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QUALITY MANAGEMENT OF LAND MANAGEMENT WORKS: ESSENCE, TOOLS, METRICS

L. Hunko, *Doctor of Economic Sciences, Associate Professor,*
Email: gunko_l@nubip.edu.ua
ORCID: 0000-0002-9454-744X
National University of Life and Environmental Sciences of Ukraine
A. Martyn, *Doctor of Economic Sciences, Professor, Corresponding Member of the NAAS,*
Email: martyn@nubip.edu.ua
ORCID: 0000-0002-6905-2445
National University of Life and Environmental Sciences of Ukraine
I. Kolhanova, *Candidate of Economic Sciences, Associate Professor,*
Email: kolganova_i@nubip.edu.ua
ORCID: 0000-0001-7771-2696
National University of Life and Environmental Sciences of Ukraine
O. Zakharenko, *Deputy Head of the Department for Certification and Supervision in Land Management*
Email: ovz-21@ukr.net
ORCID: 0009-0000-8200-837X
State Service of Ukraine for Geodesy, Cartography and Cadastre

Abstract. *The article examines the quality of land management works as a complex multidimensional category that cannot be reduced to the mere absence of formal errors, compliance with a prescribed documentation form, or minimum conformity with legal and regulatory requirements. It is substantiated that, under present conditions of digitalization of land-cadastral, registration, and spatial-planning procedures, the quality of land management documentation should be considered an integral property of a professional output that combines the completeness of land-management surveys, the accuracy of the topographic and geodetic basis, the soundness of the project decision, regulatory correctness, and the ability of the documentation to minimize risks in the acquisition, confirmation, and exercise of land rights. It is shown that existing control practice in Ukraine has historically concentrated primarily on verifying the technical validity of electronic documents, topological connectivity, logical consistency, and format suitability of geospatial data, whereas the completeness of surveys, the evidentiary substantiation of the project decision, and the post-project stability of the legal outcome remain considerably less developed in methodological terms. The purpose of the study is to provide a theoretical and methodological substantiation of the essence of quality in land management works, to develop a system of its structural elements, to elaborate a qualimetric approach to assessing land management documentation, and to identify quality management tools suitable for professional, administrative, and automated digital control. The methodological framework comprises systemic, structural-functional, formal-legal, comparative-legal, and qualimetric approaches; the source base includes Ukrainian legislation, international standards for geographic information quality, land administration documents, and current procedures for the electronic validation of land management documentation. A model of land management documentation quality is proposed that comprises five interrelated dimensions: completeness of surveys, accuracy of geodetic works, soundness of the project decision, regulatory compliance, and practical fitness for achieving the legal result. A system of quantitative metrics and an integral approach to quality assessment are developed for implementation in computer-aided design systems, the*

State Land Cadastre, the urban planning cadastre, and related public information resources. The prospects for using artificial intelligence for intelligent documentation analysis, anomaly detection, verification of the actual existence of objects, support for project decisions, and the construction of risk-oriented control are separately substantiated, provided that AI does not replace professional and public-authority discretion. The practical value of the article lies in forming a conceptually coherent and instrumentally applicable framework for the transition from formal documentation control to systemic quality management of land management works in Ukraine.

Keywords: *quality of land management works; land management documentation; quality management; qualimetry; quality metrics; State Land Cadastre; geospatial data; topological connectivity; completeness of land-management surveys; soundness of the project decision; digitalization of land management; artificial intelligence.*

Problem statement. Quality management of land management works in Ukraine has ceased to be a narrowly professional issue of an executor's internal control and has become one of the key problems in the functioning of the entire system of land relations. This is because land management documentation is not merely a technical or graphic product, but a legally significant basis for the formation of land parcels, the establishment of their boundaries, the determination of restrictions on land use, the preparation of decisions on allocation, withdrawal, or change of designated purpose of land, and subsequent state registration of rights. The Law of Ukraine "On Land Management" directly defines land management as a set of socio-economic and environmental measures aimed at regulating land relations and rational territorial organization, and also establishes the types of land management documentation and its legal significance [1]. At the same time, the Law of Ukraine "On State Registration of Property Rights to Immovable Property and Their Encumbrances" links the stability of the acquisition and exercise of rights to

the proper legal certainty of the immovable property object and, consequently, to the quality of the underlying land management documentation [2].

