

FIND THE 95% CONFIDENCE INTERVAL FOR THE STANDARD DEVIATION OF THE LENGTHS OF PIPES IF A SAMPLE OF 21

FIND THE 95% CONFIDENCE INTERVAL FOR THE STANDARD DEVIATION OF THE LENGTHS OF PIPES IF A SAMPLE OF 21 IS A COMMON STATISTICAL PROBLEM ENCOUNTERED IN QUALITY CONTROL AND ENGINEERING FIELDS. UNDERSTANDING HOW TO CALCULATE THIS CONFIDENCE INTERVAL HELPS PROFESSIONALS DETERMINE THE VARIABILITY IN PIPE LENGTHS WITH A SPECIFIED LEVEL OF CONFIDENCE, WHICH IS ESSENTIAL FOR MAINTAINING QUALITY STANDARDS AND ENSURING PRODUCT CONSISTENCY. THIS ARTICLE PROVIDES A COMPREHENSIVE GUIDE TO CALCULATING THE 95% CONFIDENCE INTERVAL FOR THE STANDARD DEVIATION WHEN A SAMPLE SIZE OF 21 PIPES IS INVOLVED, COVERING NECESSARY STATISTICAL CONCEPTS, FORMULAS, STEP-BY-STEP PROCEDURES, AND PRACTICAL EXAMPLES.

UNDERSTANDING THE BASICS OF CONFIDENCE INTERVALS FOR STANDARD DEVIATION

WHAT IS A CONFIDENCE INTERVAL?

A CONFIDENCE INTERVAL (CI) IS A RANGE OF VALUES, DERIVED FROM SAMPLE DATA, THAT IS BELIEVED TO CONTAIN THE TRUE POPULATION PARAMETER WITH A SPECIFIED DEGREE OF CONFIDENCE. IN THIS CONTEXT, THE PARAMETER OF INTEREST IS THE POPULATION STANDARD DEVIATION (σ) OF PIPE LENGTHS. A 95% CONFIDENCE INTERVAL INDICATES THAT IF THE SAME SAMPLING PROCESS IS REPEATED MULTIPLE TIMES, APPROXIMATELY 95% OF THE CALCULATED INTERVALS WILL CONTAIN THE TRUE STANDARD DEVIATION.

WHY CALCULATE A CONFIDENCE INTERVAL FOR STANDARD DEVIATION?

ESTIMATING THE STANDARD DEVIATION PROVIDES INSIGHTS INTO THE VARIABILITY OR CONSISTENCY OF PIPE LENGTHS WITHIN A PRODUCTION BATCH. A NARROW CONFIDENCE INTERVAL SUGGESTS UNIFORMITY, WHILE A WIDE INTERVAL INDICATES HIGHER VARIABILITY. CALCULATING THIS INTERVAL ALLOWS ENGINEERS AND QUALITY MANAGERS TO ASSESS WHETHER THE PROCESS MEETS THE DESIRED SPECIFICATIONS AND TO MAKE INFORMED DECISIONS REGARDING PROCESS IMPROVEMENTS.

PREREQUISITES AND ASSUMPTIONS

BEFORE CALCULATING THE CONFIDENCE INTERVAL, SEVERAL ASSUMPTIONS AND PREREQUISITES MUST BE MET:

SAMPLE SIZE AND DATA DISTRIBUTION

- THE SAMPLE SIZE SHOULD BE SUFFICIENTLY LARGE, BUT FOR VARIANCE AND STANDARD DEVIATION INTERVALS, THE SAMPLE SIZE OF 21 IS ACCEPTABLE.
- THE DATA SHOULD BE APPROXIMATELY NORMALLY DISTRIBUTED, ESPECIALLY FOR SMALLER SAMPLES, TO ENSURE THE VALIDITY OF THE CHI-SQUARE DISTRIBUTION-BASED METHODS.

SAMPLE DATA

- THE SAMPLE CONSISTS OF 21 PIPE LENGTHS, DENOTED AS $(x_1, x_2, \dots, x_{21})$.
- THE SAMPLE MEAN $(\bar{x})$ AND SAMPLE VARIANCE (s^2) ARE CALCULATED FROM THE DATA.

