International Journal of Innovative Research in Computer Science and Technology (IJIRCST)
ISSN (Online): 2347-5552, Volume-14, Issue-3, May 2026
DOI: https://doi.org/10.55524/ijircst.2026.14.3.1
Article ID IJIRE-1421, Pages 1-7
www.ijircst.org

Analytical Model for Assessing the Reliability of Accounting Data of Telecommunication Infrastructure Facilities

Makhsum Makhmudov

Director, PhD, LLC UNICON.UZ, Tashkent, Uzbekistan

Correspondence should be addressed to Makhsum Makhmudov maxmudovunicon@gmail.com

Received: 18 March 2026; Revised: 2 April 2026; Accepted: 15 April 2026

ABSTRACT- This article presents a method for quantitatively assessing the reliability of telecommunications infrastructure facility accounting data. This method combines the dynamics of facility changes, the rate of record updates, and the probability of input and processing errors. Changes to facilities and record updates are described as competing Poisson flows with intensities λo and λu, allowing for the generation of steady-state and dynamic estimates of data relevance. To interpret the system's operating modes, a degradation coefficient is introduced, characterizing the relative impact of changes on record maintenance processes. For a comprehensive assessment, an integrated indicator of information reliability is proposed, combining completeness, coordinate accuracy, topological consistency, attribute consistency, record relevance, and the impact of processing errors. An example of the method's application to a digital cadastre of telecommunications infrastructure is provided, demonstrating the model's potential for substantiating data update procedures and quality management measures.

KEYWORDS- Telecommunication Infrastructure, Digital Cadastre, Data Reliability, Record Relevance, Degradation Coefficient, Stochastic Model, Information Reliability, Data Quality, Record Update Management, GIS.

I. INTRODUCTION

Digital inventory management of telecommunications infrastructure assets has gradually evolved from a supporting registration procedure into a fundamental element of industry resource management. For telecom operators and infrastructure organizations, the quality of cadastral records determines the accuracy of inventory, the appropriateness of modernization planning, the reliability of operational support, and the validity of investment decisions. If the record does not correspond to the actual condition of the asset, the errors extend to subsequent calculations, management procedures, and operating regulations.

Data quality research has long demonstrated that this property cannot be reduced solely to the formal correctness of database fields. Information quality is viewed as a multidimensional category [1][2][3], including accuracy, completeness, consistency, timeliness, relevance, and suitability for use in a specific context. This approach became the methodological basis for the subsequent transition from local reliability assessments to integrated indicators of data quality and reliability [4].

For spatially distributed systems, coordinate accuracy, topological consistency, and object comparability in the geographic information environment are of additional importance. International standards for geographic information quality [1] and spatial data quality emphasize that when analyzing infrastructure networks, it is necessary to simultaneously consider substantive, geometric, and procedural quality aspects.

This problem is particularly pressing for the telecommunications industry [5][6], as the network's asset structure changes unevenly: some infrastructure elements are rarely upgraded, while others are constantly undergoing technological transformation. Furthermore, account update processes are subject to organizational regulations, the availability of primary information, and the quality of control procedures. Therefore, the reliability of account data must be assessed not only by the existence of the record, but also by the likelihood of its relevance and accuracy over time.

Literature on telecommunications GIS systems and infrastructure analysis has demonstrated that a geographic information approach is effective for assessing the availability, placement, and design of network facilities. However, these studies often focus on spatial representation and optimization of network configurations, while the task of analytically assessing the reliability of cadastral records themselves is significantly less well-developed. This necessitates the development of a model that links the dynamics of facility changes, record update discipline, and the quality of information processing within a single quantitative framework.

The purpose of this article is to develop and present a method for assessing the reliability of accounting data for telecommunications infrastructure facilities. To achieve this goal:

1) the stationary probability of the current state of a record is formalized;
2) a dynamic model of change in relevance over time is constructed;
3) a degradation coefficient is introduced;
4) an integral indicator of information reliability is formed;
5) an example of the practical application of the method is provided.