The problem is that, in land management practice, documentation quality is often perceived reductively: as the formal conformity of a set of documents with established requirements or as the absence of obvious technical errors. Such an approach is methodologically insufficient. The quality of land management documentation is not exhausted by the proper formatting of textual and graphic materials. It encompasses at least five interrelated dimensions: the completeness of land-management surveys; the accuracy of the topographic and geodetic basis; the soundness of the project decision; conformity with legal acts, standards, norms, and rules; and the ability of the documentation to minimize risks in the acquisition, confirmation, and exercise of land rights. The fundamental complexity of the problem lies precisely in this multidimensionality: a defect in any of these dimensions may not appear at the documentation-preparation stage, but may later cause refusal of approval, blockage of adoption, a boundary dispute, conflict with urban-planning documentation, or the impossibility of fully exercising a right in the future [1–3].

This problem becomes particularly acute under conditions of digitalization of land-cadastral, registration, and planning procedures. The Law of Ukraine “On the National Geospatial Data Infrastructure” establishes the institutional basis for the operation of geoportals, geospatial data, metadata, and services for access to them [4]. This means that land management documentation increasingly exists not only as a textual and graphic document, but also as a structured set of geospatial data that must be compatible, interoperable, machine-readable, and suitable for automated verification. At the same time, international standards ISO 19157:2013 and ISO 19157-1:2023 expressly proceed from the premise that the quality of geographic data should be described through a system of defined components, assessment procedures, and reporting rules [8; 9]. Thus, digitalization does not remove the issue of quality; rather, it intensifies it radically, because any digital procedure requires a clear formalization of what is to be considered a quality result.

In the Ukrainian context, this problem also has a distinct institutional dimension. Land management documentation is created at the intersection of several informational and regulatory circuits: materials of the State Fund of Land Management Documentation, geodetic and cartographic materials, data of state registration of property rights, urban-planning documentation, information on restrictions on land use, and environmental, engineering, and other territorial regimes [1–7]. The Law of Ukraine "On Regulation of Urban Development" directly provides that urban development activity must take into account state, public, and private interests and be aimed at sustainable territorial development [3]. This means that a land management decision cannot be considered high-quality if it is locally correct but not aligned with the spatial-planning context, does not take territorial restrictions into account, or contradicts the logic of balanced land use.

Another difficulty lies in the asymmetry of interests between the customer, the executor, and the end users of the result. The customer of land management works is often primarily interested in rapid completion of procedures and acquisition of rights, rather than in the high quality of the research and project components of the documentation. However, the direct "consumer" of quality is not only the customer, but also the state cadastre, the rights-registration system, public authorities, adjoining landowners, investors, courts, and society as a whole. Therefore, the quality of land management documentation should be viewed not as a private characteristic of a service, but as a publicly significant characteristic of the reliability of the land order. In this context, the Framework for Effective Land Administration (FELA), developed within the UN system, emphasizes that effective land administration should ensure trust, tenure security, land-market efficiency, and the institutional reliability of governance [10]. Accordingly, low-quality land management documentation is not merely a professional shortcoming, but a factor of systemic legal and economic uncertainty.

A methodological gap is also significant: in domestic practice, the issue of quantitative measurement of the quality of land management works remains insufficiently developed. As long as quality lacks a system of operational indicators,

its control remains either declarative or selectively subjective. Meanwhile, international approaches to the quality management of geospatial data are based precisely on measurable categories: completeness, logical consistency, positional accuracy, temporal quality, thematic correctness, and fitness for use [8; 9]. For land management, this means the need to move from general evaluative judgments to a qualimetric model within which documentation quality can be decomposed into individual parameters, each of which can be assessed, compared, and subsequently algorithmized in digital services.