STEP-BY-STEP CALCULATION OF THE 95% CONFIDENCE INTERVAL

THE PROCESS INVOLVES USING THE CHI-SQUARE DISTRIBUTION BECAUSE THE VARIANCE OF A NORMALLY DISTRIBUTED POPULATION FOLLOWS A SCALED CHI-SQUARE DISTRIBUTION.

STEP 1: COLLECT AND SUMMARIZE DATA

- OBTAIN THE SAMPLE DATA OF PIPE LENGTHS.
- CALCULATE THE SAMPLE MEAN:

$$\bar{x} = \frac{1}{N} \sum_{i=1}^N x_i$$

- CALCULATE THE SAMPLE VARIANCE:

$$s^2 = \frac{1}{N-1} \sum_{i=1}^N (x_i - \bar{x})^2$$

WHERE $(N = 21)$.

STEP 2: DETERMINE CHI-SQUARE VALUES FOR CONFIDENCE LEVEL

- FOR A 95% CONFIDENCE INTERVAL, IDENTIFY THE CHI-SQUARE CRITICAL VALUES $\chi^2_{(\alpha/2, N-1)}$ AND $\chi^2_{(1 - \alpha/2, N-1)}$, WHERE $(\alpha = 0.05)$.

- USING CHI-SQUARE DISTRIBUTION TABLES OR STATISTICAL SOFTWARE:

$$\chi^2_{(0.025, 20)} \text{ AND } \chi^2_{(0.975, 20)}$$

- TYPICAL VALUES (APPROXIMATE):

$$\chi^2_{(0.025, 20)} \approx 34.17$$
$$\chi^2_{(0.975, 20)} \approx 8.91$$

(VALUES SHOULD BE VERIFIED WITH PRECISE TABLES OR SOFTWARE FOR EXACT CALCULATIONS.)

STEP 3: CALCULATE THE CONFIDENCE INTERVAL FOR VARIANCE

- THE FORMULA FOR THE CONFIDENCE INTERVAL OF THE POPULATION VARIANCE σ^2 IS:

$$\left(\frac{(N-1) s^2}{\chi^2_{(1 - \alpha/2, N-1)}}, \frac{(N-1) s^2}{\chi^2_{(\alpha/2, N-1)}} \right)$$

- SUBSTITUTE THE VALUES:

$$\begin{aligned} \text{Lower Bound} &= \frac{20 \times s^2}{34.17} \\ \text{Upper Bound} &= \frac{20 \times s^2}{8.91} \end{aligned}$$

- CALCULATE THESE BOUNDS USING THE SAMPLE VARIANCE.

STEP 4: DERIVE THE CONFIDENCE INTERVAL FOR STANDARD DEVIATION

- TAKE THE SQUARE ROOT OF THE VARIANCE BOUNDS TO OBTAIN THE CONFIDENCE INTERVAL FOR THE STANDARD DEVIATION:

$$\left(\sqrt{\text{Lower Bound}}, \sqrt{\text{Upper Bound}} \right)$$

PRACTICAL EXAMPLE:

SUPPOSE THE SAMPLE DATA YIELDS:

- SAMPLE MEAN $(\bar{x} = 50)$ CM
- SAMPLE VARIANCE $(s^2 = 4)$ CM²

THEN:

$$\begin{aligned} \text{Lower Bound for Variance} &= \frac{20 \times 4}{34.17} \approx 2.34 \\ \text{Upper Bound for Variance} &= \frac{20 \times 4}{8.91} \approx 8.97 \end{aligned}$$

STANDARD DEVIATION BOUNDS:

$$\begin{aligned} \sqrt{2.34} &\approx 1.53 \text{ CM} \\ \sqrt{8.97} &\approx 3.00 \text{ CM} \end{aligned}$$

THEREFORE, THE 95% CONFIDENCE INTERVAL FOR THE STANDARD DEVIATION IS APPROXIMATELY (1.53 CM, 3.00 CM).

INTERPRETING THE RESULTS

THE CALCULATED INTERVAL PROVIDES A RANGE IN WHICH THE TRUE POPULATION STANDARD DEVIATION OF PIPE LENGTHS LIKELY FALLS WITH 95% CONFIDENCE. IF THIS INTERVAL IS WITHIN ACCEPTABLE QUALITY LIMITS, THE PROCESS IS CONSIDERED CONSISTENT. CONVERSELY, IF THE INTERVAL INDICATES HIGH VARIABILITY, PROCESS ADJUSTMENTS MAY BE NECESSARY.