II. MATERIALS AND METHODS

A. *Initial assumptions of the model*

The elementary object of analysis is an individual telecommunications infrastructure [8] facility and its corresponding cadastral record. Changes to the facility, including changes to technical specifications, upgrades, relocations, node reconfigurations, and other transformations, are assumed to occur as a Poisson flow with intensity λo. Account updates, performed according to regulations or upon detection of changes, are also modeled as a Poisson flow with intensity λu [7][8].

Let's assume that a record is considered current if the last event in the concurrent streams was an update, not a change, to the object. This assumption reflects the natural logic of data maintenance: any change to an object, without a timely update, renders the record obsolete, while the update procedure restores the record's correspondence to the actual state of the object.

$$P\{\text{latest event-update}\} = \frac{\lambda_u}{\lambda_o + \lambda_u} \qquad (1)$$

The resulting expression (1) specifies the stationary probability of a record being in an up-to-date state in the absence of information processing errors.

In the real-world operating conditions of cadastral systems, it is necessary to consider the probability of data entry and processing errors due to human error, software failures, and limited control procedures. Let ε denote the probability of a processing error. Then, the probability of error-free processing will be (1− ε), and the basic steady-state estimate of the reliability of accounting data will be written as follows.

$$R_{\text{D}}^{(\infty)} = \frac{\lambda_u}{\lambda_o + \lambda_u} \cdot (1 - \varepsilon) \qquad (2)$$

Expression (2) relates the intensity of object changes, the intensity of record updating, and the quality of information processing. For convenience in further calculations, we introduce an auxiliary quantity p - the stationary probability of the current state of a record.

$$R_{\text{D}}^{(\infty)} = P \cdot (1 - \varepsilon) \qquad (3)$$

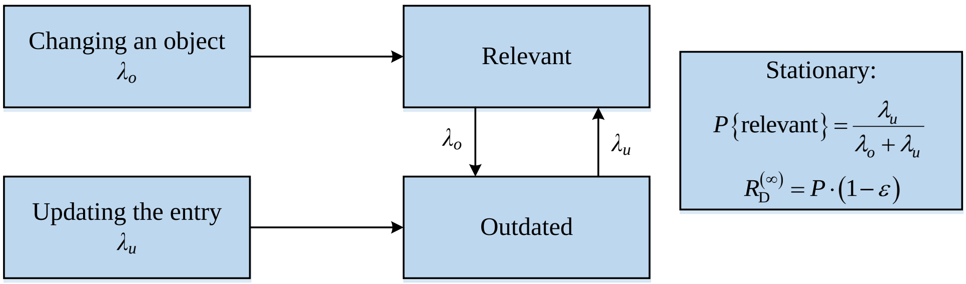

Figure 1: Competition of “change-update” flows (λo, λu)

Figure 1 illustrates the transition of a record from the "Relevant" state to the "Outdated" state with intensity λo and the reverse transition with intensity λu. This diagram corresponds to two states of an account and serves as the basis for stationary and dynamic analysis.

B. *Dynamic model of data relevance change*

For monitoring and control purposes, it's important to consider not only the limiting steady-state values but also the time dynamics of the system's transition to a stable state. Let p(t) denote the probability that a cadastral record is current at time t. Changes to the object then transition the record from the "Relevant" state to the "Outdated" state, and updates transition it back:

$$\frac{dp(t)}{dt} = \lambda_u \left(1 - p(t)\right) - \lambda_o p(t) \qquad (4)$$

With the initial condition p(0)=p0 the solution of the differential equation (4) has the form:

$$p(t) = \frac{\lambda_u}{\lambda_o + \lambda_u} + \left(p_0 - \frac{\lambda_u}{\lambda_o + \lambda_u}\right) e^{-(\lambda_o + \lambda_u)t} \qquad (5)$$

To move from relevance to reliability of credentials, we introduce an error-free processing factor:

$$R_{\text{D}}(t) = p(t) \cdot (1 - \varepsilon) \qquad (6)$$

Formulas (4)–(6) form the dynamic block of the model and allow us to estimate the rate of loss of relevance, the speed of recovery after an update, and the maximum level of reliability of the record.

