

How to Calculate Binomial Probability in Excel

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Performing a Binomial Test in Excel provides a streamlined method for evaluating whether an observed proportion of successes significantly differs from a hypothesized population proportion. To execute this test, data must first be organized within a spreadsheet. The core calculation relies on the powerful built-in function, BINOM.DIST.

This statistical function requires precise input, including the number of observed successes, the total number of trials conducted, the hypothesized baseline probability of success, and a logical value specifying whether a cumulative distribution or a discrete probability mass is required. The ultimate output of the Binomial Test is the resulting P-value, which quantifies the probability that the observed success rate occurred purely due to random chance, providing the foundation for rigorous statistical inference.

Understanding the Binomial Test

A **binomial test** is a specific type of statistical test used to compare a sample proportion against a known or theoretical population proportion. This test is appropriate when analyzing data that meets the criteria of a binomial distribution--specifically, when there are a fixed number of independent trials, where each trial results in exactly one of two possible outcomes (often termed "success" or "failure"), and the probability of success remains constant across all trials.

Consider a classic scenario involving a standard 6-sided die. If this die is rolled 24 times, statistical expectation dictates that any specific number, such as "3," should appear with a frequency proportional to its theoretical probability, which is 1/6. Therefore, the expected number of occurrences for the number "3" would be calculated as 24 trials multiplied by the success probability (1/6), resulting in an expected count of 4 times. This baseline expectation forms the null hypothesis for our analysis.

However, if empirical observation reveals that the number "3" actually appears 6 times out of the 24 rolls, we encounter a difference between the expected value (4) and the observed value (6). The critical question then becomes: Is this deviation sufficient evidence to conclude that the die is statistically biased towards showing the number "3," or is this merely a minor, random fluctuation? To provide a statistically robust answer to this query, we must perform a Binomial Test, which assesses the likelihood of observing 6 or more successes under the assumption that the die is fair.

The Essential Excel Function: BINOM.DIST

In the environment of Microsoft Excel, the methodology for executing a Binomial Test is encapsulated within the primary function designed for binomial distribution analysis: BINOM.DIST. This function calculates either the probability mass function (PMF) or the cumulative distribution function (CDF) for a given set of binomial parameters. Understanding how to structure the input for

this function is paramount to generating an accurate P-value for hypothesis testing.

The precise syntax required in Excel for this operation is:

BINOM.DIST(number_s, trials, probability_s, cumulative)

Each argument within this formula plays a specific, critical role in defining the scope and nature of the probability calculation. Errors in defining these arguments will lead to invalid statistical conclusions. Typically, when conducting a one-tailed Binomial Test to see if an outcome is significantly higher or lower than expected, we utilize the cumulative form, often calculating the complement (1 minus the CDF) to find the probability of observing the outcome or something more extreme.

The proper application of BINOM.DIST transforms raw data--success count, total attempts, and theoretical chance--into the crucial P-value necessary for determining statistical significance. This process ensures objectivity in determining whether the observed data supports rejecting the initial assumption of equality or fairness established by the null hypothesis.

Detailed Breakdown of BINOM.DIST Parameters

Each parameter in the BINOM.DIST function serves to define the specific binomial scenario being investigated. A clear understanding of these roles is essential for accurate hypothesis testing in Excel.

The arguments are defined as follows:

number_s: This integer represents the number of "successes" observed in the sample. When calculating the cumulative probability for a one-tailed test (e.g., probability of X or more successes), the use of this number must be adjusted in the formula (typically $n-1$ successes are used in the CDF when calculating $P(X \geq n)$ using the complement rule).

trials: This is the total number of independent trials or observations conducted. This value defines the sample size for the statistical test.

probability_s: This decimal value represents the hypothesized population probability of success on any single trial, often denoted as π or p_0 . This is the value against which the sample proportion is compared under the premise of the null hypothesis.

cumulative: This is a logical argument (TRUE or FALSE). If set to **TRUE**, BINOM.DIST returns the cumulative distribution function (CDF), providing the probability that there are at most **number_s** successes ($P(X \leq \text{number}_s)$). If set to **FALSE**, it returns the probability mass function (PMF), providing the probability that there are exactly **number_s** successes ($P(X = \text{number}_s)$). For standard Binomial Tests used in hypothesis testing, we almost always use **TRUE** in conjunction with the complement rule to calculate the relevant P-value for one-tailed tests.

The subsequent examples illustrate the practical application of this function across various real-world statistical problems, focusing on the interpretation of the resulting P-value relative to the standard significance level (**alpha**, usually 0.05).

Case Study 1: Analyzing Die Bias (One-Tailed Test)

Example 1: We roll a 6-sided die 24 times, resulting in the number "3" appearing exactly 6 times. We perform a binomial test to determine if there is sufficient evidence that the die is biased towards the number "3." This scenario requires a one-tailed test because we are specifically testing for bias **towards** the number "3" (an increase in the success rate).

The formal structure for hypothesis testing must be established prior to calculation. We define the null and alternative hypotheses based on the theoretical probability ($\pi_0 = 1/6$):

$H_0: \pi \leq 1/6$ (The die is not biased; the true proportion is less than or equal to the theoretical expectation.)

$H_A: \pi > 1/6$ (The die is biased towards "3"; the true proportion is greater than the theoretical expectation.)

To calculate the P-value, we seek the probability of observing 6 or more successes, given the null hypothesis is true ($P(X \geq 6)$). Since BINOM.DIST with TRUE calculates $P(X \leq x)$, we use the complement rule: $P(X \geq 6) = 1 - P(X \leq 5)$.