ADDITIONAL CONSIDERATIONS AND TIPS

ENSURING DATA NORMALITY

- USE NORMALITY TESTS (E.G., SHAPIRO-WILK) OR GRAPHICAL METHODS (Q-Q PLOTS) TO VERIFY THE NORMALITY ASSUMPTION.
- IF DATA SIGNIFICANTLY DEVIATE FROM NORMALITY, CONSIDER NON-PARAMETRIC METHODS OR DATA TRANSFORMATION.

USING STATISTICAL SOFTWARE

- SOFTWARE SUCH AS R, PYTHON, OR SPSS CAN AUTOMATE CALCULATIONS:
- IN R: USE `'var.test()'` OR CUSTOM SCRIPTS FOR CHI-SQUARE BASED INTERVALS.
- IN PYTHON: USE `'scipy.stats'` FOR CHI-SQUARE CRITICAL VALUES.

LIMITATIONS OF THE METHOD

- THE METHOD ASSUMES NORMAL DISTRIBUTION.
- SMALL SAMPLE SIZES MAY LEAD TO WIDER CONFIDENCE INTERVALS.
- OUTLIERS CAN AFFECT VARIANCE ESTIMATES, SO DATA CLEANING IS RECOMMENDED.

CONCLUSION

CALCULATING THE 95% CONFIDENCE INTERVAL FOR THE STANDARD DEVIATION OF PIPE LENGTHS WITH A SAMPLE SIZE OF 21 INVOLVES UNDERSTANDING KEY STATISTICAL CONCEPTS, APPLYING THE CHI-SQUARE DISTRIBUTION, AND INTERPRETING RESULTS WITHIN THE CONTEXT OF QUALITY CONTROL. BY FOLLOWING THE OUTLINED STEPS, ENGINEERS AND STATISTICIANS CAN ACCURATELY ASSESS VARIABILITY AND MAKE DATA-DRIVEN DECISIONS TO IMPROVE MANUFACTURING PROCESSES. REMEMBER, THE ACCURACY OF THE INTERVAL HINGES ON THE NORMALITY OF DATA AND PROPER CALCULATION OF CHI-SQUARE CRITICAL VALUES. WITH PRACTICE AND PROPER TOOLS, THIS METHOD BECOMES AN INVALUABLE PART OF STATISTICAL QUALITY CONTROL IN INDUSTRIAL SETTINGS.

FREQUENTLY ASKED QUESTIONS

HOW DO I CALCULATE THE 95% CONFIDENCE INTERVAL FOR THE STANDARD DEVIATION OF PIPE LENGTHS WITH A SAMPLE SIZE OF 21?

TO FIND THE 95% CONFIDENCE INTERVAL FOR THE STANDARD DEVIATION, FIRST COMPUTE THE SAMPLE VARIANCE, THEN USE THE CHI-SQUARE DISTRIBUTION WITH $n-1$ DEGREES OF FREEDOM. THE INTERVAL IS GIVEN BY: $\left[\sqrt{\frac{(n-1)s^2}{\chi^2_1}}, \sqrt{\frac{(n-1)s^2}{\chi^2_2}} \right]$, WHERE χ^2_1 AND χ^2_2 ARE THE CHI-SQUARE CRITICAL VALUES AT 2.5% AND 97.5% LEVELS RESPECTIVELY.

WHAT IS THE FORMULA FOR CONSTRUCTING A CONFIDENCE INTERVAL FOR THE STANDARD DEVIATION BASED ON A SAMPLE?

THE CONFIDENCE INTERVAL FOR THE STANDARD DEVIATION σ IS: $\left[\sqrt{\frac{(n-1)s^2}{\chi^2_1}}, \sqrt{\frac{(n-1)s^2}{\chi^2_2}} \right]$, WHERE s^2 IS THE SAMPLE VARIANCE, n IS THE SAMPLE SIZE, AND χ^2_1 AND χ^2_2 ARE CHI-SQUARE CRITICAL VALUES AT THE DESIRED CONFIDENCE LEVEL.

WHY DO WE USE THE CHI-SQUARE DISTRIBUTION WHEN CALCULATING THE CONFIDENCE INTERVAL FOR STANDARD DEVIATION?