C. *Degradation coefficient and integral indicator of information reliability*

To separate the impact of external object dynamics from the system's internal data management capabilities, we introduce a dimensionless degradation coefficient, K_{deg}. It characterizes the proportion of changes that are not compensated for by timely record updates.

$$K_{\text{deg}} = \frac{\lambda_o}{\lambda_o + \lambda_u}, \quad 0 \le K_{\text{deg}} \le 1 \cdot \qquad (7)$$

Substituting expression (7) into the formula for stationary reliability yields a compact form of the dependence:

$$R_{\text{D}}^{(\infty)} = \left(1 - K_{\text{deg}}\right) \cdot (1 - \varepsilon) \cdot \qquad (8)$$

Record relevance is a necessary but not sufficient condition for the proper functioning of a cadastral system. Therefore, for a comprehensive assessment of data quality, we will use a multi-criteria index that takes into account completeness *C*, coordinate accuracy *A*, topological consistency *T*, and attribute consistency *S*.

$$I_{\text{inf}} = \left(C^{\alpha}\cdot A^{\beta}\cdot T^{\gamma}\cdot S^{\delta}\right)^{\frac{1}{\alpha+\beta+\gamma+\delta}}\cdot p(t)\cdot(1-\varepsilon), \quad (9)$$

where $\alpha, \beta, \gamma, \delta$ - coefficients that set priorities (for example, for trunk lines, topology may be more critical, for radio relay objects, the accuracy of coordinates and heights).

In the limiting case, when all particular quality characteristics reach their maximum value, the integral indicator of information reliability coincides with the indicator of data reliability:

$$R_{\text{D}}(t) \equiv I_{\text{inf}} \text{ at } C = A = T = S = 1. \quad (10)$$

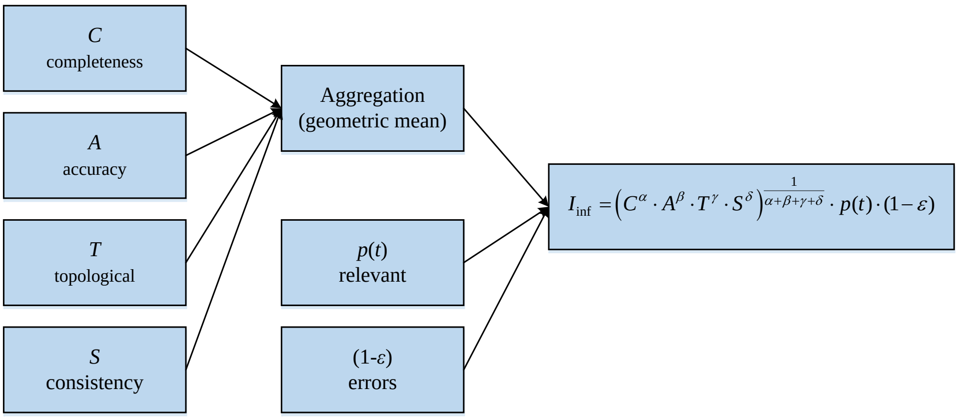

Figure 2: Structural diagram of the formation of the information reliability index I_{inf}

III. RESULTS

A. Analysis of stationary operating modes

The steady-state model allows for a transition from individual calculations to an analysis of the cadastral system's operating modes in the space of parameters λ_o and λ_u. For a fixed value of the processing error probability ε, the steady-state reliability color map reflects the regions of stable and degraded conditions.