Thus, the scientific problem is not only the need to improve the quality of land management works, but above all the need to fundamentally clarify the very content of the category “quality of land management documentation”, determine its structural elements, establish the limits of applying international approaches and standards to this field, and form a system of quantitative metrics suitable for professional, administrative, and digital control. Without this, it is impossible either to build a modern quality management system for land management works or to ensure the effective integration of land management with the cadastre, rights registration, urban planning, and the national geospatial data infrastructure [1–10].

The purpose of the article is to provide a theoretical and methodological substantiation of the essence of quality in land management works as a multidimensional characteristic that combines the completeness of land-management surveys, the accuracy of the topographic and geodetic basis, the soundness of project decisions, their legal and regulatory correctness, and their fitness for minimizing risks in the acquisition and exercise of land rights, as well as to develop a modern toolkit for managing this quality on the basis of qualimetry, international approaches to the assessment of geospatial data, and the needs of digitalization of land-cadastral and planning procedures, with the formation of a system of quantitative metrics suitable for professional control, algorithmization of checks, application in public administration, and use in public-procurement procedures for land management works.

Materials and methods. The materials of the study include current legal acts of Ukraine in the field of land management, maintenance of the State Land Cadastre, state registration of property rights to immovable property, urban development activity, and the functioning of the national geospatial data infrastructure, as well as subordinate legislation and methodological documents that regulate the electronic circulation of the results of land management works, their structural and format validity, the procedure for verifying electronic documents, and information interaction between cadastral and registration systems [1–4; 12–14; 18–21]. In addition, the study uses international standards and conceptual documents that define approaches to assessing geographic-information quality, effective land administration, and proper use of digital technologies, in particular ISO 19157:2013, ISO 19157-1:2023, INSPIRE documents, the Framework for Effective Land Administration (FELA), and analytical materials on the use of artificial intelligence in public administration [8–11; 22]. The methodological basis of the study is a combination of dialectical, systemic, structural-functional, formal-legal, comparative-legal, and logical-semantic approaches. To identify the essence of the category "quality of land management documentation", the method of conceptual decomposition was used to distinguish its main components; to analyze control procedures, functional modeling was applied; and to form a system of quantitative indicators, elements of the qualimetric approach, indicator normalization, expert-analytical grouping of criteria, and construction of an integral assessment model were used.

At the same time, the study has several methodological reservations that must be taken into account when interpreting its results. First, the proposed model of quality metrics is theoretical and methodological in nature and is intended to form a framework for subsequent testing, rather than to declare finally established standards for all types of land management documentation. Second, due to the heterogeneity of types of land management documentation, differences in their functional purpose, and the uneven digital maturity of information systems, weighting coefficients, threshold values, and the set of indicators should be treated as adaptive rather than

universal. Third, the study deliberately does not equate formal conformity of documentation with legislative requirements with its full quality, since some determining parameters - primarily the completeness of surveys, the evidentiary substantiation of the project decision, and the risk of subsequent defective exercise of rights - are only partially amenable to direct automated verification and require a combination of digital, expert, and post-project assessment methods. In view of this, the conclusions obtained should be understood as a scientifically substantiated methodological basis for further development of sectoral standards, digital control procedures, and applied models for assessing the quality of land management works, rather than as a completed regulatory model that can be mechanically implemented without additional testing and institutional coordination.

