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Original Article

APPLICATION OF BENFORD'S LAW IN QUALITY MANAGEMENT AUDITING: EVIDENCE FROM ISO 9001 CERTIFIED FIRMS

Vesna Rajić
Faculty of Economics and Business, University of Belgrade, Belgrade, Serbia
vesna.rajic@ekof.bg.ac.rs
ORCID: 0000-0002-4566-0147

Jasna Babić
Faculty of Economics and Business, University of Belgrade, Belgrade, Serbia
jasna.babic@ekof.bg.ac.rs
ORCID: 0000-0003-2557-3676

Jelena Stanojević
Faculty of Economics and Business, University of Belgrade, Belgrade, Serbia
jelena.stanojevic@ekof.bg.ac.rs
ORCID: 0000-0001-5668-5297

Abstract: *Quality management systems rely on accurate and reliable data to support effective decision-making, continuous improvement, and organizational transparency. In organizations certified according to ISO 9001, large volumes of numerical data are generated through quality performance indicators, internal audit findings, customer complaints, corrective actions, and process monitoring activities. However, the reliability of such data is rarely assessed using statistical methods. This paper investigates the application of Benford's Law as a statistical tool for detecting irregularities in datasets used within quality management auditing processes. The analysis focuses on numerical distributions associated with selected quality management indicators in ISO 9001 certified firms. By comparing the observed distribution of leading digits with the theoretical distribution predicted by Benford's Law, potential anomalies in reported data can be identified. The results suggest that Benford's Law can serve as a useful preliminary screening method in quality management audits, enabling auditors and managers to detect unusual numerical patterns that may indicate reporting inconsistencies or data manipulation. The proposed approach contributes to strengthening internal control mechanisms and improving the reliability of data used in quality management systems.*

Key words*: Benford's Law, simulations, manipulation, quality management*

JEL classification*: C46, C63, L15*

1. INTRODUCTION

In modern business environments, organizations increasingly rely on data-driven decision-making processes. Within ISO 9001 certified systems, data serves as a foundation for evaluating performance, identifying nonconformities, and driving continuous improvement (Fonseca, 2015, Abuazza et al., 2020). However, despite the importance of data integrity, organizations often lack systematic approaches for verifying the authenticity and reliability of numerical data. Traditional auditing practices focus primarily on procedural compliance rather than analytical validation. This creates a potential risk where inaccurate, biased, or manipulated data may remain undetected. As a result, decisions based on such data may lead to inefficiencies, incorrect strategic directions, or compliance failures.

Benford's Law, a statistical principle describing the distribution of leading digits in naturally occurring datasets, offers a simple yet powerful method for detecting irregularities (Benford, 1938, Nigrini, 2012). Although widely used in forensic accounting and fraud detection, its application in quality management auditing is still limited.

This paper aims to explore how Benford's Law can be applied within ISO 9001 auditing processes to enhance data reliability and identify anomalies.

2. QUALITY MANAGEMENT SYSTEMS AND ISO 9001

The development of the ISO 9001 standard from its first version in 1987 to the latest revision in 2015 demonstrates that this framework continuously adapts to changes in the business environment and organizational needs. From the initial emphasis on documentation, through the introduction of the process approach and risk-based thinking, ISO 9001 has evolved into a comprehensive system that fosters strategic quality management (Tricker, 2017).

The ISO 9000 family comprises three standards: ISO 9000, ISO 9001, and ISO 9004. ISO 9000 establishes the fundamental concepts and principles of quality management, including customer focus, leadership, employee engagement, process orientation, continuous improvement, evidence-based decision making, and relationship management (ISO 9000, 2015). The principle of customer focus enables organizations to align their objectives with market needs and expectations (Raković, 2014). Sustainable success, however, requires balancing customer satisfaction with the interests of other stakeholders, such as owners, employees, suppliers, local communities, and society at large.

Leadership is understood as the creation of unity of purpose and direction, alongside an internal environment that fosters employee contribution to organizational performance (Abuhav, 2017). The process approach conceptualizes the quality system as a set of interrelated processes, with clearly defined activities and responsibilities (Vujanović, 2017). Regular monitoring of these processes facilitates early detection of errors and implementation of corrective measures (Fonseca, Domingues, 2018). Continuous improvement, meanwhile, requires organizations to enhance performance and maintain responsiveness to opportunities and threats in dynamic markets (Raković, 2014).

