



## **DETERMINATION OF SAMPLE SIZE AND SAMPLING METHODS IN APPLIED RESEARCH**

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### Keywords:

*Sample size; Sampling Method,  
Health science; Agricultural science,  
survey research.*



### ABSTRACT

*Sample size, sampling method and sampling technique plays a major role in social sciences, business, health science, agricultural science research and survey research. If the sample size is inappropriate it may lead to wrong inferences on the population. Precise sampling techniques are used for specific research problems because one technique may not be appropriate for all problems. Significant factors considered for the estimation of sample size were population size, confidence level proportion of outcome in case of categorical variables, standard deviation of the outcomes in case of ordinal variables, essential precision from the research. The present paper gives an outline of commonly used techniques in the research to find out the sample size precisely. Probability sampling techniques are more suitable for health science related research.*

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### 1. INTRODUCTION

Statistics are used in research to draw the inferences about the population through the statistical behaviour of the sample. The role of the researcher is to decide the sample size such that the sample observations should represent the actual population observations.

Sampling techniques commonly used in the research for a better estimate at nominal cost and time with greater precision. If the sample size is too small, even well conducted study may lead biased inference about the population, at the same time if the sample size is too large the study may become more complex may yield an inaccurate result. Therefore, the sample size is a vital factor of any scientific research. Design of study and primary objectives of the research can affect the sample size and power of analysis. There are different methods for sample size estimation for a different design of study

and objectives of the research. Singh and Masuku (2014) argued that for sample size estimation, there are two approaches of drawing statistical inference from the research results on the basis of confidence interval approach and test of significance approach. Sathian et al. (2010) argued that in medical research for better reliability of result the significant level and power must be fixed before sample size determination. The study also revealed that Power of the study, Level of significance, Event rate and Effect of compliance is the important factor that affects the sample size.

Chow (2017) argued that the primary objective of the clinical trial research is to reveal the safety and effectiveness of drugs under investigation, sample size calculation plays a vital role to ensure that there are adequate subjects for providing a reliable and accurate assessment of the drug with convinced statistical assurance.

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Rao (2012) argued that sample size is a significant part of the design of both, analytic and descriptive studies. Research also concluded that to achieve the desired aim in research studies concerned with establishing a difference between groups or in those conducted to estimate a quantity, appropriate sample size planning is mandatory.

The present paper is an attempt to give an overview of commonly used techniques for sample size calculation for social sciences, business, health science, agricultural science research and survey research.

## 2. SAMPLING

Brown (2006) defined population as "the entire group of people that a particular study is interested in", sample is the part or portion of the population. The process of selecting a sample from a population is known as sampling. The sample is the representative of the population. Population statistical characteristics are inferred based on the sample statistics. If any error occurred in the sampling methods it directly effect on the inferences drawn on the population. That is sample size is one of the prominent factors effects on the result and inferences of the whole research.

## 3. TYPES OF SAMPLING METHOD

Sampling methods are broadly classified into probability sampling methods or random sampling and non probability sampling method or non random sampling method.

### 3.1 Probability sampling method

In this method following four techniques are preferred for accurate un biased sampling.

#### 3.1.1 Simple random sampling

In this method ever member of the population has an equal and independent chance of being selected. The frame for experiment allows the researcher to draw elements from the population by randomly generating the numbers of the members.

#### 3.1.2 Stratified Sampling

This method is most suitable when the population consist of heterogeneous subpopulation groups. The sub population groups are more homogenous as compared to the whole population. Sample is drawn from each group in appropriate proportion to represent the population. Based on the age, location, type of the industry, gross sales, number of employees, in the medical research groups can be formed based on BP level, Sugar level, type of the diseases, type of the blood group, in case of agricultural research type of the crop, variety of the soil, raining level etc.

### 3.1.3 Cluster Sampling

This method is also known as area sampling. In this method entire population to be analyzed is divided into smaller groups called as clusters. In this cluster samples offers more heterogeneity within the groups and homogeneity among groups. It is most suitable for market research and agricultural research and it is not suitable for medical research.

## 3.2 Non Probability sampling

In this method following **four** techniques are preferred for accurate un biased sampling.

### 3.2.1 Judgement sampling

This method is preferred when a limited number of respondents have the information that needed. This method involves the selection of sample respondents who are in the best position to provide the required information. The validity of the result is depends on the proper judgment of the investigator in selecting the sample.