We enter the following formula into Excel, where 5 is the maximum number of successes we accept under the non-extreme distribution:

$$P(x \geq 6) = 1 - \text{BINOM.DIST}(5, 24, 1/6, \text{TRUE}) = 1 - 0.80047 = \mathbf{0.19953}.$$

The resulting P-value (0.19953) is significantly greater than the standard significance level ($\alpha = 0.05$). Consequently, we fail to reject the null hypothesis. This finding indicates that the observed difference (6 successes instead of 4) is highly likely to be attributed to random variation, and we do not possess sufficient statistical evidence to definitively conclude that the die is biased towards the number "3."

Case Study 2: Assessing Coin Fairness (One-Tailed Test)

Example 2: A standard coin is flipped 30 times, resulting in heads exactly 19 times. We perform a binomial test to determine if the coin is biased towards heads. Similar to the previous example, we are investigating if the observed rate is significantly higher than the expected rate, necessitating a one-tailed upper test.

For a fair coin, the theoretical probability of success (heads) is $\pi_0 = 1/2$ (or 0.5). The hypotheses are structured to test for an elevated rate:

$H_0: \pi \leq 1/2$ (The coin is fair or biased away from heads.)

$H_A: \pi > 1/2$ (The coin is biased towards heads.)

We are interested in finding the probability of observing 19 or more heads out of 30 flips ($P(X \geq 19)$). Utilizing the complement rule with the cumulative distribution function calculated by BINOM.DIST, we calculate $1 - P(X \leq 18)$.

We enter the necessary parameters into Excel:

$P(x \geq 19) = 1 - \text{BINOM.DIST}(18, 30, 1/2, \text{TRUE}) = 1 - 0.89976 = \mathbf{0.10024}$.

Since the resulting P-value (0.10024) is greater than the standard α level of 0.05, we again fail to reject the null hypothesis. While 19 heads is more than the expected 15, the observed difference is not statistically significant at the 95% confidence level. We lack sufficient evidence from this sample to claim that the coin is biased towards heads, reinforcing the principle that statistical conclusions must be based on low probabilities of chance occurrence.

Case Study 3: Evaluating Process Improvement (Rejection of H_0)

Example 3: A shop traditionally produces widgets with an 80% effectiveness rate. They introduce a new manufacturing system aimed at improving this rate. A random sample of 50 widgets from the new process yields 46 effective units. We conduct a binomial test to ascertain if the new system genuinely leads to statistically higher effectiveness. This is a crucial application of hypothesis testing in quality control.

The theoretical success rate is $\pi_0 = 0.80$. The hypotheses are set up to test for improvement:

$H_0: \pi \leq 0.80$ (The new system does not lead to an increase in effectiveness; the rate is less than or equal to the original 80%.)

$H_A: \pi > 0.80$ (The new system results in statistically increased effectiveness.)

We observe 46 successes out of 50 trials. We calculate the probability of observing 46 or more effective widgets ($P(X \geq 46)$) using the complement of the cumulative distribution function for $X \leq 45$. This is essential for determining how unlikely this result is under the assumption of the null hypothesis.

The Excel formula is structured as follows:

$$P(x \geq 46) = 1 - \text{BINOM.DIST}(45, 50, 0.8, \text{TRUE}) = 1 - 0.9815 = \mathbf{0.0185}.$$

In this case, the calculated P-value (0.0185) is less than the predetermined significance level ($\alpha = 0.05$). Because this probability is low, we reject the null hypothesis. We have found sufficient statistical evidence to conclude, with 95% confidence, that the implementation of the new system has led to a statistically significant increase in the effectiveness rate of the widgets, moving beyond mere chance variation.

Determining Minimum Successes using BINOM.INV

Example 4: A shop produces gadgets with 60% reliability. They introduce a new process hoping to improve this rate. In a random selection of 40 gadgets from the new production run, what is the minimum number of reliable gadgets required to state, with 95% confidence, that the new process truly improves reliability? This problem differs from the previous examples as it asks for the critical success threshold rather than testing a specific outcome.

To answer this question, we must utilize the inverse function of the binomial distribution, which is designed to identify the minimum number of successes necessary to achieve a specified cumulative probability. In Excel, this function is BINOM.INV.

The function calculates the smallest value for which the cumulative binomial distribution is greater than or equal to a specified criterion. The syntax is:

BINOM.INV(trials, probability_s, alpha)

The arguments are defined as follows:

trials: The total number of trials planned for the test ($n = 40$).

probability_s: The hypothesized probability of "success" on each trial under the null hypothesis ($\pi_0 = 0.60$).

alpha: The desired significance level for the cumulative probability. Since we require 95% confidence in improvement, we are looking for the threshold where $P(X \leq k)$ is 0.95. This value (0.95) represents $1 - \alpha$.

We enter the formula into Excel to determine the minimum number of successes (k) required:

$$\text{BINOM.INV}(40, 0.60, 0.95) = \mathbf{29}.$$

The result, 29, signifies the minimum critical value. To reject the null hypothesis and confidently assert that the new process improves reliability at the 95% confidence level, the shop must observe at least 29 reliable gadgets out of the 40 sampled. Any result below 29 would force the

shop to conclude that the observed reliability increase could still be plausibly explained by random chance. This inverse function is vital for planning quality control tests and determining statistical acceptance criteria before data collection.

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