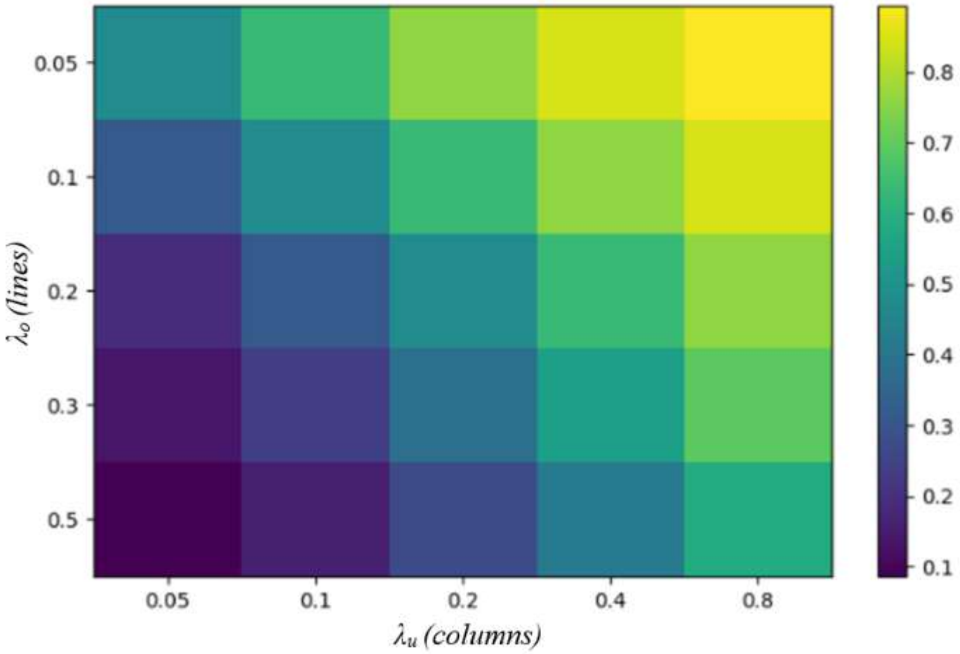

Figure 3: Heat map (λ_o, λ_u) at ε = 0.05

In Figure 3, the lighter areas correspond to high values $R_{\text{D}}^{(\infty)}$, i.e., modes in which the update rate is sufficient to compensate for infrastructure changes. Darker zones, on the other hand, characterize areas of reduced reliability, when update processes lag behind the rate of change in objects. This visualization is useful for substantiating maintenance procedure requirements and for differentiating classes of objects based on the required update frequency.

B. Dynamics of data relevance and reliability

The results of modeling using formulas (5) and (6) show that the update rate influences both the rate of relevance restoration and the steady-state limit. The larger λ_u, the faster the *p(t)* curve reaches a steady-state level and the higher this level (Figure 4).

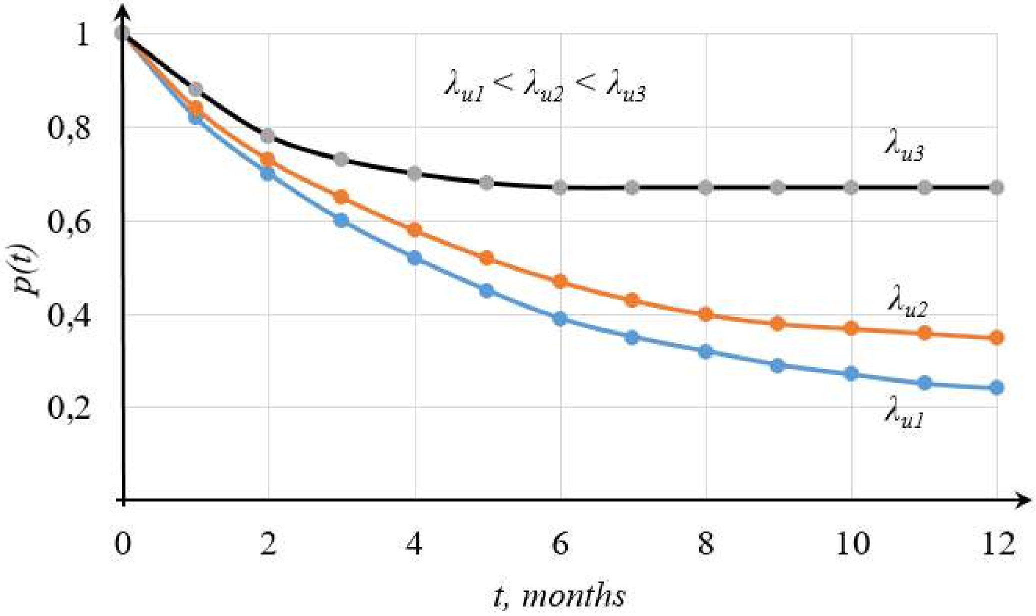

Figure 4: Dynamics of relevance *p(t)* for different λ_u

For fixed values of λ_o and λ_u, an increase in the error probability ε leads to a systematic downward shift of the $R_D(t)$ curves (Figure 5). This means that even with well-organized updating, the quality of the input and processing processes forms a natural "ceiling" of achievable reliability.