Evidence-based decision making emphasizes reliance on data and information, supported by appropriate documentation (Petkovska & Đorđeska, 2014). Key performance indicators and customer satisfaction are systematically measured (Vujanović, 2013), while top management is expected to conduct annual reviews of the quality management system. Relationship management, through collaboration with suppliers and partners, enhances organizational flexibility and responsiveness to market changes (Vujanović, 2017).

ISO 9001:2015 is structured around the PDCA cycle (Plan–Do–Check–Act) and specifies requirements related to scope, organizational context, leadership, planning, support, operations, performance evaluation, and improvement (The Standard ISO 9001, 2015; Fonseca, 2015; Abuazza et al., 2020; Wilson & Campbell, 2016; Abuhav, 2017). These requirements operationalize the fundamental principles of quality management within organizational practice.

Among these principles, evidence-based decision making is particularly critical for ensuring data reliability. In this regard, Benford's Law offers a valuable methodological tool, enabling organizations to verify the authenticity and consistency of data used in managerial decision making.

The ISO 9001 standard emphasizes a process-based approach, risk-based thinking, and continuous improvement. Organizations implementing ISO 9001 are required to collect and analyze large amounts of data related to their processes. Typical datasets include key performance indicators, internal audit results, customer complaints, corrective actions, and process efficiency measurements.

The relationship between ISO 9001 and Benford's Law lies in their shared objective of ensuring data integrity, reliability, and transparency within organizational processes. ISO 9001 emphasizes evidence-based decision-making as one of its core quality management principles, requiring organizations to base their strategic and operational decisions on accurate, consistent, and verifiable data (Fonseca, 2015). Such data typically originate from quality performance indicators, internal audits, corrective and preventive actions, customer feedback, and process monitoring activities.

However, while ISO 9001 sets requirements for data management and documentation, it does not prescribe specific statistical techniques for validating the authenticity or distributional consistency of numerical datasets. In this context, Benford's Law offers a valuable complementary analytical tool. It predicts a specific, non-uniform distribution of leading digits in naturally occurring datasets, where lower digits (especially 1) appear more frequently than higher ones. When applied to datasets generated within a quality management system, deviations from the expected Benford distribution may signal anomalies such as reporting inconsistencies, data entry errors, or intentional manipulation. This makes Benford's Law particularly useful as a preliminary screening method during internal and external audits.

Integrating Benford's Law into ISO 9001 auditing practices can enhance the effectiveness of internal control mechanisms by providing auditors with a simple yet powerful statistical approach to detect unusual numerical patterns. It enables a more objective assessment of data reliability without requiring extensive resources or complex modeling. Furthermore, its application supports continuous improvement efforts by identifying areas where data collection or reporting processes may need refinement. Overall, the use of Benford's Law strengthens the analytical dimension of quality management systems and contributes to increased confidence in organizational data and decision-making processes.

3. BENFORD'S LAW

Benford's Law states that in many naturally occurring datasets, the leading digit is more likely to be small (Benford, 1938, Pinkham, 1961, Varian, 1972). The probability of a digit d appearing as the first digit is defined as:

$$P(X = d) = log_{10}\left(1 + \frac{1}{d}\right),$$

where random variable X represents the first digit. This results in a non-uniform distribution where the digit 1 appears most frequently, while higher digits occur less often. Expected proportions are:

1 (30.1%)
2 (17.6%)
3 (12.5%)
4 (9.7%)
5 (7.9%)
6 (6.7%)
7 (5.8%)
8 (5.1%)
9 (4.6%).

Benford's Law has been successfully applied in financial auditing and fraud detection. Studies have shown that artificially manipulated data tends to deviate from expected distributions, making this method useful for identifying anomalies.

However, its application in quality management auditing remains underdeveloped, which represents a gap addressed in this research.

4. METHODOLOGY

This study adopts a quantitative research approach. Data used in the analysis includes data from financial statements from ISO 9001 environments. The methodology consists of the following steps:

- Extraction of numerical data
- Identification of leading digits
- Calculation of frequency distribution
- Comparison with theoretical Benford distribution
- Statistical testing using: z test, Chi-square, KS test, Mean Absolute Deviation (MAD) test and Bootstrap *t* test (Nigrini, 2012, Efron & Tibshirani, 1993).