BECAUSE THE SAMPLE VARIANCE FOLLOWS A CHI-SQUARE DISTRIBUTION SCALED BY THE TRUE VARIANCE, USING THE CHI-SQUARE DISTRIBUTION ALLOWS US TO ACCOUNT FOR SAMPLING VARIABILITY AND CONSTRUCT ACCURATE CONFIDENCE INTERVALS FOR THE POPULATION STANDARD DEVIATION.

How do degrees of freedom affect the confidence interval for the standard deviation in this context?

Degrees of freedom, which is $n-1$ for a sample of size n , influence the chi-square critical values. Larger degrees of freedom lead to narrower confidence intervals, providing more precise estimates of the standard deviation.

What are the steps to find the 95% confidence interval for the standard deviation of pipe lengths when $n=21$?

Steps include: 1) Calculate the sample mean and standard deviation; 2) Find the sample variance; 3) Determine chi-square critical values at 2.5% and 97.5% for $df=20$; 4) Compute the interval limits using the formula: $\left[\frac{(n-1)s^2}{\chi^2_2}, \frac{(n-1)s^2}{\chi^2_1} \right]$.

If the sample standard deviation of pipe lengths is 2 meters with a sample size of 21, what is the 95% confidence interval for the population standard deviation?

First, find the chi-square critical values for $df=20$ at 2.5% and 97.5%. Then, compute the interval: $\left[\frac{(20)4}{\chi^2_2}, \frac{(20)4}{\chi^2_1} \right]$. Plugging in the values yields the interval. For example, if $\chi^2_1=10.85$ and $\chi^2_2=34.91$, the interval is approximately $\left[\frac{80}{34.91}, \frac{80}{10.85} \right] \approx [1.52, 2.72]$ meters.

What assumptions are necessary for calculating the confidence interval of the standard deviation in this problem?

The main assumptions are that the pipe lengths are normally distributed, the sample is random and independent, and the data accurately represent the population of pipe lengths.

Additional Resources

Find the 95% confidence interval for the standard deviation of the lengths of pipes if a sample of 21

Introduction

In quality control and manufacturing processes, understanding the variability of product measurements is critical. For industries producing pipes, ensuring that the lengths conform to specified standards is essential for compatibility, safety, and customer satisfaction. A key statistical measure in this context is the standard deviation, which quantifies the spread or dispersion of the pipe lengths in a sample.

When analyzing a sample of pipe lengths, a common question is: what is the true standard deviation of the entire production batch? Since we rarely have access to the entire population, statisticians rely on confidence intervals to estimate this parameter with a specified level of certainty. Specifically, the 95% confidence interval for the standard deviation provides an interval estimate that has a 95% probability of containing the true standard deviation.

This article examines the process of calculating the 95% confidence interval for the standard deviation based on a sample of 21 pipes. We will explore the underlying statistical principles, the assumptions involved, and the step-by-step methodology to arrive at a reliable interval estimate.

The Importance of Confidence Intervals in Manufacturing

WHY ESTIMATE THE STANDARD DEVIATION?

STANDARD DEVIATION REFLECTS THE CONSISTENCY OF A MANUFACTURING PROCESS. A SMALL STANDARD DEVIATION INDICATES THAT PIPE LENGTHS ARE TIGHTLY CLUSTERED AROUND THE MEAN, SIGNIFYING HIGH PRECISION. CONVERSELY, A LARGE STANDARD DEVIATION SUGGESTS VARIABILITY THAT COULD LEAD TO DEFECTIVE PRODUCTS OR INCOMPATIBILITY ISSUES.

THE ROLE OF CONFIDENCE INTERVALS

WHILE POINT ESTIMATES OF STANDARD DEVIATION ARE USEFUL, THEY DO NOT ACCOUNT FOR SAMPLING VARIABILITY. CONFIDENCE INTERVALS PROVIDE A RANGE WITHIN WHICH THE TRUE STANDARD DEVIATION IS EXPECTED TO LIE WITH A CERTAIN PROBABILITY—IN THIS CASE, 95%. THIS HELPS MANUFACTURERS ASSESS PROCESS STABILITY AND MAKE INFORMED DECISIONS ABOUT QUALITY IMPROVEMENTS.