Analysis of recent studies and publications. An analysis of the contemporary scientific and regulatory-methodological corpus gives grounds to state that the issue of quality in the field of land management has been developed very unevenly. The most elaborated segment is the one in which quality is understood as a property of geospatial data and digital models: logical consistency, topological connectivity, format validity, positional accuracy, dataset completeness in the narrow technical sense, and suitability for machine processing [8; 9]. It is precisely in this plane that international approaches are conceptually mature: within ISO 19157 and ISO 19157-1, geographic-information quality is decomposed into separate elements and sub-elements, including completeness, logical consistency, including topological consistency, positional accuracy, temporal validity, and usability, for which assessment and documentation procedures are provided [8; 9]. Similarly, in the INSPIRE methodology, geodata quality is conceived as a formalized and measurable characteristic that must be presented in the form of metadata and verifiable indicators at the level of the dataset, spatial-object type, or individual object [9; 11].

For Ukrainian land management practice, it is indicative that this very technical-formal dimension of quality began to be institutionalized earlier than others. Already at the stage of formation of electronic document flow in the land-cadastral sphere, Order No. 136 of the State Committee of Ukraine for Land Resources of 23

May 2003 introduced requirements for the structure, content, and format of the data-exchange file for the results of land management works, and subsequent methodological documents established verification of the conformity of exchange files with these requirements as a separate procedure [11; 12]. Later, this approach was developed by Order No. 573 of the State Committee for Land Resources of 2 November 2009, which approved requirements for the structure, content, and format of presenting the results of land management works in electronic form; and in the contemporary model of maintaining the State Land Cadastre, verification of an XML electronic document generated in accordance with the Procedure for maintaining the State Land Cadastre has already been implemented as a separate electronic-cabinet service for certified land surveyors [12–14]. This shows that the concept of quality in terms of electronic-document validity, file structure, syntactic correctness, part of attribute logic, and basic geometric/topological checks is not new or unknown in the domestic system; on the contrary, it has proved most suitable for early formalization and algorithmization [12–14].

At the same time, the scientific and practical development of this segment should not create the illusion that the problem of the quality of land management documentation as a whole has already been solved. Existing standards and procedures mainly answer the questions of whether geodata are technically correct, whether an electronic document can be accepted by the system, whether it contains internal logical contradictions, and whether it is compatible with a specified data model [8; 9; 13; 14]. However, these approaches cover much more weakly those characteristics that are no less, and often more, important in land management documentation: the completeness of land-management surveys as the sufficiency of processing all relevant sources; the evidentiary substantiation of the project decision as the justification of precisely this spatial and legal decision rather than another; the identification of latent conflicts between cadastral, legal, and urban-planning information; and the ability of the documentation to minimize risks of subsequent blockage or defective exercise of rights [1–4; 10]. In this sense, the contemporary body of sources explains well how to check geometric correctness, but much less

how to check the completeness of professional cognition of the object and the rationality of the project judgment itself.

The issue of completeness requires separate attention. In international documents on geodata quality, completeness is mostly interpreted as the presence or absence of required objects, attributes, or records in a dataset, that is, as commission/omission in the data structure [9; 11]. For land management, however, this is not sufficient. The completeness of land-management surveys has a much broader meaning: it includes not only the absence of omissions in a set of coordinates or attributes, but also the completeness of processing the State Fund of Land Management Documentation, materials of the State Cartographic and Geodetic Fund, information from state registration of property rights, urban-planning documentation, and environmental, engineering, regime-based, and other restrictions. This broader, intersystemic, and evidentiary completeness is today described much less fully than completeness in the sense of an information model. In existing standards, it is only partially reflected through the categories of usability or fitness for purpose, but it is not developed to the level of a special methodology for land-management control [8–10].

The problem of evidentiary substantiation of the project decision is even less developed. In works and standards devoted to the quality of spatial data, attention is naturally focused on data quality as such, whereas a project decision in land management is not simply the result of data processing, but the result of professional judgment that simultaneously has technical, legal, planning, and social dimensions [8–10]. For land management documentation, it is fundamentally important not only whether a boundary is described correctly, but also why it is proposed in this particular way; not only whether restrictions are reflected, but also whether they are correctly embedded into the configuration of rights and use regimes; not only whether the document is aligned with current norms, but also whether the decision is internally persuasive, proportionate, and resilient to conflict. In the identified body of sources, this topic is present mainly implicitly - through general requirements of rationality, sustainability, and the integration of land administration and spatial

planning - but not as a specially developed methodology for measuring the quality of a project decision specifically in land management documentation [3; 4; 10].

