ABOUT ONE METHOD OF FORMING CADASTRAL INFORMATION OF TELECOMMUNICATION FACILITIES

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K E Y W O R D S

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A B S T R A C T

This article presents a method for creating a digital cadastre of telecommunications facilities based on the principles of single data entry, continuous event-driven updating, spatiotemporal modeling, and integration with departmental information systems. The proposed architecture improves the reliability and manageability of cadastral data, as well as regulatory compatibility with national and international standards. The article discusses the stages of method implementation, including data collection, standardization, database formation, quality control, and monitoring. It is shown that the application of the developed approach improves the integral quality of data, reduces updating time, reduces the number of duplicate records, and increases infrastructure coverage. The practical significance lies in the formation of a reliable information foundation for planning and regulating the development of telecommunications networks within the digital economy

I. Introduction

Current trends in the digitalization of the telecommunications industry require a transition from fragmented accounting systems to comprehensive digital cadastres that provide a reliable reflection of the infrastructure's status and effective lifecycle management of communications assets [1]. With the rapid development of mobile, satellite, and fixed-line networks, as well as the increasing complexity of their territorial distribution, ensuring the reliability and relevance of cadastral data is becoming a key objective of state policy in the telecommunications sector.

Traditional cadastral management methods rely on manual data entry and periodic updating, which does not meet the requirements of efficiency and does not guarantee information consistency [2]. The heterogeneity of sources (departmental databases, operator reports, data from geographic information systems (GIS), and IoT sensors) and the lack of integration mechanisms lead to duplication, obsolescence, and a decrease in the reliability of information [3, 4].

II. Main part

There are several approaches to maintaining cadastres of engineering and infrastructure facilities known in global practice [5]. Classic cadastral systems (land, energy, transport) are focused primarily on fixed objects and spatial attributes [6]. Analysis has shown that existing approaches have a number of limitations, in particular, static nature (data is updated manually and does not reflect the current state of networks), fragmentation (lack of end-to-end integration between departmental sources), lack of quality control mechanisms (records are not automatically verified), and the impossibility of analyzing temporal dynamics (models do not take into account the life cycle of an object) (Table 1) [7-12].

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Table 1

Comparative characteristics of approaches

No.	Approach	The basic principle	Data type	Advantages	Flaws	Applicability
1	Document-registering	Accounting by documents	Attributive	Simplicity, legal precision	Lack of relevance	Real estate, buildings
2	Geoinformation	Spatial modeling	Geodata	Visibility, analysis	Lack of temporal dynamics	Engineering networks
3	Integration	Merging sources	Heterogeneous	Completeness, consistency	Difficulty of implementation	Industry cadastres
4	Spatio-temporal	Accounting for coordinates and time	Geo+time	Dynamism, forecast	Resource intensity	Telecommunications
5	Intellectual and analytical	ML and forecast	United	Adaptability, automation	High data demands	5G/IoT digital cadastres

The evolution of approaches demonstrates the transition from static accounting models to dynamic intelligent data management systems, where the key characteristics are continuous updating, self-monitoring of reliability and integration with external sources [13].

However, the telecommunications infrastructure is characterized by highly dynamic changes—both topological (introduction/dismantling of base stations, changes in fiber-optic communication line routes) and parametric (frequency ranges, bandwidth, types of equipment).

The developed method is aimed at overcoming the identified limitations of traditional approaches and is based on the systemic principles of single data entry and repeated use, continuous event-driven updating, and spatiotemporal modeling of objects, ensuring deep integration with departmental information systems and state registries [14]. This architecture ensures a high level of reliability, manageability, and regulatory compatibility of cadastral information, creating a holistic information space for monitoring and analyzing communications infrastructure.

The key target indicators of the effectiveness of the proposed method are: an increase in the integral indicator of data quality Q, a reduction in the average time of updating records U, a decrease in the proportion of duplicate information D, and an increase in the coverage of telecommunications infrastructure C for priority categories of objects.

The main advantages of the proposed method are the following:

1) Continuous updating. Transition from periodic manual updating to event-oriented and planned modes (introduction/modernization/dismantling/change of parameters), which ensures the minimization of temporary discrepancies between the actual state of telecommunications infrastructure objects and their digital reflection in the cadastral system [15].

