

# Learn How to Perform a One Proportion Z-Test in R with Examples

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## The Core Principles of the One Proportion Z-Test

The **One Proportion Z-Test** stands as a cornerstone method in inferential statistics, specifically engineered to evaluate claims about the proportion of a binary outcome within a large population. This powerful statistical procedure allows researchers to compare an observed sample proportion ( $\hat{p}$ ) derived from collected data against a known or hypothesized theoretical [population proportion](#) ( $p_0$ ). Essentially, it addresses the fundamental question: Is the true population parameter consistent with our initial expectations, or is the deviation observed in our sample too large to be attributed merely to random chance?

Unlike tests designed for continuous data, the [Z-Test](#) for proportions is uniquely suited for data arising from Bernoulli trials--situations where outcomes fall into one of two categories, typically labeled "success" or "failure." The reliability of this test hinges on a critical statistical concept: approximating the underlying [binomial distribution](#) using the continuous [normal distribution](#). This approximation simplifies the calculation of probabilities and is only valid when certain structural conditions regarding sample size are met. Failure to satisfy these preconditions necessitates the use of more exact methods, such as the Binomial Test, which we will discuss later in the context of R programming.

The primary goal when conducting a **One Proportion Z-Test** is to quantify the standardized difference between the observed sample result and the hypothesized population value. This quantification is achieved by calculating the Z-statistic, which measures this difference in terms of standard errors. If the calculated Z-statistic falls into the rejection region (defined by the chosen significance level,  $\alpha$ ), it provides compelling statistical evidence against the initial assumption, strongly suggesting that the true population proportion is indeed unequal to  $p_0$ . This ultimately leads to the rejection of the [null hypothesis](#) ( $H_0$ ).

### Assumptions and Conditions for Normality

For the results of the One Proportion Z-Test to be statistically valid and reliable, several key assumptions must be satisfied. These conditions ensure that the distribution of the sample proportion ( $\hat{p}$ ) closely follows a [normal distribution](#), allowing us to use the standard normal tables (Z-tables) for calculating p-values and critical values. Ignoring these prerequisites can lead to inaccurate conclusions and flawed [hypothesis testing](#).

The most important requirements revolve around the sampling process and the magnitude of the sample size. First, the data must come from a **simple random sample**, ensuring that all individuals in the population have an equal chance of being included and that the observations are independent. Second, the population size must be large relative to the sample size; typically, the population should be at least ten times larger than the sample size ( $N \geq 10n$ ) to avoid issues related to sampling without replacement. This ensures that the variance of the proportion is not

unduly underestimated.

Crucially, we must satisfy the **Success/Failure Condition**, which confirms that the sample size ( $n$ ) is large enough for the [normal approximation](#) to be appropriate. This is mathematically checked using the hypothesized proportion ( $p_0$ ) rather than the sample proportion ( $\hat{p}$ ):

Expected number of successes:  $n \cdot p_0 \geq 10$

Expected number of failures:  $n \cdot (1 - p_0) \geq 10$

If these products are both greater than or equal to 10, the sampling distribution of the sample proportion is considered approximately normal. If these conditions are not met, the Z-Test should be abandoned in favor of the exact binomial test, which is robust even for limited data.

## Defining Hypotheses and Calculating the Z-Statistic

The rigorous procedure for any [hypothesis test](#) starts with the precise definition of the null and alternative hypotheses. The [null hypothesis](#) ( $H_0$ ) represents the baseline assumption, stating that the true population proportion ( $p$ ) is exactly equal to the hypothesized value ( $p_0$ ). This is the status quo that we challenge with statistical evidence.

**$H_0$ :**  $p = p_0$  (The true population proportion is precisely equal to the hypothesized proportion  $p_0$ ).

The alternative hypothesis ( $H_1$ ), conversely, represents the claim or theory the researcher is attempting to prove. The selection of  $H_1$  dictates the nature of the test, determining whether the critical region for rejection is located in one tail (directional test) or split between both tails (non-directional test).

**$H_1$  (Two-Tailed Test):**  $p \neq p_0$ . This tests for any significant difference, regardless of whether the true proportion is higher or lower than  $p_0$ .