FUNDAMENTAL STATISTICAL CONCEPTS

THE SAMPLE AND POPULATION

- SAMPLE SIZE (N): 21 PIPES
- SAMPLE DATA: LENGTHS OF THE 21 PIPES
- POPULATION PARAMETER: TRUE STANDARD DEVIATION (σ) OF ALL PIPES PRODUCED

ASSUMPTIONS

FOR THE CONFIDENCE INTERVAL FOR THE STANDARD DEVIATION TO BE VALID, THE FOLLOWING ASSUMPTIONS SHOULD BE SATISFIED:

- THE SAMPLE IS RANDOMLY SELECTED FROM THE POPULATION.
- THE DATA ARE APPROXIMATELY NORMALLY DISTRIBUTED.
- THE PROCESS IS STABLE DURING SAMPLING.

VIOLATIONS OF THESE ASSUMPTIONS MAY LEAD TO INACCURATE ESTIMATES, BUT FOR SUFFICIENTLY LARGE SAMPLES OR SYMMETRIC DISTRIBUTIONS, THE METHODS REMAIN ROBUST.

THEORETICAL FOUNDATION

CHI-SQUARE DISTRIBUTION AND VARIANCE

THE KEY TO CONSTRUCTING THE CONFIDENCE INTERVAL FOR THE STANDARD DEVIATION LIES IN THE RELATIONSHIP BETWEEN THE SAMPLE VARIANCE AND THE CHI-SQUARE DISTRIBUTION.

- THE SAMPLE VARIANCE (s^2) IS CALCULATED AS:

$$s^2 = (1 / (n - 1)) \sum (x_i - \bar{x})^2$$

- THE SCALED SAMPLE VARIANCE ($(n - 1) s^2 / \sigma^2$) FOLLOWS A CHI-SQUARE DISTRIBUTION WITH $(n - 1)$ DEGREES OF FREEDOM.

CONFIDENCE INTERVAL FORMULA

GIVEN THE CHI-SQUARE DISTRIBUTION, THE 95% CONFIDENCE INTERVAL FOR THE POPULATION VARIANCE (σ^2) IS:

$$[(n - 1) s^2 / \chi^2_{(UPPER)}, (n - 1) s^2 / \chi^2_{(LOWER)}]$$

WHERE:

- $\chi^2_{\text{(LOWER)}} = \text{CHI-SQUARE CRITICAL VALUE AT } (1 - \alpha/2) \text{ PERCENTILE WITH } (n - 1) \text{ DEGREES OF FREEDOM}$
- $\chi^2_{\text{(UPPER)}} = \text{CHI-SQUARE CRITICAL VALUE AT } (\alpha/2) \text{ PERCENTILE WITH } (n - 1) \text{ DEGREES OF FREEDOM}$

ONCE THE INTERVAL FOR Σ^2 IS OBTAINED, TAKE SQUARE ROOTS TO GET THE INTERVAL FOR Σ :

$[\sqrt{\Sigma^2_{\text{(LOWER)}}}, \sqrt{\Sigma^2_{\text{(UPPER)}}}]$

STEP-BY-STEP CALCULATION

1. COLLECT SAMPLE DATA

SUPPOSE THE SAMPLE OF 21 PIPE LENGTHS YIELDS:

- SAMPLE MEAN ($\bar{x}$): CALCULATED FROM THE DATA
- SAMPLE STANDARD DEVIATION (s): CALCULATED FROM THE DATA

NOTE: SINCE ACTUAL DATA ARE NOT PROVIDED, WE'LL DEMONSTRATE THE CALCULATION WITH HYPOTHETICAL SAMPLE VARIANCE.

2. DETERMINE SAMPLE VARIANCE

ASSUMING THE SAMPLE VARIANCE (s^2) HAS BEEN CALCULATED AS, FOR EXAMPLE, 0.25 (UNITS SQUARED).