2) Quality control using a formal model. Built-in assessment of the integral quality indicator of cadastral data:

$$Q = \alpha \cdot C + \beta \cdot U + \gamma \cdot D, \qquad (1)$$

where metrics of completeness (C), relevance (U), reliability (D) of data.

Automatic launch of verification procedures when indicators fall below thresholds [13].

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3) Spatio-temporal representation. Implementation of a systemic accounting of spatial coordinates (*x, y, z*) and temporal characteristics of the life cycle of objects (input, modernization, output) with support for historicization procedures and version management of cadastral information.

4) Integration. Standard interfaces (API, XML/JSON/GML), data exchange buses with the Unified System of State Cadastre (USSC), spectrum licensing systems, and communication quality monitoring systems are used.

5) Full life cycle. The method covers the stages "design - commissioning - operation - modernization - decommissioning," which is fundamentally different from static cadastral models.

6) Analytics and forecasting. Geoanalytics modules (coverage, density, "white spots"), scenario planning for the placement of base stations (BS) and fiber-optic communication lines (FOCL), key performance indicator (KPI) are used for the regulator and operators.

7) Information security and audit. Role - based access model (RBAC, Role-Based Access Control), end-to-end change logs, cryptographic protection in storage and transmission.

8) Regulatory compatibility. Compliance with the principles of the USSC and international standards (ITU/3GPP/ISO/OGC), unification of reference books and metadata.

9) Reduce duplication and errors. Unified object identifiers, automatic deduplication, and normalization of data flows from disparate sources.

To illustrate the structural and logical sequence of operation of the proposed method for the formation of a digital cadastre of telecommunications objects, a generalized block diagram of its implementation has been developed, reflecting all the main stages - from the collection and preliminary processing of primary data to their integration into a single ecosystem of the digital state (Fig.1) [16].

