^2 \times 0.25}$$

Suppose the population is 100, the margin of error is .05, and the confidence level is 95%.

Krejcie and Maoran (1970) recommended that the researcher use .50 as the level of precision as an estimate of the population proportion.
Determine the ideal sample size.

$$n = N \times \frac{Z^2 \times 0.25}{e^2\,(N-1)+z^2 \times 0.25} = 100 \times \frac{(1.96)^2 \times 0.25}{(.05)^2\,(100-1)+(1.96)^2 \times 0.25}$$

$$= \frac{96.04}{0.2475+0.9604} = \frac{96.04}{1.2079} = 79.5 = 80$$

Desired Confidence Level	Sided	Z-Score
90%	One-sided	1.282
	Two-sided	1.645
95%	One-sided	1.645
	Two-sided	1.960
99%	One-sided	2.326
	Two-sided	2.576

A Z-score, also known as a standard score, is a statistical measure that quantifies the relationship of a particular data point to the mean of a group of data points. It is expressed in terms of standard deviations from the mean. Generally, we use two-sided Z-score value in the research studies. The formula for calculating the Z-score of a data point (X) in a dataset with mean (μ) and standard deviation (σ) is given by:

$$Z = \frac{X - \mu}{\sigma}$$

Where,
Z= Z-score
X = Individual data point
μ = Mean of the dataset,
σ = Standard deviation of the dataset
A Z-score can be positive or negative. A positive Z-score indicates that the data point is above the mean, while a negative Z-score suggests that the data point is below the mean.

The sample size increases as we increase the confidence level. Suppose we take 5% (.05) margin of error and 99% confidence level with two sides. The sample size will be:

$$n = N \times \frac{Z^2 \times 0.25}{e^2\,(N-1)+z^2 \times 0.25} = 100 \times \frac{(2.576)^2 \times 0.25}{(.05)^2\,(100-1)+(2.576)^2 \times 0.25} = \frac{165.8944}{0.2475+1.658944} = \frac{165.8944}{1.906444} = 87$$

Similarly, if we increase the confidence level and decrease the margin of error, the sample further increases. Let's take 99% confidence level and 1% margin of error.

$$n = N \times \frac{Z^2 \times 0.25}{e^2\,(N-1)+z^2 \times 0.25} = 100 \times \frac{(2.576)^2 \times 0.25}{(.01)^2\,(100-1)+(2.576)^2 \times 0.25} = \frac{165.8944}{0.0099+1.658944} = \frac{165.8944}{1.668844} = 99$$

3. Formula Three: Cochran's Modified Formula

$$n = \frac{n_0}{1+\frac{n_0-1}{N}}$$

Where,
n= Required sample Size
N= Population Size
n0 = Cochran's sample size recommendation= 385

Suppose the population is 100. Determine the ideal sample size.

$$n = \frac{n_0}{1+\frac{n_0-1}{N}} = \frac{385}{1+\frac{385-1}{100}} = \frac{385}{1+\frac{384}{100}} = \frac{385}{1+3.84} = \frac{385}{4.84} = 79.5 = 80$$

2.14 SAMPLE SIZE FOR INFINITE OR UNKNOWN POPULATION

In Cochran's formula, the alpha level is incorporated into the formula by utilizing the t-value for the alpha level selected (e.g., t-value for alpha level of .05 is 1.96 for the sample size of above 120).

Cochran Formula

$$n = \frac{Z^2 pq}{e^2}$$

Where,
n= Ideal sample size
p = Sample proportion = .5
q = 1-p= 1-.5= .5
e = Margin of error = .05
z = Critical value of normal distribution at the required confidence level = 1.96

$$n = \frac{Z^2 pq}{e^2} = \frac{(1.96)^2 \times .5 \times .5}{(.05)^2} = \frac{0.9604}{0.0025} = 384.16 = 385$$

(Source: Cochran, 1977)

2.15 USE OF SAMPLE SIZE TABLES

The sample size table can be observed to determine the sample size. The table shows that the sample size to be applied in research studies depends the confidence level and the margin of error. Sample sizes are based on the population proportion with the value of 50% (.5). It is generally assumed to be good if a researcher retains a high confidence level and a low margin of error.