3. IDENTIFY DEGREES OF FREEDOM

- $n = 21$
- DEGREES OF FREEDOM (DF) = $n - 1 = 20$

4. FIND CHI-SQUARE CRITICAL VALUES

USING CHI-SQUARE DISTRIBUTION TABLES OR SOFTWARE:

- $\chi^2_{\text{(LOWER)}} = \chi^2 \text{ VALUE AT } 2.5\text{TH PERCENTILE WITH } 20 \text{ DF}$
- $\chi^2_{\text{(UPPER)}} = \chi^2 \text{ VALUE AT } 97.5\text{TH PERCENTILE WITH } 20 \text{ DF}$

FROM STANDARD TABLES:

- $\chi^2_{\text{(LOWER)}} \approx 10.85$
- $\chi^2_{\text{(UPPER)}} \approx 34.17$

5. CALCULATE CONFIDENCE INTERVAL FOR VARIANCE

APPLYING THE FORMULA:

LOWER BOUND FOR Σ^2 :

$$(n - 1) s^2 / \chi^2_{\text{(UPPER)}} = 20 \cdot 0.25 / 34.17 \approx 0.146$$

UPPER BOUND FOR Σ^2 :

$$(n - 1) s^2 / \chi^2_{\text{(LOWER)}} = 20 \cdot 0.25 / 10.85 \approx 0.462$$

6. DERIVE CONFIDENCE INTERVAL FOR STANDARD DEVIATION

TAKING SQUARE ROOTS:

- LOWER BOUND: $\sqrt{0.146} \approx 0.382$ UNITS
- UPPER BOUND: $\sqrt{0.462} \approx 0.68$ UNITS

THUS, THE 95% CONFIDENCE INTERVAL FOR THE TRUE STANDARD DEVIATION OF PIPE LENGTHS IS APPROXIMATELY [0.382, 0.68] UNITS.

PRACTICAL IMPLICATIONS

QUALITY ASSURANCE

THIS INTERVAL ESTIMATE INFORMS QUALITY MANAGERS WHETHER THE PROCESS VARIABILITY IS WITHIN ACCEPTABLE LIMITS. IF THE UPPER BOUND EXCEEDS THE ALLOWABLE PROCESS VARIATION, CORRECTIVE MEASURES MIGHT BE NECESSARY.

PROCESS IMPROVEMENT

IDENTIFYING THE DEGREE OF VARIABILITY HELPS IN PINPOINTING SOURCES OF INCONSISTENCY, SUCH AS TOOL WEAR, MATERIAL VARIABILITY, OR OPERATOR DIFFERENCES.

REGULATORY COMPLIANCE

CERTIFYING BODIES MAY REQUIRE DOCUMENTED CONFIDENCE INTERVALS TO DEMONSTRATE PROCESS CONTROL AND ADHERENCE TO STANDARDS.

LIMITATIONS AND CONSIDERATIONS

NORMALITY ASSUMPTION

THE VALIDITY OF THE CHI-SQUARE BASED INTERVAL DEPENDS HEAVILY ON THE NORMALITY OF THE DATA. NON-NORMAL DATA MAY RESULT IN INACCURATE ESTIMATES.

SAMPLE SIZE

WHILE THE SAMPLE SIZE OF 21 IS MODERATE, LARGER SAMPLES TEND TO PRODUCE MORE RELIABLE ESTIMATES. SMALL SAMPLES INCREASE UNCERTAINTY.

OUTLIERS

EXTREME VALUES CAN SKEW THE VARIANCE ESTIMATE, AFFECTING THE CONFIDENCE INTERVAL. DATA SHOULD BE INSPECTED FOR OUTLIERS BEFORE ANALYSIS.

CONCLUSION

ESTIMATING THE 95% CONFIDENCE INTERVAL FOR THE STANDARD DEVIATION OF PIPE LENGTHS BASED ON A SAMPLE OF 21 PIPES INVOLVES UNDERSTANDING THE RELATIONSHIP BETWEEN SAMPLE VARIANCE AND THE CHI-SQUARE DISTRIBUTION. BY CAREFULLY CALCULATING THE SAMPLE VARIANCE, IDENTIFYING APPROPRIATE CHI-SQUARE CRITICAL VALUES, AND APPLYING THE FORMULA, MANUFACTURERS AND QUALITY ASSURANCE PROFESSIONALS CAN OBTAIN A MEANINGFUL INTERVAL ESTIMATE.

THIS STATISTICAL INSIGHT NOT ONLY AIDS IN ASSESSING PROCESS STABILITY BUT ALSO GUIDES DECISIONS REGARDING PROCESS IMPROVEMENTS, COMPLIANCE, AND CUSTOMER SATISFACTION. AS WITH ALL INFERENTIAL STATISTICS, ASSUMPTIONS AND SAMPLE QUALITY PLAY VITAL ROLES IN ENSURING THE ACCURACY AND USEFULNESS OF THE CONCLUSIONS DRAWN.

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