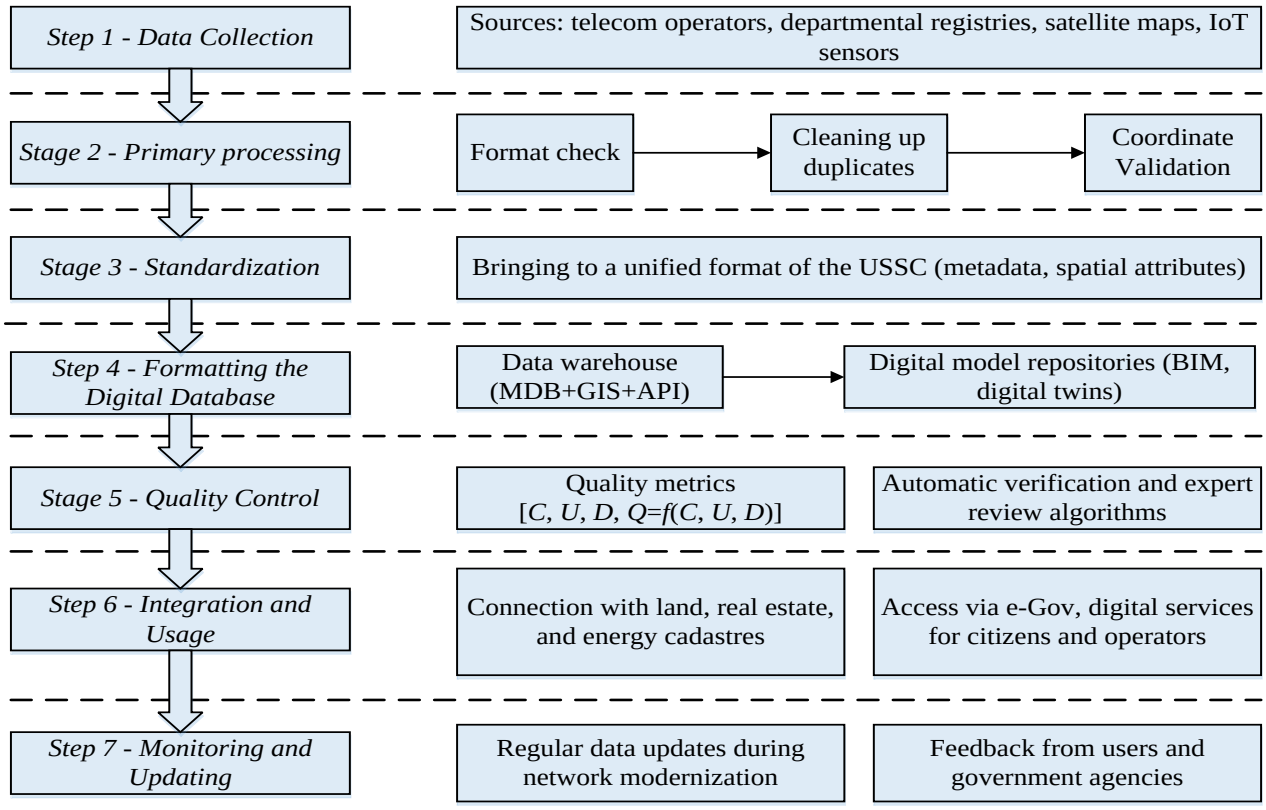


Fig.1. Block diagram of the implementation of an improved method for forming a cadastre of telecommunications facilities

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The implementation of the method includes seven stages.

Stage 1. Data collection. This key stage involves integrating diverse sources, from departmental databases to IoT sensors recording the actual state of equipment. At this stage, the following data are collected: the geographic coordinates of the assets, technical parameters (equipment type, power, frequencies), and operational data.

Stage 2. Primary processing ensures error correction (e.g., duplicate entries) and coordinate validation, which is especially important for distributed telecom infrastructure.

Stage 3. Standardization. This ensures compatibility with other cadastral systems, eliminates errors (such as duplicate entries), and verifies the correctness of coordinates, which is especially important for a distributed telecommunications infrastructure. Data is standardized.

Stage 4. Creation of a digital database. This involves not only data storage but also working with digital twins of telecommunications assets, which increases the analytical value of the cadastre. Creation of a centralized database with support for distributed access. The database architecture is multilayered (data - metadata - analytical services). API support for exchange with external systems.

Stage 5. Quality control. Implemented through both automated algorithms and expert verification, ensuring high information reliability. Comparison with reference data sets, use of statistical verification methods. Implementation of machine learning algorithms for anomaly detection. Criteria: completeness, relevance, accuracy, consistency [11].

Stage 6. Integration and use. Makes the system part of the digital state, allowing citizens and operators to access up-to-date data through online services.

Stage 7. Monitoring and updating. Ensures the inventory is up-to-date and compliant with rapidly changing technologies. Automatic synchronization with operator systems. Scheduled data validation checks. Use of predictive analytics to anticipate network changes (e.g., load increases, upgrades).