#### 3.2.1.2 Convenience sampling

In this method samples are selected at the convenience of the investigator. This method is very easy for data collection on a particular issue. Probability of misinterpreting about the population is more. Marshall et al. (2013) argued that most of the present researches are not taken care about the sampling method and sample size because of this researchers are fail to draw accurate and reliable inferences about the population.

## 4. SAMPLE SIZE

Evans et al. (2000) defined s ample size is the number of observations in a sample . It is commonly denoted n or N.

Based on the sample statistics, inference will draw on population. It is important to estimate the size of the sample because the standard error depends on the sample size.

Standard error of sampling distribution of sample statistics  $\bar{x}$

$$\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}} \quad (1)$$

Standard error of sampling distribution of sample statistics  $\bar{p}$

$$\sigma_{\bar{p}} = \sqrt{\frac{p*q}{n}} \quad (2)$$

Miaoulis and Michener (1976) argued that for research sample size calculation three critical components need

to consider for appropriateness they are required a level of precision, level of confidence or risk and degree of variability in attributes to be measured.

Rao (2012) defined that the sample size is an estimation of the number of subjects required to detect an association of a given effect size and variability, at a specified likelihood of making Type I (false-positive) and Type II (false negative) errors. Browner et al., (1988) proved that Type I error is very serious as compared to Type II error.

#### 4.1 Level of statistical precision / Sampling Error

Cohen (1988) defined the statistical precision as "the closeness between the calculated value and relevant population value". Thompson (2006) suggested that statistical precision is normally estimated by standard error in two ways one is descriptively and other is inferentially in his book foundation of behavioral statistics: An insight based approach.

Descriptively, precision can be estimate using standard error that is the difference between sample estimate and population parameters.

$$SE_M = \frac{s^2}{\sqrt{n}} \quad (3)$$

$SE_M$  = Standard error of the mean  
S = Standard deviation  
N = sample size

Inferentially standard error is commonly used in estimating the significance differences between or among parameter estimates.

$$t = \frac{M_T - M_C}{\sqrt{\frac{s_T^2}{n_T} + \frac{s_C^2}{n_C}}} \quad (4)$$

$M_T$  = Mean of the treatment group  
 $M_C$  = Mean of control group  
 $S_T$  = Standard deviation of Treatment group  
 $S_C$  = Standard deviation of controlled group  
 $n_T$  = Sample size of Treatment group  
 $n_c$  = Sample size of Controlled group  
t = t test statistics

Level of precision is the range in which the true value of the population is to be estimated; this range is expressed in percentage points like  $\pm 5$ . This level of precision or error based on the type of the research, the researcher has to define. In general for political polling research level of precision is consider as  $\pm 10\%$ , for market research  $\pm 5\%$ , and for manufacturing, medical research  $\pm 1\%$ .

Cohen (1988) argued that sample size is one of the major factor effects on the statistical precision.

#### 4.2 Confidence / Risk Level

Confidence/risk level is the degree to which an assumption or number is likely to be true. That is the probability that a random variable lies within the confidence interval of an estimate. This confidence level is based on the central limit theorem. According to central limit theorem when repeatedly draw the sample from the population, the average of an attribute like mean obtained from that sample are equal to the true population attribute. And the attributes obtained from those samples are normally distributed about the true value.

##### 4.2.1 Interval estimation for single mean

Confidence interval = Point estimator  $\pm$  [( Z critical Value) \* (Standard Error)]

$$\text{Confidence Interval} = \bar{X} \pm Z_\alpha * \frac{\sigma}{\sqrt{n}} \quad (5)$$

$$\text{Upper Confidence Limit UCL} = \bar{X} + Z_\alpha * \frac{\sigma}{\sqrt{n}} \quad (6)$$

$$\text{Lower Confidence Limit LCI} = \bar{X} - Z_\alpha * \frac{\sigma}{\sqrt{n}} \quad (7)$$

$\bar{X}$  = Sample Mean  
 $Z_\alpha$  = Represents the preferred level of statistical significance  
 $\sigma$  = Sample standard deviation  
n = sample size

##### 4.2.2 Interval estimation for Differences of Two mean

Confidence interval = Differences between the two means  $\pm$  [(Z critical Value) \* (Differences between the two Standard Error)]

$$\text{Confidence Interval} = (\bar{x}_1 - \bar{x}_2) \pm Z_\alpha * \sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}} \quad (8)$$

$\bar{x}_1$  = Sample mean of Group 1  
 $\bar{x}_2$  = Sample mean of group 2  
 $Z_\alpha$  = Represents the preferred level of statistical significance  
 $\sigma_1$  = Standard deviation of group 1  
 $\sigma_2$  = Standard deviation of group 1  
 $n_1$  = Sample size of group 1  
 $n_2$  = Sample size of group 2

#### 4.3 Degree of Variability

The degree of variability is the distribution of attributes in the population. For more heterogeneous population larger sample size is required for given precision level,

at the same time for homogenous population small sample size is sufficient to meet given precision level.