**$H_1$  (Left-Tailed Test):**  $p < p_0$ . This tests whether the true proportion is significantly less than the hypothesized value.

**$H_1$  (Right-Tailed Test):**  $p > p_0$ . This tests whether the true proportion is significantly greater than the hypothesized value.

Once the hypotheses are established, the next crucial step is calculating the [test statistic](#) ( $z$ ). This value standardizes the observed difference, allowing us to compare it against the standard normal distribution. The formula for the Z-statistic used in the One Proportion Z-Test is:

$$z = \frac{\hat{p} - p_0}{\sqrt{\frac{p_0(1-p_0)}{n}}}$$

Where the components are defined as:

**$\hat{p}$** : The **observed sample proportion**, calculated directly from the sample data as the number of successes ( $x$ ) divided by the total sample size ( $n$ ).

**$p_0$** : The **hypothesized population proportion**, specified by the null hypothesis.

**$n$** : The **sample size**, representing the total number of trials or observations.

The denominator, often termed the standard error of the sample proportion, is calculated using the hypothesized proportion ( $p_0$ ) because, under the framework of hypothesis testing, we assume the [null hypothesis](#) is true until proven otherwise.

## Implementing the Test in R: `prop.test()` vs. `binom.test()`

The statistical programming language [R](#) provides efficient built-in functions for conducting proportion tests, but researchers must choose carefully between the two primary options: `binom.test()` and `prop.test()`. Making the correct choice depends entirely on whether the crucial assumptions for the [normal approximation](#) have been met, particularly the Success/Failure Condition.

The `binom.test()` function calculates the **exact binomial probability**. It is the appropriate choice when the sample size ( $n$ ) is small, or when the conditions for using the normal approximation are not satisfied (i.e., either  $n \cdot p_0 < 10$  or  $n \cdot (1 - p_0) < 10$ ). Because it calculates exact probabilities, `binom.test()` is highly accurate even with limited data, offering a robust alternative when the Z-Test assumptions fail.

Conversely, the `prop.test()` function utilizes the chi-squared distribution, which is mathematically equivalent to the square of the Z-statistic when testing one proportion. This function relies on the normal approximation and is therefore suitable when the sample size is sufficiently large and the Success/Failure conditions hold. In essence, `prop.test()` performs the classical **One Proportion Z-Test**.

The standard syntax and parameters for these vital functions are defined as follows:

**Using the Exact Binomial Test (Small  $n$ ):** `binom.test(x, n, p = 0.5, alternative = "two.sided")`

**Using the Normal Approximation (Large  $n$ ):** `prop.test(x, n, p = 0.5, alternative = "two.sided", correct=TRUE)`

In both expressions,  **$x$**  represents the count of observed successes,  **$n$**  is the total number of trials,  **$p$**  specifies the hypothesized population proportion ( $p_0$ ), and **alternative** sets the direction of  $H_1$ . A unique feature of `prop.test()` is the **correct** parameter. When set to `TRUE` (the default in [R](#)), it applies [Yates' continuity correction](#). This small adjustment is applied to improve the accuracy of approximating the discrete binomial distribution with the continuous normal distribution,

yielding a slightly more conservative result.

## Practical Example: Analyzing Public Opinion Data

To illustrate the application of the One Proportion Z-Test in R, consider a common scenario in political polling. A prominent legislative body claims that exactly 60% of eligible county residents support a newly introduced environmental bill ( $p_0 = 0.60$ ). A non-partisan watchdog group suspects this figure might be inaccurate and conducts its own survey to determine if the true support rate differs from the claimed 60%.

A random sample of 100 residents is collected ( $n=100$ ). Of these, 64 residents indicate their support for the legislation ( $x=64$ ). We are conducting a two-tailed test since we are looking for evidence that the true proportion is simply "not equal" to 0.60.