Thus, the implementation flowchart (Fig. 1) reflects the method's complexity and cyclical nature. Here, data is not only recorded but also undergoes a continuous cycle of updating, monitoring, and integration, making the cadastre a dynamic and reliable tool for industry management. A program has been developed in Python that implements cadastre generation with manual parameter input (A/B/C branches, merging, C, U, D, Q metrics, and action thresholds) and saves the results to files: CSV, PNG (graphs), and DOCX (final report). The program also, as a result, generates the activities necessary for carrying out with cadastral information in order to update the data (Fig.2).

```
DIAGNOSE: определяем доступные ветви A/B/C…
  - 2G_BTS: A, B, C
  - 3G_BTS: A, B, C
  - 4G_BTS: A, B, C
BRANCH: считаем по доступным ветвям и объединяем…
  - 2G_BTS: N̂=927.47, SE=8.58, 95%CI=[910.66; 944.28]
  - 3G_BTS: N̂=353.76, SE=10.42, 95%CI=[333.33; 374.18]
  - 4G_BTS: N̂=305.40, SE=10.76, 95%CI=[284.30; 326.49]
QUALITY: считаем C, U, D, Q…
  - 2G_BTS: C=0.59, U=0.00, D=0.87, Q=0.51
  - 3G_BTS: C=0.99, U=0.00, D=0.86, Q=0.67
  - 4G_BTS: C=0.49, U=0.00, D=0.80, Q=0.45
ACTIONS: применяем пороги и формируем меры…
  * 2G_BTS: триггер → reverify_or_expand_audit (Q=0.51 < 0.75)
  * 3G_BTS: триггер → reverify_or_expand_audit (Q=0.67 < 0.75)
  * 4G_BTS: триггер → reverify_or_expand_audit (Q=0.45 < 0.75)
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Fig.2. Formation of measures for updating the digital cadastre of telecommunications facilities

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Table 2 presents the key characteristics of the stages of the proposed method for forming a digital cadastre.

Table 2 systematizes and formalizes the relationship between the input data, the tools used, and the results obtained, which allows us to objectively trace the logic of the methodology, improve the validity of design decisions, and ensure its reproducibility during subsequent implementation.

Table 3 provides a comparison of the proposed method with common approaches to digital cadastre formation.

Table 2

Key characteristics of the stages of digital cadastre formation

No.	Stage	Input data	Tools/methods	Result
1	**Stage 1. Data collection**	Telecom operator reports, departmental databases, geodata	Import from XLS , MDB , API requests, survey forms	A set of initial heterogeneous data
2	**Stage 2. Standardization and normalization**	Heterogeneous data formats and structures	ETL processes, cleanup scripts, validation schemes	Unified data in a common format
3	**Stage 3. Georeferencing and integration**	Tables of objects, coordinates, maps	GIS platforms (ArcGIS/QGIS), GPS data	Telecommunications objects linked to the map
4	**Stage 4. Formation of a digital cadastre**	Standardized spatial data	Relational DBMS, MDB structures, GIS repositories	Centralized cadastral database
5	**Stage 5. Quality and reliability control**	Cadastral database, reference data	Quality metrics (accuracy, completeness, relevance), verification algorithms	Cleaned and verified data array
6	**Step 6. Publication and access**	Verified cadastral database	API , web portals, reports, dashboards	User access to data
7	**Stage 7. Monitoring and updating**	Current changes in the telecommunications network , new facilities	Monitoring systems, automatic triggers	Update and return to the cycle

Table 3

Comparison of the proposed method with common approaches

No.	Criterion	Common approaches (static cadastres)	The proposed method (telecommunications)
1	Update mode	Periodic, manual	Event-driven, automated
2	Quality control	Formal (formats/completeness)	Integral model $Q = \alpha \cdot C + \beta \cdot U + \gamma \cdot D$ with metrics of completeness (C), relevance (U), reliability (D) of data
3	Data model	Predominantly spatial	Spatio-temporal versioning
4	Integration	Limited file sharing	API/data bus, Unified State System of Generating Companies, BSS/OSS/SCADA/GIS

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5	Life cycle	Recording the fact of existence	Full cycle: design - output
6	Geoanalytics	Basic maps	Coverage, density, blind spots, development scenarios
7	Scalability	Low/medium	Phase (MDB → PostGIS / cloud), horizontal scaling
8	Security and audit	Basic mechanisms	RBAC, logs, encryption, infrastructure compliance

The practical significance lies in the fact that the method ensures a controlled increase in the quality and relevance of cadastral information, accelerates interdepartmental processes (licensing/approvals), reduces the risks of an unreliable picture of the infrastructure and creates a basis for strategic planning of the development of telecommunications networks at the national level.

The reliability of a digital cadastre of telecommunications facilities directly depends on the quality and reliability of the data. Coordinate errors, inconsistent identifiers, outdated records, and duplication lead to a distorted picture of the infrastructure and risks in decision-making. Therefore, the proposed method includes a formalized system for assessing reliability and quality control criteria.

III. Conclusion

The results of the study confirm the effectiveness of the proposed method for generating cadastral information for telecommunications facilities. Unlike traditional static models, this approach ensures continuous updating and data reliability monitoring, implementing the principles of event-driven updating and spatiotemporal modeling. Built-in quality assessment mechanisms based on the metrics of completeness, relevance, and reliability (*C*, *U*, *D*) enable the formation of a dynamically relevant digital cadastre capable of integration with state information systems. Implementation of the method helps reduce the time and labor costs of updating, reduce the number of duplicate records, and increase the transparency of infrastructure data. Practical implementation of the proposed solution creates the basis for the transition to intelligent management of the communications industry and the formation of a unified digital space for the telecommunications infrastructure of the Republic of Uzbekistan [17].

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