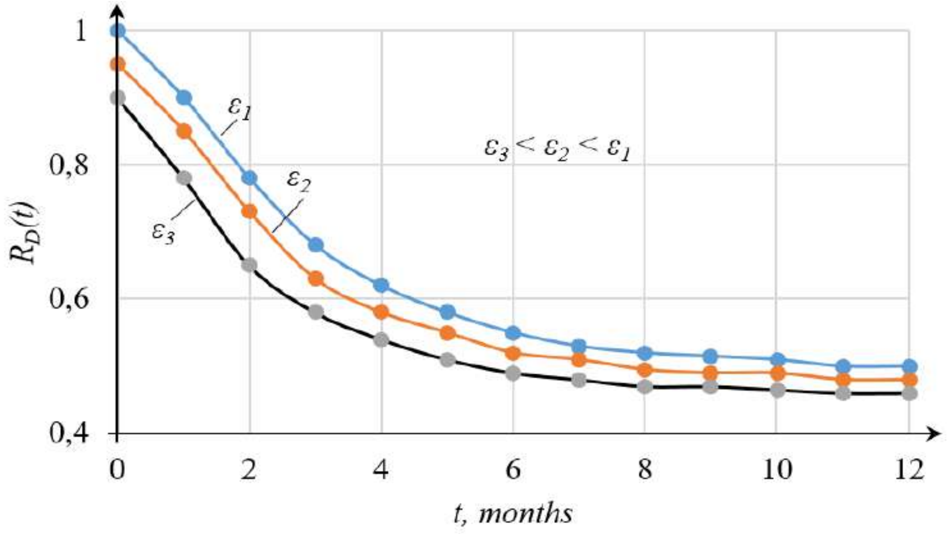

Figure 5: Reliability of data $R_D(t)$ for different ε

Thus, increasing the reliability of accounting data requires simultaneous action on two groups of factors: firstly, on the intensity and discipline of updating records, and secondly, on reducing the likelihood of errors in information processing.

C. Parameterization of the model based on update statistics

The practical significance of the model is determined by the fact that the parameter λ_u is formed not abstractly, but based on observed statistics of intervals between successive record updates. The histogram in Figure 6 reflects the actual update rate and allows one to identify the proportion of records for which update intervals exceed the specified values.

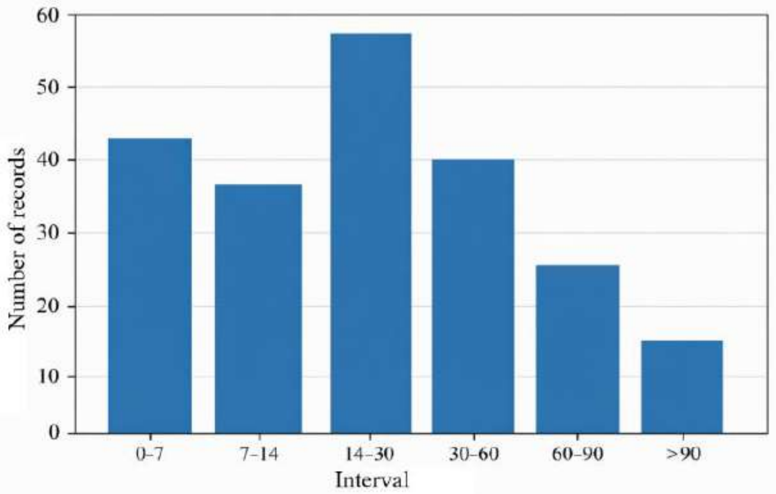

Figure 6: Distribution of cadastral records by the duration of the interval between updates (days)

The presence of a significant proportion of records with extended update intervals means a reduction in the effective intensity λ_u. This, in turn, leads to an increase in the degradation rate and a decrease in the steady-state reliability level.

