Systematic Sampling for Population Mean Estimation under Cost and Time Constraints

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December 16, 2025

Abstract

This paper presents a systematic sampling framework for estimating the population mean when the population is divided into subgroups. Sampling bias, survey cost, and time constraints are incorporated into the design. An interactive R Shiny application is developed to compute optimal sample size, perform systematic sampling, and visualize the experimental design.

1 Introduction

Systematic sampling is a probability sampling technique where elements are selected at regular intervals after a random start. It is widely used due to its simplicity and operational efficiency.

2 Problem Statement

Given a population divided into subgroups, determine the required sample size for estimating the population mean while incorporating sampling bias, expected cost, and time of survey in each subgroup.

3 Methodology

- Divide population into G subgroups
- Derive sample size under bias constraint
- Allocate samples optimally using cost and time
- Apply systematic sampling within each subgroup

4 Mathematical Formulation

Required sample size:

$$n = \frac{z^2 \sum_{g=1}^{G} W_g^2 \sigma_g^2}{d^2 - b^2}$$

where $W_g = N_g/N$.

Systematic interval:

$$k_g = \frac{N_g}{n_g}$$

5 Experimental Design

For each subgroup, a random start is chosen and every k_g-th unit is selected. This ensures uniform coverage of the population.

6 Implementation

The methodology is implemented using an R Shiny application that dynamically computes sample size, subgroup allocation, and visualizes the sampling design.

7 Conclusion

Systematic sampling offers an efficient and nearly unbiased approach for population mean estimation under practical constraints such as cost and time.