The situation with qualimetry is no less indicative. In related fields - in particular, assessment of the quality of urbanized space or certain areas of real property valuation - qualimetric approaches have been applied, demonstrating at least the principled possibility of converting complex spatial characteristics into a system of weights, criteria, and integral indices [15]. However, within land management itself, namely with respect to assessing the quality of land management documentation, land-management surveys, project decisions, and the procedures for their preparation, the available specialized scientific corpus does not reveal an established tradition of special qualimetric analysis. In other words, there are developed tools for assessing individual technical properties of geodata and separate examples of qualimetry in related fields, but there is no holistic theory and methodology for the qualimetric measurement of the quality of land management documentation as a complex legal and engineering product [8; 9; 15]. In our view, this gap is one of the key reasons why the discussion of quality in land management often remains either normative-declarative or reduced to checks of format and geometry.

Thus, the review of recent studies and publications makes it possible to draw three principal conclusions. First, the concept of quality in terms of topological connectivity, logical consistency, format validity, and geodata quality in general has been studied sufficiently thoroughly both in international standardization and in Ukrainian cadastral practice, where the corresponding checks have long acquired procedural form [8; 9; 11–14]. Second, when the discussion moves from technical correctness of data to completeness of land-management surveys and evidentiary substantiation of the project decision, the degree of development of the problem sharply decreases, and existing approaches do not provide a complete methodological answer to the needs of land management [1–10]. Third, qualimetry as a special tool for measuring the quality of land management works and documentation has not in

fact been formed as a separate research direction, which determines the relevance of developing an appropriate system of criteria, indicators, and metrics.

Presentation of the main research material. The quality of land management documentation is a category that cannot be reduced to formal errorlessness. The absence of errors, violations of law, or technical defects is only a minimum condition of documentation acceptability, but it does not yet indicate high quality. Documentation may be prepared without obvious deviations, pass a formal check, and at the same time remain incomplete in its source base, insufficiently accurate in the topographic and geodetic part, weakly substantiated in the project decision, or risky from the standpoint of subsequent acquisition and exercise of land rights. Therefore, the quality of land management documentation should be understood as an integral property of a professional output that reflects the degree of its cognitive sufficiency, engineering accuracy, legal correctness, project persuasiveness, and practical fitness for safe inclusion in cadastral, registration, urban-planning, and law-application procedures [1–10].

In this sense, land management documentation has a dual nature. It is simultaneously the result of surveying, that is, professional cognition of the factual and legal condition of a territory, and the result of design, that is, a substantiated choice of a spatial decision. Therefore, its quality always has two interrelated sides: the quality of the data on which it is built and the quality of the judgment derived from these data. The first side has already been largely formalized in modern cadastral systems: the electronic document is checked for conformity with the data of the State Land Cadastre, requirements for content, structure, and technical characteristics, as well as the data of the land management documentation itself [13]. The second side - the completeness of identifying regime-forming objects, the legal grounds of adjoining land use, the correctness of identifying buildings and structures, and the persuasiveness of the chosen configuration of boundaries, restrictions, or functional designation - remains considerably less formalized and therefore less controllable [1–4].