D. Degradation coefficient by object classes

Calculating the degradation factor for different classes of telecommunications infrastructure objects reveals significant heterogeneity in the data support regime. Higher K_{deg} values are typical for dynamic objects, while for stationary network elements the figure is lower (Figure 7).

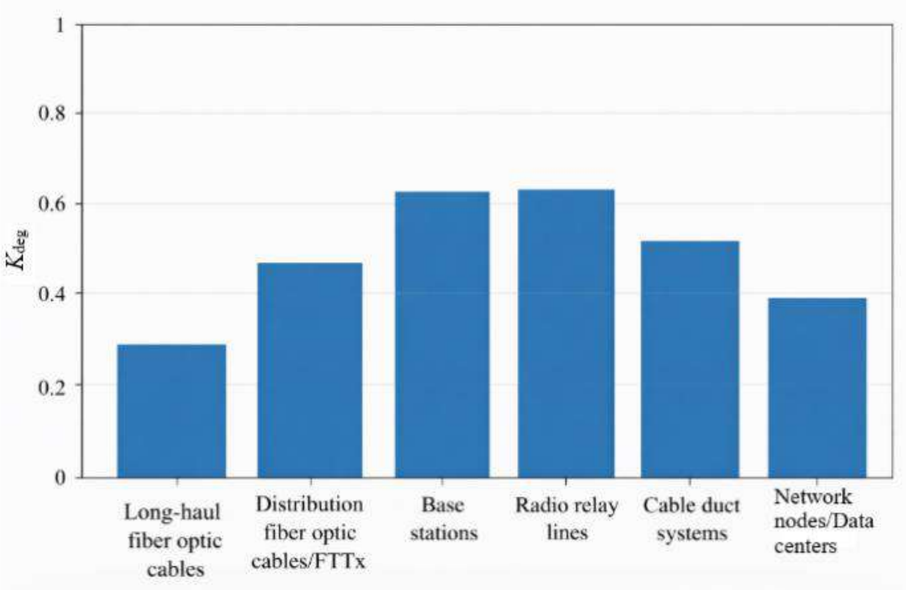

Figure 7: Degradation coefficient K_{deg} by object classes

The results presented in Figure 7 confirm the need for a differentiated approach to the frequency of accounting data updates. A unified regulation proves insufficient, as object classes differ in the rate of change and their sensitivity to update delays.

E. Data Defect Analysis

For practical adjustment of the I_{inf} index, it is important to determine which defect categories contribute most to the reduction of information reliability. Figure 8 shows a Pareto diagram that allows one to identify a limited number of dominant error sources.

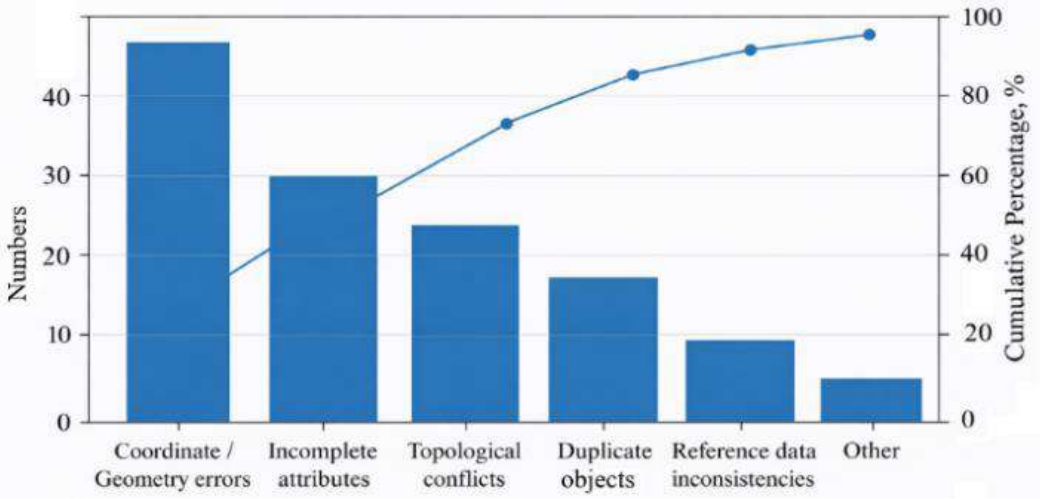

Figure 8: Pareto diagram of data defects

The use of Pareto analysis ensures the prioritization of activities to improve data quality and helps to reasonably select the weighting coefficients α, β, γ and δ depending on the specifics of the object or subsystem.