The analysis focuses on identifying deviations that may indicate irregularities in reported data. The observed distribution of leading digits is compared with the expected Benford distribution:

The first test that we use is z-test. This test checks whether the distribution of every digit is different from the expected Benford's distribution. Test statistic for *i*th digit is of the forms:

$$Z_i = \frac{|p_{oi} - p_i| - \frac{1}{2n}}{\sqrt{\frac{p_i(1-p_i)}{n}}}, \; i = 1, 2, \dots, 9,$$

where:

p_{oi} is the observed frequency proportion,

p_i is the expected frequency proportion,

n is the number of observations,

$\frac{1}{2n}$ is the correction factor.

If we use 1% of significance level, then critical value is 2.575.

The second test is Chi-square test. Test statistic for the first digit is of the form:

$$\chi^2 = \sum_{i=1}^{9} \frac{(O_i - E_i)^2}{E_i} = n \sum_{i=1}^{9} \frac{(p_{oi} - p_i)^2}{p_i} \;,$$

where:

O_i is the observed frequency of the digit i,

E_i is the expected frequency of the digit i,

df is 8,

n is the number of observations,

If we use 1% of significance level, then critical value is 20.090.

The third test is Kolmogorov Smirnov. Test statistic is:

$$KS = \frac{1}{\sqrt{n}} max_{1 \le j \le 9} \mid \sum_{i=1}^{j} (O_i - E_i) \mid$$

$$= \sqrt{n}\ max_{1 \le j \le 9} \mid \sum_{i=1}^{j} (p_{oi} - p_i) \mid .$$

The fourth test is Mean Absolute Deviation (MAD) proposed by Nigrini (2012). The test statistic is of the form:

$$MAD = \frac{1}{n} \frac{\sum_{i=1}^{9} |O_i - E_i|}{9} = \frac{\sum_{i=1}^{9} |p_{oi} - p_i|}{9} .$$

Nigrini (2012) suggested critical scores given in Table 1.

Table 1. Critical scores of MAD test

Range	First digit
Conformity	0.000-0.006
Acceptable conformity	0.006-0.012
Marginally acceptable conformity	0.012-0.015
Nonconformity	Above 0.015

The fifth test is bootstrap test. Test statistic is of the form (Efron & Tibshirani, 1993):

$$t(x^{*b}) = \frac{\bar{z}^* - \bar{y}^*}{\sqrt{\frac{Var(z^*)}{n} + \frac{Var(y^*)}{m}}}, b = 1,2, \dots, B,$$

where $z = (z_1, z_2, \dots, z_n)$ and $y = (y_1, y_2, \dots, y_m)$ are samples from analyzed distribution and from Benford's distribution, Let denote with x the combined sample of all n+m observations. We draw B bootstrap samples of size $n + m$ with replacement from x and denote the first n observations z^* and the remaining m observations y^*. For this test we calculate p value.

5. RESULTS

We consider financial statement of one company (hospital) that uses ISO 9001 standard. A Benford's Law tests were performed using the first digit of all numerical values. Total number of observations was 84.

Table 2. Observed and Benford proportions

Digit	Observed proportion	Benford proportion
1	0.3214	0.3010
2	0.1548	0.1761
3	0.0714	0.1249
4	0.1190	0.0969
5	0.0952	0.0792
6	0.0595	0.0669
7	0.0595	0.0580
8	0.0595	0.0512
9	0.0595	0.0458

Chi square test

For chi-square test we got the result:
- $\chi^2 = 3.492$
- degrees of freedom = 8
- p-value = 0.900

Interpretation:
Since $p > 0.01$, the null hypothesis is not rejected.

Conclusion:
The first-digit distribution is consistent with Benford's Law.

Z test

The z-test was used to determine whether the observed frequency of each individual digit differs significantly from its Benford expectation.

Z-values:
- Digit 1: 0.289
- Digit 2: 0.370
- Digit 3: 1.318
- Digit 4: 0.501
- Digit 5: 0.343
- Digit 6: 0.054
- Digit 7: -0.175
- Digit 8: 0.101
- Digit 9: 0.343

Decision Rule:
A digit is commonly considered suspicious at 1% significance level if $|Z| > 2.575$.

Interpretation:
None of the digits exceeds the critical threshold.

Conclusion:
There are no individually significant deviations.