This is precisely where the fundamental limit of the current control model becomes apparent. Under the current legal regime, a cadastral registrar or an official of the authority that approves or adopts documentation checks the submitted document for its conformity with the requirements of laws, regulatory legal acts adopted pursuant to them, land management documentation, or urban-planning documentation; only such non-conformity may constitute grounds for refusal to approve or adopt the documentation [20]. Consequently, by its legal construction, control is primarily directed at what has already entered the documentation, rather than at what may have remained outside it. Therefore, the verification procedure itself does not automatically answer whether all relevant regime-forming objects were fully identified and studied, whether the existence of title documents for adjoining parcels not reflected in the cadastre was established, or whether buildings and structures on which the project decision relies were correctly identified. This is not a defect of an individual registrar; it is a structural limitation of a system that is capable of checking what has been submitted, but is not always capable of identifying unresolved incompleteness of initial cognition. This explains the emergence of Draft Law No. 10095 on introducing a unified list of questions, i.e., a checklist, to establish conformity or non-conformity of documentation provisions; however, the draft-law card records that, after the committee stage, it was rejected and withdrawn from consideration as of 21 March 2024 [20; 16].

It is indicative that socially resonant corruption practices in the land sphere arise precisely at the boundary between the formal validity of a document and the substantive quality of its initial premises. According to NABU information on Operation “Clean City”, the investigation incriminated a scheme in which ownership rights to structures that did not actually exist on the relevant land plots were registered to controlled persons, after which, on that basis, rights to land were initiated without auction; in public discourse such practices became known as so-called “toilet schemes” [17]. For the theory of quality of land management documentation, this example is fundamental: it demonstrates that the formal presence of an object in the submitted data package and documents is not yet identical to its

factual and legal authenticity. In other words, documentation quality begins not with checking whether the file has been filled in correctly, but with verifying whether the document actually expresses the real condition of the object and the legal situation, rather than an artificially constructed appearance.

In view of the above, the quality of land management documentation should be modeled as a system of five interrelated dimensions: 1) completeness of land-management surveys; 2) accuracy of topographic and geodetic surveys; 3) soundness of the project decision; 4) regulatory compliance; and 5) satisfaction of consumer needs through minimization of risks in the acquisition and exercise of land rights. Such a model relies, on the one hand, on the Ukrainian regulatory construction of land management, cadastre, rights registration, and urban development activity and, on the other hand, on the international approach to geographic-data quality, according to which quality is described through multiple individual components and procedures for their assessment [1–9].

In a philosophical sense, this five-component model reflects different forms of documentation truth. Completeness of surveys is source truth: it answers the question of whether we know enough about the object. Accuracy of geodetic works is metric truth: it answers the question of how correctly the object is described in space. Soundness of the project decision is the truth of practical judgment: it answers the question of whether the proposed decision follows from the available data and whether it is the best among permissible alternatives. Regulatory compliance is legal truth. Finally, satisfaction of consumer needs is functional truth: whether the documentation performs the social and private role for which it was created. If at least one of these dimensions is defective, the documentation may remain formally acceptable but be substantively low-quality.

In order to move quality management from the plane of general assessments to the plane of digital administration, qualimetry is required, that is, a system of quantitative measurement of a complex object through a set of partial indicators. Since specialized qualimetry of land management documentation has not in fact been

formed in the specialized literature, it is appropriate to construct an author's model of an integral quality indicator based on normalized indicators [15].

An integral quality index for land management documentation is proposed:

$$IQ_x = \Sigma_{i=1}^{n} w_i \cdot S_i$$

where S_i is the normalized indicator of a separate quality dimension on a scale from 0 to 1;

w_i is the weight of the corresponding dimension;

$\Sigma w_i = 1$.

For typical cases, in the authors' opinion, the following baseline weights may be proposed: completeness of surveys - 0.25; accuracy of topographic and geodetic surveys - 0.20; soundness of the project decision - 0.20; regulatory compliance - 0.15; risk safety for the acquisition and exercise of rights - 0.20. However, the weights should not be regarded as universal: for projects establishing the boundaries of administrative-territorial units or restrictions on land use, the weight of project substantiation may be higher; for technical documentation on boundary establishment, the weight of geodetic accuracy may be higher.

Below is the proposed system of partial indicators suitable for use in computer-aided design systems, the State Land Cadastre, the urban planning cadastre, and related state information systems (Table 1).