F. An example of application of the proposed method

Let's consider a telecommunications infrastructure object with moderate change dynamics. We'll take a month as the unit of time. According to maintenance statistics, the object's change rate is λ_o=0.18 [1/month], the record update rate is λ_u=0.42 [1/month], the processing error probability is ε=0.04, and the initial state of the record is considered current: p_0=1.

Table 1: Initial data for the calculation example

Parameter	Designation	Meaning
Intensity of changes in the object	λ_o	0.18 [1/month]
Record update rate	λ_u	0.42 [1/month]
Probability of processing error	ε	0.04
Initial relevance	p_0	1.00

The stationary probability of the current state of the record according to formula (1) is equal to

$$p = 0.42 / (0.18 + 0.42) = 0.70.$$

Then the steady-state reliability of the data according to formula (2) will be:

$$R_{\mathrm{D}}^{(\infty)} = 0.70 \cdot 0.96 = 0.672.$$

According to formula (5) for the time moment t = 3 months we obtain:

$$p(3) = 0.70 + 0.30 \cdot \exp(-1.8) \approx 0.75.$$

Therefore, the dynamic reliability of the recording according to formula (6) will be equal to:

$$R_D(3) \approx 0.75 \cdot 0.96 \approx 0.72.$$

The degradation coefficient according to formula (7) will be:

$$K_{\mathrm{deg}} = 0.18/0.60 = 0.30.$$

Substituting this value into formula (8) again yields:

$$R_{\text{Д}}^{(\infty)} = (1-0.30) \cdot 0.96 = 0.672,$$

which confirms the consistency of the obtained dependencies.

Let the results of the data quality audit show that the values of the partial indicators are C=0.92; A=0.88; T=0.95 and S=0.90 with equal weights $\alpha=\beta=\gamma=\delta=1$. Then the geometric component of the index I_{inf} is approximately 0.912, and the final information reliability at t=3 months will be:

$$I_{\mathrm{inf}} \approx 0.912 \cdot 0.75 \cdot 0.96 \approx 0.66.$$

Table 2: Results of the calculation example

Indicator	Formula	Result
Stationary relevance	(1)	0.70
Stationary reliability	(2)	0.672
Dynamic relevance at t=3 months	(5)	≈ 0.75
Dynamic reliability at t=3 months	(6)	≈ 0.72
Degradation coefficient	(7)	0.30
Information reliability	(9)	≈ 0.66

The example above demonstrates that even with relatively high levels of individual data quality indicators, the resulting information reliability significantly depends on the update discipline and the likelihood of processing errors. Therefore, to practically improve the quality of the digital cadastre, it is necessary to combine organizational measures to reduce update intervals with measures to reduce the incidence of input and verification errors.

IV. DISCUSSION

The proposed method draws on ideas developed in research on data quality, spatial information, and stochastic [6] [9] [10] modeling, but applies them to the applied context of a digital cadastre of telecommunications infrastructure. Unlike studies that focus on describing quality as a set of independent attributes, in this model, data quality is linked to the temporal dynamics of an object and the recording mode.

The model's strength is its interpretability. The parameters λ_o, λ_u, and ε have direct practical meaning and can be obtained or estimated from operational logs, audit results, and error statistics. This makes the model suitable not only for analytical studies but also for engineering support of management decisions.

Another important advantage is the transition from a one-dimensional relevance indicator to the integral index I_{inf}. This transition allows us to combine the temporal reliability of a record with the qualitative characteristics of spatially attributed data. The use of a geometric mean eliminates the undesirable effect of completely compensating for a critically low value of one characteristic with high values of others.

However, the model also has limitations. First, the initial formulation is based on the assumption that change and update flows are independent, whereas in real systems they may be statistically related. Second, the parameter ε in its current form aggregates heterogeneous error causes. Third, the model does not differentiate update types by depth and execution quality. These limitations do not diminish the value of the obtained results, but they do suggest directions for further development of the method.