#### 4.4. The significance of the sample size

The sample size is important because it effects on the statistical power at the same time statistical power influence on the statistical test significance. Browner and Newman (1978) argued that sensitivity of the test depends on the statistical power. Many types of research provide evidence that an adequate sample size gives a statistical test enough power. Moher et al. (1994) and Freiman et al. (1978) argued that those many published clinical research studies have low statistical power due to inadequate sample size. Singh and Masuku (2014) argued that sample size depends on five parameters like the effect of size, variability statistical power, significance criteria and type of statistical test.

### 5. METHODS OF DETERMINING SAMPLE SIZE

Cochran (1963), Gupta and Kapoor (1970) and Israel et al. (1992) proposed four methods to determine the sample size for the research they are census method small populations, replicate a sample size of similar studies, sample size from the published tables, and applying formulas to calculate a sample size.

In census method consider the entire population as the sample; this method is suitable only when population size is very small otherwise cost associated with this method is more. This method is very suitable for medical research because of its accurate preciseness.

If the researcher doing research in same field or domain and literature are available, replicate the sample size of similar studies. The disadvantage of this method is the same error will carry forward from the previous research what we consider for sample size determination.

A third method is determined to sample size is based on published tables which provide the sample size for predefined criteria.

Using formulas for a different combination of levels of precision, confidence and variability researcher can determine the sample size. In this method, the researcher can customize the sample size based on the precision and type of the research.

#### 5.1 Sample size calculation, when mean is the parameter of research

The confidence interval contains an estimate, above or below a margin of error. The margin of error for  $\alpha$  confidence interval is Z (acceptance region) times the standard error. For 95% confidence interval Z= 1.96, for 99% confidence interval Z= 2.56. It shows the accuracy

of the estimate and is based on the variability of the estimate. Let E denote the margin of error.

$$E = \bar{X} - \mu \quad (9)$$

Calculate the minimum sample size required to verify this if allowable error at some % risk, for 1 % risk E=1, for 2% of risk E= 2 it depends on the accuracy level required for the research.

$$n = \frac{Z^2 * \sigma^2}{E^2} \quad (10)$$

#### 5.2 Sample Size calculation, when the proportion is the parameter of research

##### 5.2.1 Cochran's Sample Size Formula

Cochran formula is used to calculate the essential sample size for the required level of precision, confidence level and the estimated proportion of the attribute present in the population. Cochran formula is most suitable for a large population.

Cochran (1963) developed an equation to find the sample size for the large population proportion.

$$n_0 = \frac{Z^2 * p * q}{e^2} \quad (11)$$

Which is valid where  $n_0$  is the sample size,  $Z^2$  is the area under the acceptance region in a normal distribution ( $1 - \alpha$ ),  $e$  is the preferred level of precision,  $p$  is the estimated proportion of an attribute that is present in the population, and  $q$  is  $1 - p$ .

##### 5.2.2 Modified Cochran Formula for Small Populations

If the population is small then the sample size can be reduced slightly. This is because a given sample size provides proportionately more information for a small population than for a large population.

The sample size ( $n_0$ ) can be adjusted as

$$n = \frac{n_0}{\left[1 + \left\{\frac{(n_0 - 1)}{N}\right\}\right]} \quad (12)$$

Where  $n$  is the sample size and  $N$  is the population size. This adjustment can substantially reduce the necessary sample size for small populations and also called the population correction.

#### 5.3 For Observational Studies sample size for a case-control study under binary exposure difference in proportions formula

$$n = \left(\frac{r+1}{r}\right) * \frac{(P)(1-P) \left(Z_{\beta} - Z_{\alpha} \frac{1}{2}\right)^2}{(P_1 - P_2)^2} \quad (13)$$

n = Sample size in the case group,  
r = ratio of controls to cases,  
 $(\bar{P})(1 - \bar{P})$  = measure of variability  
 $Z_{\beta}$  = required power,  
 $Z_{\frac{\alpha}{2}}$  = required a level of statistical significance,  $(P_1 - P_2)$  = difference in proportion and

$$\bar{P} = \frac{P_1 + P_2}{2} \quad (14)$$

#### 5.4 For Observational Studies sample size for a case-control study under continuous exposure Use difference in means formula

$$n = \left(\frac{r+1}{r}\right) * \frac{\sigma^2 \left(Z_{\beta} - Z_{\frac{\alpha}{2}}\right)^2}{(\bar{X}_1 - \bar{X}_2)^2} \quad (15)$$

n = Sample size in the case group,  
r = ratio of controls to cases,  
 $\sigma$  = Standard deviation,  
 $Z_{\beta}$  = required power,  
 $Z_{\frac{\alpha}{2}}$  = required level of statistical significance,  
 $(\bar{X}_1 - \bar{X}_2)$  = difference in the mean.