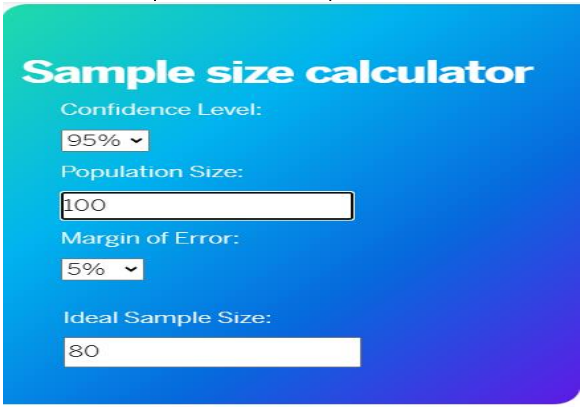
Table 1: *Sample Size with the Finite Population*

Required Sample Size								
	Confidence = 95%				Confidence = 99%			
Population Size	Margin of Error				Margin of Error			
	5%	3.5%	2.5%	1%	5%	3.5%	2.5%	1%
10	10	10	10	10	10	10	10	10
20	19	20	20	20	19	20	20	20
30	28	29	29	30	29	29	30	30
50	44	47	48	50	47	48	49	50
75	63	69	72	74	67	71	73	75
100	80	89	94	99	87	93	96	99
150	108	126	137	148	122	135	142	149
200	132	160	177	196	154	174	186	198
250	152	190	215	244	182	211	229	246
300	169	217	251	291	207	246	270	295
400	196	265	318	384	250	309	348	391
500	217	306	377	475	285	365	421	485
600	234	340	432	565	315	416	490	579
700	248	370	481	653	341	462	554	672
800	260	396	526	739	363	503	615	763

One of the demerits of such sample size tables is that they may not include all the population sizes. For example, using this table, we can't determine the sample size if the population size is not mentioned in the table for instance, the population of 534. In this case, it is better to use the formulae given above.

2.16 USE OF THE SOFT WARES FOR DETERMINING THE SAMPLE SIZE

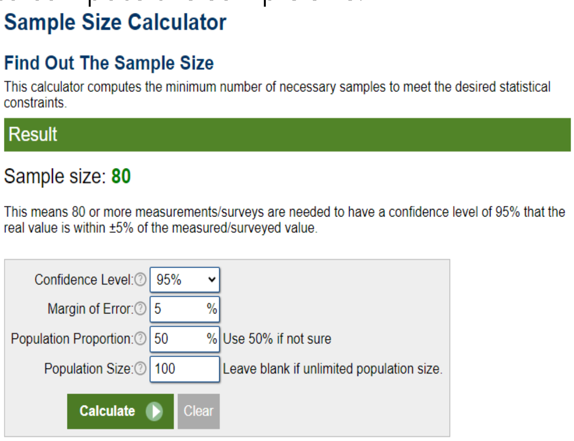
The sample size can be computed by exploiting diverse software calculators. The first software calculator uses a confidence level, a margin of error, and a population size to compute the sample size.



(Link:https://www.qualtrics.com/blog/calculating-sample-size/)

The ideal sample size is required to be 80 if the confidence level is 95%, the population size is 100, and the margin of error is 5%.

The second software calculator uses a confidence level, a margin of error, a population size and a population proportion to compute the sample size.



(Link: https://www.calculator.net/sample-size-calculator.html)

3. MATERIALS AND METHOD

In this study, qualitative data in the form of words were gathered through observational methods and descriptive analysis. Additionally, data collection involved extracting relevant information from books and journal articles, forming a foundational basis for the research. The research methodology also included a meticulous review of literature to determine key parameters such as sample size, population, margin of error, confidence level, and population proportion, utilizing four common sample size calculating formulae, two software calculators, and reference to a sample size table for comprehensive methodological planning.

3.1 ETHICAL CONSIDERATIONS

As this study involved a review of existing literature, ethical approval was not required. However, proper citation and acknowledgments were ensured to respect the intellectual property of the original authors.