A promising development of this work is the transition to temporally non-uniform intensities, the introduction of state classes for partially relevant records, the consideration of dependent event flows, and the use of monitoring logs for adaptive parameterization of the model in real time. For large-scale digital communications asset metering systems, this creates the preconditions for the development of intelligent quality control procedures and risk-based data management.

V. CONCLUSION

This article develops a method for assessing the reliability of telecommunications infrastructure facility accounting data. The method is based on a stochastic description of facility changes and record updates as competing Poisson flows and allows for obtaining both stationary and dynamic estimates of data relevance.

It is shown that account reliability is determined not only by the update rate but also by the rate of change of the object and the likelihood of information processing errors. A degradation coefficient is introduced to interpret operational modes, and an integrated indicator of information reliability is developed for a comprehensive assessment of data state, taking into account the completeness, accuracy, topological consistency, and consistency of attributes.

An application example demonstrated the method's suitability for practical analysis of the digital cadastre, comparison of object classes, justification of update procedures, and selection of priority measures to improve data quality. The proposed approach can be used as an analytical basis for developing cadastral data reliability monitoring systems in the telecommunications industry.

REFERENCES

[1] ISO 19157-1:2023, *Geographic information — Data quality — Part 1*. Geneva, Switzerland: ISO, 2023. Available from: https://doi.org/10.1080/17538947.2023.2198778

[2] ISO/IEC 25012:2008, *Software engineering — Software product Quality Requirements and Evaluation (SQuaRE) — Data quality model*. ISO/IEC, 2008. Available from: https://doi.org/10.1016/j.datak.2023.102152

[3] M. Batini and C. Scannapieco, *Data Quality: Concepts, Methodologies and Techniques*. Springer, 2020. Available from: https://link.springer.com/chapter/10.1007/3-540-33173-5_7

[4] I. Taleb, N. Dahmani, S. S. Mathew, and K. Hayawi, “Big Data quality assessment in the IoT era,” in Empowering IoT with Big Data Analytics, Academic Press, 2025, pp. 141–171 Available from: https://doi.org/10.1016/B978-0-443-21640-4.00003-X

[5] C. Liu, P. Nitschke, S. P. Williams, and D. Zowghi, “Data quality and the Internet of Things,” Computing, vol. 102, no. 2, pp. 573–599, 2020. Available from: https://doi.org/10.1007/s00607-019-00746-z

[6] R. Hu, J. Du, and L. L. Lai, “Reliability evaluation of communication-constrained protection systems using stochastic-flow network models,” IEEE Transactions on Smart Grid, vol. 9, no. 3, pp. 2371–2381, 2017. Available from: https://doi.org/10.1109/TSG.2017.2727227

[7] S. Wang and L. Zhang, “Data reliability and quality in digital infrastructure systems,” *Future Generation Computer Systems*, vol. 125, pp. 789–799, 2022.

[8] ITU-T Recommendation E.800, “Definitions of terms related to quality of service and network performance,” 2021. Available from: https://ieeexplore.ieee.org/abstract/document/11380356

[9] K. S. Trivedi, *Probability and Statistics with Reliability, Queuing and Computer Science Applications*. Wiley, 2016. Available from: https://tinyurl.com/3m8xy5z7

[10] H. C. Tijms, *A First Course in Stochastic Models*. Wiley, 2003. Available from: https://tinyurl.com/4nezp7em

ABOUT THE AUTHOR

Makhsum Makhmudov has 32 years of work experience and has been serving in the current position since 2018.

Candidate of Technical Sciences.

Makhsum Makhmudov is a highly qualified engineer-economist and a strong innovator capable of effectively implementing innovative solutions in production processes. He has extensive experience in managing large teams and is recognized as a competent leader with broad potential, capable of finding professional solutions to various tasks.

In total, 30 articles on the research topic have been published in journals recommended by the Higher Attestation Commission of the Republic of Uzbekistan, including 12 in foreign journals and 18 in national journals. In addition, 5 certificates of registration for computer software programs have been obtained.