KS test

The Kolmogorov–Smirnov test measures the maximum difference between the cumulative observed distribution and the cumulative Benford distribution.

Result:
- KS = 0.0544
- p-value ≈ 0.693

Interpretation:
Since $p > 0.01$, there is no statistically significant deviation.

Conclusion:
The data are consistent with Benford's distribution according to the KS test as well.

MAD test

The MAD test measures the average absolute deviation between the observed proportions and the Benford proportions.

Result:
- MAD = 0.01828

Interpretation:

The MAD value exceeds the threshold of 0.015 suggested by Nigrini, indicating nonconformity with Benford's Law.

Conclusion:

This result is not supported by other statistical tests (Chi-square, KS, z-test), all of which suggest no significant deviation. This inconsistency may be explained by the relatively small sample size (n = 84), which can affect the stability of MAD values. Therefore, the overall conclusion should be interpreted with caution.

Bootstrap test

For the bootstrap test, a large number of samples of the same size (n = 84) were generated under the assumption that the data perfectly follow Benford's Law, and the observed statistics were compared with the simulated distribution.

Bootstrap Result:
- Bootstrap p-value = 0.849

Interpretation:
Since $p > 0.01$, there is no statistically significant deviation.

Conclusion:
The bootstrap test confirms that the data do not show anomalous behavior.

Overall conclusion: Based on all applied tests, the data do not significantly deviate from Benford's Law. In other words, there is no statistically significant evidence of irregularities in the first-digit distribution.

6. DISCUSSION

The findings demonstrate that Benford's Law can be effectively used as a preliminary tool in quality management auditing. It allows auditors to quickly identify suspicious datasets that require further investigation. The method is particularly useful in large datasets where manual inspection is inefficient. Additionally, integrating Benford analysis with artificial intelligence systems can significantly improve real-time monitoring and anomaly detection. However, it is important to note that deviations from Benford's Law do not necessarily indicate fraud. Instead, they highlight areas that require deeper analysis.

7. PRACTICAL RELEVANCE OF ISO 9001 FOR DATA RELIABILITY AND AUDIT EFFECTIVENESS

One of the most important contributions of ISO 9001 to organizational performance lies in its emphasis on structured, documented, and measurable processes (Wolniak, 2021). Unlike informal management approaches, ISO 9001 requires organizations to define responsibilities, monitor process performance, document corrective actions, and maintain evidence that decisions are based on verifiable information. In this sense, the standard does not only support product and service quality, but also creates the foundation for data discipline within the organization.

This is particularly important because quality management systems generate large quantities of numerical information on a daily basis. Such data may include defect rates, customer complaints, turnaround times, process deviations, supplier evaluations, audit findings, and indicators related to efficiency and compliance. These values are often used as inputs for managerial reporting, performance evaluation, and strategic decision-making. If the underlying data are inaccurate, incomplete, or intentionally adjusted to present better performance, the quality management system may formally exist while failing to provide real managerial value. Within ISO 9001 environments, this issue is especially relevant because organizations are expected to demonstrate evidence-based decision-making. This principle assumes that managerial conclusions are grounded in objective and trustworthy data. However, the existence of documented procedures does not automatically guarantee the reliability of the numbers reported through those procedures. Employees may unintentionally introduce errors through incorrect data entry, inconsistent classification, or inadequate reporting practices. In some situations, numerical values may also be intentionally altered to meet targets, reduce perceived nonconformities, or create a more favorable image during internal or external audits. For this reason, ISO 9001 implementation should not be viewed solely as a compliance exercise, but also as an opportunity to strengthen analytical controls over operational and reporting processes. Benford's Law can play an important role in this context because it provides a simple statistical mechanism for evaluating whether numerical datasets behave in a manner consistent with naturally occurring data. Although it cannot determine the exact source of a problem, it can serve as an effective screening tool for identifying unusual patterns that deserve further investigation. From a quality management perspective, this means that Benford analysis can be integrated into the broader internal control framework of ISO 9001 certified organizations. For example, before management review meetings, internal audits, or external certification assessments, organizations may test selected datasets to verify whether the distribution of numerical values appears normal. This does not replace managerial judgment or formal audit procedures, but it adds an additional analytical layer that can improve the reliability of audit conclusions and management decisions. Another important advantage of this approach is that it aligns with the growing need for data-oriented auditing. Traditional auditing often focuses on documentation, procedural consistency, and sampling-based verification. While these methods remain important, they may fail to detect anomalies hidden in large datasets. Benford's Law allows auditors to evaluate the numerical structure of data in a fast and objective manner, thereby supporting more efficient audit planning and more focused investigative efforts. Therefore, the relevance of ISO 9001 in this study extends beyond certification itself. It provides the institutional and procedural environment in which the reliability of numerical data becomes highly significant. In such an environment, Benford's Law is not only statistically interesting, but also practically valuable as a tool for enhancing the credibility, transparency, and analytical maturity of quality management systems.