#### 5.5 Sample size if unequal numbers in each group

$$n_1 = \frac{(Z_{\beta} + Z_{\frac{\alpha}{2}}) \left(\frac{\sigma_1^2 + \sigma_2^2}{\lambda}\right)}{\delta^2} \quad (16)$$

$Z_{\beta}$  = required power,  
 $Z_{\frac{\alpha}{2}}$  = required level of statistical significance,  
 $\sigma_1^2$  = Variance of group one,  
 $\sigma_2^2$  = Variance of group two, Use if want  $\lambda$  patients randomized to the treatment arm for every patient randomized to the placebo arm.

#### 5.6 Lehr's formula

Lehr's et al. (1984) designed a formula to determine the sample size for research, it is most suitable when the research studies expected to be verified by paired or unpaired through t-tests and Chi-squared test.

$$n = \frac{16}{(\text{Standardized difference})^2} \quad (17)$$

The disadvantage of this method is, if the standardized difference is small, this overestimates the sample size. It depends on the power required.

#### 5.7 Yamane

Yamane (1967) provides a simplified formula to calculate sample sizes.

$$n = \frac{N}{[1 + N * e^2]} \quad (18)$$

Where n is the sample size, N is the population size, and e is the level of precision.

#### 5.8 Rao

Rao (1985) presented some another calculation for sample size under different circumstances in a simple manner.

When it is a field survey to estimate the prevalence rate of specific event or cases

$$n = \frac{4 * p * q}{[L^2]} \quad (19)$$

Where n is the required sample size, p is the approximate prevalence rate for which the survey is to be conducted. The knowledge of this is to be obtained from previous surveys or from a pilot survey.  $q = 1 - p$  and L is the permissible error in the estimate.

When conducting research investigation on quantitative data, the sample size is calculated by the given formula

$$n = \frac{t_{\alpha}^2 * s^2}{\epsilon^2} \quad (20)$$

Where n is the preferred sample size, s is the standard deviation of observations,  $\epsilon$  is permissible in the estimate of mean and  $t_{\alpha}$  is the value of at 5% level of significance.

Dell et al. (2002) described the methodology of sample size determination for use in animal base experimental research.

#### 5.9 Sample size for a single group experiment

$$n = \frac{\log \beta}{\log p} \quad (21)$$

Where  $\beta$  is the probability of Type II error (usually 0.10 or 0.05) and p represents the proportion of the animals are not infected/infected.

#### 5.10 Bartlett equation of estimate sample size for Categorical Data considering Confidence Interval

Bartlett, Kotrlik, and Higgins (2001) designed the following equations to determine the sample size for categorical data

$$n_0 = \frac{t^2 * p * (1-p)}{d^2} \quad (22)$$

$n_0$  is the minimum estimated sample size,  
t is the value of the t-distribution corresponding to the chosen alpha level,  
p is the estimate of population proportion.

When p is unknown, generally it is best to set it at 0.5, d is the margin of error – Bartlett et al. (2001) recommend using 5%.

If the estimate  $n_0$  is greater than 5% of the overall population, make the following correction

$$n_1 = \frac{n_0}{\left[1 + \frac{n_0}{N}\right]} \quad (23)$$

$n_1$  is the adjusted minimum estimated sample size,  
N is the population size.

### 5.11 Bartlett equation of estimate sample size for continuous data considering Confidence Interval

Bartlett, Kotrlik, and Higgins (2001) designed the following equations to determine the sample size for continuous data

$$n_0 = \frac{t^2 * s^2}{d^2} \quad (24)$$

$n_0$  is the minimum estimated sample size, t is the value of the t-distribution corresponding to the chosen alpha level for .05 this is 1.96, s is the estimate of standard deviation, d is the margin of error.