Table 1 - Components of land management documentation quality and proposed quantitative metrics

Quality component	Content of the component	Quantitative metric	Formula / calculation logic	Data source for automation	Level of automation
Completeness of land-management surveys	Coverage of all relevant sources and circumstances	Source completeness index (SCI)	SCI = Nf / Nr, where Nf is the number of actually processed relevant sources and Nr is the number of sources mandatory for the type of documentation	log of requests to funds, registers, the urban planning cadastre, and the rights register	high
Completeness of land-management surveys	Identification of regime-forming objects	Coefficient of unidentified restrictions (CUR)	CUR = Nlate / Nall, where Nlate is the number of restrictions identified after submission of the documentation or at the stage of exercising rights	restriction layers, urban-planning documentation, environmental registers	medium
Completeness of land-management surveys	Identification of adjoining rights not reflected in the State Land Cadastre	Index of legal completeness of adjoining-rights analysis (ILCA)	share of adjoining parcels for which analysis of the rights register, archival documents, and actual use has been confirmed	State Register of Property Rights, archival funds, boundary-agreement acts, field acts	medium
Accuracy of topographic and geodetic surveys	Metric correctness of coordinates	Root mean square error (RMSE)	calculated from control measurements	field logs, GNSS/total-station files, control points	high
Accuracy of topographic and geodetic surveys	Conformity of points with regulatory tolerances	Share of points within tolerance (SPT)	SPT = Nok / Np	measurement logs, automatic CAD reports	high
Accuracy of topographic and geodetic surveys	Topological correctness of geometry	Topological integrity index (TII)	TII = 1 - Ne / Nc, where Ne is the number of topological errors and Nc is the number of checks	XML/GML, cadastral layers, topology rules	very high
Soundness of the project decision	Presence of a causal link between data and the decision	Project evidentiary substantiation index (PESI)	share of project propositions that contain a reference to a source, calculation, or spatial analysis	document text, electronic links to sources, restriction layers	medium

Quality component	Content of the component	Quantitative metric	Formula / calculation logic	Data source for automation	Level of automation
Soundness of the project decision	Assessment of alternatives	Alternativity index (AI)	ratio of the number of considered alternatives to the minimum determined by the methodology	explanatory note, CAD analytical modules	low/medium
Soundness of the project decision	Spatial consistency of the decision	Decision conflict index (DCI)	number of conflicts with urban-planning documentation, restrictions, and infrastructure zones per project unit	urban planning cadastre, protection layers, transport and engineering networks	high
Regulatory compliance	Conformity of documentation composition and content	Regulatory compliance index (RCI)	RCI = 1 - (2Ncrit + Nminor) / Nchk	machine rules, checklists, electronic forms	very high
Regulatory compliance	Correctness of the electronic document	Format validity index (FVI)	share of successfully passed syntactic and semantic checks	XML schemas, State Land Cadastre validators	very high
Practical fitness	Probability of smooth procedural passage	Procedural success index (PSI)	composite indicator: acceptance at first submission, absence of refusals, passage time	State Land Cadastre, State Register of Property Rights, electronic cabinets	high
Practical fitness	Risk of subsequent dispute or correction	Post-project stability index (PPSI)	PPSI = 1 - (Ndisputes + Nfix) / Nall for a defined period	court registers, correction statistics, complaint data	medium
Consumer value	Fitness for achieving the legal result	Right-realizability index (RRI)	share of projects completed by acquisition or proper exercise of the right without repeated preparation of documentation	State Register of Property Rights, State Land Cadastre, registers of decisions	medium

Note: developed by the authors.

This table is of fundamental importance. It transfers the discussion of quality from the plane of intuition to the plane of operationalization. The key point is that only some indicators initially belong to the classical properties of geodata - format validity, topological integrity, accuracy, and consistency. Another group concerns more complex dimensions: evidentiary substantiation, completeness of source search, and post-project stability of the right. True qualimetry of land management emerges precisely from the combination of these two groups of indicators.