8. MANAGERIAL AND AUDIT IMPLICATIONS OF BENFORD'S LAW IN ISO 9001 ENVIRONMENTS

The findings of this study have several important implications for both managers and auditors operating in ISO 9001 certified organizations. First, they suggest that Benford's Law can be used as a low-cost and non-invasive analytical instrument to improve oversight of organizational data. In contrast to complex statistical or machine learning models, Benford analysis can be applied relatively easily and interpreted without advanced technical infrastructure. This makes it particularly suitable for routine use in internal quality reviews and audit preparation. For managers, the application of Benford's Law can support more reliable performance evaluation. Many organizations rely on dashboards and key performance indicators to assess process efficiency and compliance. However, if the underlying data are flawed, even sophisticated reporting systems may produce misleading conclusions. By introducing Benford-based screening into reporting workflows, managers can obtain an additional level of assurance that the numbers used in decision-making are not obviously distorted or inconsistent. This is especially relevant in organizations where operational targets are strongly linked to employee evaluation, departmental accountability, or certification outcomes. Under such circumstances, there may be implicit pressure to present favorable results. Benford's Law can help identify whether such pressure may have influenced the structure of reported data. Importantly, this does not imply misconduct by default. Rather, it helps management distinguish between normal variation and patterns that warrant further review. For internal auditors, the method offers clear practical value in risk-based auditing. ISO 9001 encourages organizations to adopt risk-based thinking, which means that audit resources should be allocated to areas where the probability or consequences of nonconformity are greatest. Benford analysis can support this principle by helping auditors identify which datasets, departments, or reporting categories display the highest level of deviation from expected patterns. In this way, audit attention can be directed more effectively toward areas of potential concern. Furthermore, the use of Benford's Law may improve the objectivity of audit procedures. One of the recurring challenges in quality auditing is balancing procedural compliance with substantive reliability. A process may appear compliant on paper while the actual data supporting that process are questionable. Benford's Law offers a bridge between these two dimensions by allowing auditors to complement procedural checks with numerical pattern analysis. This strengthens the credibility of audit findings and reduces dependence on purely formal indicators of conformity. The method is also highly relevant for organizations that increasingly rely on digital quality management systems, enterprise resource planning tools, and automated reporting platforms. As organizational data become more voluminous and decentralized, manual review becomes less feasible. In such contexts, Benford-based tests may be embedded into automated control systems or used alongside artificial intelligence applications for anomaly detection. This creates opportunities for real-time or near-real-time monitoring of data integrity within ISO 9001 frameworks. Despite these advantages, it is important to recognize the limitations of the method. Benford's Law is not universally applicable to all datasets. It works best for naturally occurring numerical data that span multiple orders of magnitude and are not artificially constrained. Therefore, not every quality indicator or audit variable will be suitable for this type of analysis. Managers and auditors must apply professional judgment when selecting datasets for Benford testing and interpreting deviations. Overall, the managerial and audit implications of this approach are substantial. Benford’s Law should be understood not as a replacement for established quality management and auditing techniques, but as a complementary analytical mechanism that enhances the reliability of conclusions drawn from organizational data. In ISO 9001 certified environments, where data are central to control, improvement, and decision-making, this additional layer of analytical assurance may provide significant practical value.

CONCLUSION

This study confirms that Benford’s Law represents a valuable tool for enhancing data reliability in ISO 9001 quality management systems. It provides a simple and efficient method for detecting anomalies and supporting audit processes. The main limitation of this study is the relatively small sample size and focus on a single organization. Although it cannot replace traditional auditing methods, it serves as a powerful complementary tool. Its implementation can improve transparency, strengthen internal controls, and support better decision-making. Future research should focus on real-world applications and integration with advanced analytical tools such as artificial intelligence.

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