If the estimate  $n_0$  is greater than 5% of the overall population, make the following correction

$$n_1 = \frac{n_0}{\left[1 + \frac{n_0}{N}\right]} \quad (25)$$

$n_1$  is the adjusted minimum estimated sample size, N is the population size

### 5.12 Determination of sample size for laboratory animal study

For laboratory animal's research to estimate sample size, Kish (1965) proposed Mead's resource equation, he argued that this equation provides approximate sample size as compared to other methods. Kirkwood and Robert (2010) argued that Mead's resource equation is suitable when parameters such as expected standard deviations between groups are unknown. Below equation represents the Mead's resource equation.

$$E = N - B - T \quad (26)$$

Where E = Degrees of freedom of error components it should be in the range of 10-20  
N = Total number of individuals or units in the research  
B = Blocking component, representing environmental effects allowed in the design  
T = Treatment component, corresponding to the number of experimental groups

All the parameters in the above equation are in fact the degrees of freedom hence; their numbers are subtracted by one before incorporation into the equation.

### 5.13 One-sample t-test and Paired t-test

For testing the hypothesis:  $H_0: \mu = k$  vs.  $H_1: \mu \neq k$  with a two-tailed test, the formula is:

$$n = \left[ \frac{(Z_{\beta} + Z_{\alpha/2}) \sigma}{d} \right]^2 \quad (27)$$

$Z_{\beta}$  = Represents the preferred power (typically .84 for 80% power)

$Z_{\alpha/2}$  = Represents the preferred level of statistical significance (typically 1.96)

$\sigma$  = Standard deviation

### 5.14 Estimation of sample size for Cluster Randomized Trial for testing Hypothesis

m = Size of the cluster

$\sigma_A^2$  = Variance between the clusters

$\sigma_W^2$  = Variance within cluster

$\rho$  = Intra cluster correlation coefficient

$$\rho = \frac{\sigma_A^2}{[\sigma_A^2 + \sigma_W^2]} \quad (28)$$

d = Precision

$\sigma$  = Standard deviation of outcomes

k = Number of clusters, clusters like – villages, communities, households, schools, classrooms, designation, qualification etc.)

$$k = \frac{n}{m} \quad (29)$$

#### 5.14.1 Estimation of sample size for the continuous outcome

$$n = \frac{\left(\frac{Z_{\alpha}}{2}\right)^2 \sigma^2 [1 + (m-1)\rho]}{d^2} \quad (30)$$

#### 5.14.2 Estimation of sample size for the Binary outcome

$$n = \frac{\left(\frac{Z_{\alpha}}{2}\right)^2 p * q [1 + (m-1)\rho]}{d^2} \quad (31)$$

p = occurrence (percentage or proportion)

#### 5.14.3 Comparison of means of Equal cluster size

The number of subjects required per intervention group to test the hypothesis

$H_0: \mu_1 = \mu_2$  is given by

$$n = \frac{\left(\frac{Z_{\alpha} + Z_{\beta}}{2}\right)^2 (2\sigma^2) [1+(m-1)\rho]}{(\mu_1 - \mu_2)^2} \quad (32)$$

$\mu_1$  = Mean of the intervention group

$\mu_2$  = Mean of the control group

#### 5.14.4 Comparison of means of unequal cluster size

The number of subjects required per intervention group to test the hypothesis

$H_0: \mu_1 = \mu_2$  is given by

$$n = \frac{\left(\frac{Z_{\alpha} + Z_{\beta}}{2}\right)^2 (2\sigma^2) [1+(m_{\max}-1)\rho]}{(\mu_1 - \mu_2)^2} \quad (33)$$

$\mu_1$  = Mean of the intervention group

$\mu_2$  = Mean of the control group

#### 5.15 Determination of sample size based on Probability Assessment method

Sample size determination based on power analysis in clinical research for detecting small differences in the incidence rate of rare events may not be appropriate; in

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such case probability assessment method is most suitable and accurate to determine the sample size. It is assumed that mean of the two identical and independent variables distributed as Bernoulli random variables.

$$n = \frac{Z_{\beta}^2 [P_1(1-P_1) + P_2(1-P_2)]}{(P_2 - P_1)^2} \quad (34)$$

$Z_{\beta}$  = Represents the preferred power (typically .84 for 80% power)

$P_1$  = Mean of group 1

$P_2$  = Mean of group 2

#### 6. CONCLUSION

Sampling method and sample size in research play a vital role in research. Based on the collected sample data, researcher has to draw the inference on the population, if the sample itself is insufficient the inference will lead misinterpretation about population, at the same time if the sample size is too big, it leads to excessive utilization of resources like manpower, time, cost etc. the present paper is an attempt to suggest the generalized sample size technique for social sciences, business, health science, agricultural science research and survey research.

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