The necessary parameters for the test are defined:

**Hypothesized Proportion ( $p_0$ ):** 0.60

**Observed Successes ( $x$ ):** 64

**Sample Size ( $n$ ):** 100

**Observed Sample Proportion ( $\hat{p}$ ):**  $64/100 = 0.64$

Since the Success/Failure conditions are met ( $100 \cdot 0.60 = 60$  and  $100 \cdot 0.40 = 40$ ), we use the `prop.test()` function to execute the Z-Test, comparing our observed sample proportion (0.64) against the null hypothesized value (0.60).

```
prop.test(x=64, n=100, p=0.60, alternative="two.sided")
```

```
1-sample proportions test with continuity correction
```

```
data: 64 out of 100, null probability 0.6
```

```
X-squared = 0.51042, df = 1, p-value = 0.475
```

```
alternative hypothesis: true p is not equal to 0.6
```

```
95 percent confidence interval:
```

```
0.5372745 0.7318279
```

```
sample estimates:
```

```
p
```

```
0.64
```

## Interpreting the Results: The P-Value and Decision Rule

The output generated by the `prop.test()` function in R provides a comprehensive summary of the

test, but the most critical component for making a statistical decision is the [p-value](#). The p-value quantifies the evidence against the [null hypothesis](#); it represents the probability of observing a sample statistic as extreme as, or more extreme than, the one calculated, assuming that  $H_0$  is true.

A small p-value indicates that such an extreme observation would be highly unlikely if  $H_0$  were correct, thus providing strong evidence for rejecting  $H_0$ . In our legislative approval example, the calculated [p-value](#) is **0.475**. We compare this value against the predetermined significance level,  $\alpha$ , which is commonly set at 0.05. The decision rule is simple:

If  $P\text{-value} \leq \alpha$ , we **reject the null hypothesis**.

If  $P\text{-value} > \alpha$ , we **fail to reject the null hypothesis**.

Since  $0.475$  is significantly greater than the typical  $\alpha = 0.05$  threshold, we **fail to reject the null hypothesis**. This substantial [p-value](#) indicates that the observed difference between the sample proportion (0.64) and the hypothesized proportion (0.60) is not statistically significant. We conclude that the observed variation can reasonably be explained by normal random sampling variation. Therefore, we do not have sufficient statistical evidence to claim that the true proportion of residents supporting the law differs significantly from 0.60.

## Using the Confidence Interval for Hypothesis Confirmation

In addition to the [p-value](#), the R output provides a 95% [confidence interval](#) (CI), which is instrumental for contextualizing the test results. The [confidence interval](#) constructs a range of plausible values for the true population proportion based on the sample data. We are 95% confident that the true population proportion lies somewhere within this calculated range.

For our example, the 95% [confidence interval](#) (CI) is reported as: .

The relationship between the CI and a two-tailed hypothesis test is direct: if the hypothesized value ( $p_0$ ) falls within the boundaries of the CI, we must fail to reject  $H_0$ . Conversely, if  $p_0$  falls outside the interval, we would reject  $H_0$ . In this case, the hypothesized proportion,  $p_0 = 0.60$ , is clearly contained within the interval spanning from 0.5373 to 0.7318. This independent verification strongly confirms our decision derived from the p-value: there is no compelling evidence to dispute the political group's claim that 60% support the legislation.

## Further Exploration and Advanced Considerations

The One Proportion Z-Test serves as an excellent entry point into frequentist hypothesis testing, but statisticians often encounter scenarios requiring more complex approaches. Users should always be mindful of the impact of the `correct=TRUE` parameter in R's `prop.test()` function. As

noted earlier, this parameter applies [Yates' continuity correction](#).

While this correction generally makes the test more conservative (yielding a slightly larger p-value) and is recommended for situations where  $n \cdot p_0$  or  $n \cdot (1 - p_0)$  is close to the threshold of 10, some statisticians argue that for very large samples, this correction is unnecessary and potentially misleading. If you wish to achieve results that strictly align with the raw Z-statistic calculation without the continuity adjustment, you may set the parameter to `correct=FALSE` in the `prop.test()` function.

For those interested in exploring the **One Proportion Z-Test** further, the following resources provide valuable information and tools for deeper understanding and practical application:

[Detailed Introduction to the One Proportion Z-Test Methodology](#)

[Interactive One Proportion Z-Test Calculator Tool](#)

[Guide to Performing a One Proportion Z-Test in Microsoft Excel](#)