3.2 VIEWS ON THE DETERMINATION OF SAMPLE SIZE: LEADING REMARKS

Determining a suitable sample size is a critical aspect of research design, as it ensures the reliability, validity, and generalizability of study findings. This analysis examines how various factors, such as statistical determinants, the nature of the population, and the types of research studies influence the sample size determination.

Statistical determinants include confidence level, margin of errors, population size, and population proportion in the quantitative research. The confidence level indicates the degree of certainty that the true population parameter falls within the estimated confidence interval. A higher confidence level, such as 95% or 99%, requires a larger sample size to maintain precision (Cochran, 1977). The margin of error, the acceptable amount of error in the results, directly influences sample size. A smaller margin of error requires a larger sample size to achieve the desired precision in estimating the population parameter (Krejcie & Morgan, 1970). Population size refers to the total number of individuals in the group being studied. For large populations, sample size needs to be sufficiently large to ensure representativeness (Israel, 1992). However, as the population size increases, the required sample size reaches a point of diminishing returns, where increases in population size result in smaller increases in sample size. The population proportion is the expected percentage of the population that has a particular characteristic. When this proportion is unknown, it is often assumed to be 50%, as this maximizes the required sample size, providing a conservative estimate that ensures sufficient representation (Sudman, 1976).

Population can be homogeneous or heterogeneous. A homogeneous population has individuals who are similar in key characteristics, leading to less variability. In such cases, smaller sample sizes can be sufficient because fewer participants are needed to achieve reliable results (Patton, 2015). Qualitative research often involves homogeneous populations where the focus is on depth rather than breadth, and sample sizes are determined based on reaching data saturation (Guest, Bunce, & Johnson, 2006). A heterogeneous population exhibits a high degree of variability, requiring larger sample sizes to capture this diversity adequately. Quantitative research typically deals with heterogeneous populations, where the goal is to generalize findings across different subgroups within the population (Fowler, 2014).

There are mainly two types of research: quantitative and qualitative research. The quantitative research focuses on statistical analysis to test hypotheses and generalize findings. Determining sample size in quantitative studies is driven by the confidence level, margin of error, population size, and population proportion (Bartlett, Kotrlik, & Higgins, 2001). Sample size calculations often involve using statistical formulas, such as those based on the central limit theorem, to ensure that the study has sufficient power to detect meaningful effects. Qualitative research prioritizes understanding phenomena in depth rather than making statistical generalizations. Sample size in qualitative research is often smaller, with the goal being to reach saturation—the point at which no new information or themes are emerging (Mason, 2010). The nature of the population, whether homogeneous or heterogeneous, plays a more significant role in determining sample size in qualitative research than in quantitative research.

4. CONCLUSION

This article has probed into the critical and intricate process of determining an applicable sample size in research studies. Through a comprehensive exploration of various formulae and considerations, the significance of a well-calculated sample size in ensuring the reliability and validity of study outcomes has been highlighted. By addressing the crucial factors of population size, margin of error, confidence level, and population proportion, researchers can tailor their sampling approach to align with the specific distinctions of their study objectives. The article underscores the versatility of methodologies, ranging from traditional sample size calculating formulae to the convenience of software calculators and sample size tables. This article extensively examines existing literature on sample size, ultimately determining that the sample size in quantitative research studies is statistically influenced by factors, such as a confidence level, a margin of error, a population size, and a population proportion. Furthermore, the nature of the population and the type of research studies play crucial roles in providing a foundational understanding of the sample size. Before calculating the ideal or necessary sample size, it is observed that homogeneous populations and qualitative research studies typically demand a smaller sample size, while heterogeneous populations and quantitative research studies require a larger sample size. Determining the appropriate sample size involves balancing statistical requirements with the nature of the population and the type of research study. This article will certainly stand as a guiding light for researchers towards robust and meaningful research outcomes through applying an appropriate and adequate sample size.

AUTHOR AFFILIATIONS

Dr. Lok Raj Sharma
Professor of English,
Makawanpur Multiple Campus, Hetauda
lokraj043i@gmail.com

Teknath Bhattarai
Lecturer of Statistics
Makawanpur Multiple Campus, Hetauda
bhattaraitn2026.tb@gmail.com

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