Under conditions of complete or predominant digitalization of the processes of initiating, drafting, approving, adopting, and implementing land management documentation, a key methodological rule arises: only what has first been conceptually defined and formally described can be automated. If quality remains an undefined professional intuition, it cannot be transformed into an algorithm. If, however, it is decomposed into individual properties, and for each property an indicator, data source, permissible threshold, and consequence of deviation are defined, control can be embedded in digital services. International standards of geographic-data quality are built on this logic: they do not merely state that data may be “quality” data, but specify the structure of indicators, assessment procedures, and reporting rules [8; 9].

For the land management sphere, this means that quality control must be multi-level:

1) The first level is syntactic and structural control. This includes checking the electronic-document format, completion of mandatory fields, conformity with XML schemas, signing, correctness of archive structure, absence of duplicates, and formal correctness of attributes. In Ukraine, this level has already been largely implemented in XML electronic-document verification services and in the Procedure for maintaining the State Land Cadastre [13; 14].
2) The second level is geometric and topological control. This includes checking self-intersections, contour breaks, overlaps, logical consistency of boundaries, consistency of geometry with attributes, and conformity

with the basic rules of the spatial model. This sphere is also highly amenable to algorithmization and already has established standards both in international practice and in the Ukrainian system of cadastral data acceptance [8; 9; 11–14].

3) The third level is inter-register logical control. Its task is to identify conflicts between land management documentation, cadastre data, the register of rights, urban-planning documentation, registers of restrictions, engineering networks, and environmental protection zones. It is here that the main development of digital services should occur in the coming years. The formal possibility of such interaction is embedded both in the legal regime of the national geospatial data infrastructure and in acts on information interaction between the cadastre and rights registration [4; 21].
4) The fourth level is control of survey completeness. It is considerably more complex, but also partly amenable to algorithmization. For each type of documentation, a digital profile of mandatory sources may be formed: whether the developer applied to the State Fund of Land Management Documentation; whether materials of the State Cartographic and Geodetic Fund were examined; whether data from the register of rights were checked; whether urban-planning documentation was integrated; and whether data on restrictions and engineering networks were processed. Here, control should operate not as an assessment of the “correctness of an opinion”, but as an assessment of the evidentiary completeness of the professional search.
5) The fifth level is control of project substantiation. It is the least suitable for full automation, but it can be substantially strengthened by digital tools: comparison of alternatives, automatic conflict detection, spatial analysis of access, overlay of multiple layers of regimes, and fixation of the sources on which each project provision relies. Here, automation

should not replace the land surveyor, but should make the professional judgment transparent, reproducible, and verifiable.

For discussion purposes, the authors have attempted to comprehensively systematize known methods of quality control of land management documentation within a single systemic framework (Table 2).

Table 2 - Methods of quality control of land management documentation

Control method	Essence of the method	What it checks	Can it be algorithmized?	Where it can be implemented
Format and structural validation	Checking the electronic document for conformity with the schema, structure, and mandatory fields	FVI, basic regulatory correctness	yes, fully	State Land Cadastre, CAD, electronic cabinets
Topological check	Control of geometric and topological errors	TII, contour conflicts	yes, fully	CAD, GIS, State Land Cadastre, urban planning cadastre
Geodetic control	Control of errors, closures, coordinates, and conformity with accuracy class	RMSE, SPT	yes, predominantly	CAD, field programs, acceptance systems
Cross-register verification	Comparison with the cadastre, rights register, urban planning cadastre, and protection zones	DCI, ILCA, CUR	yes, to a significant extent	integrated state systems
Checklist verification of composition and content	Checking the presence of all required documentation elements	RCI, SCI	yes, fully or almost fully	electronic forms, approval services
Analysis of the evidence base	Determining whether each documentation provision has proper substantiation	PESI	partially	digital systems with linked references and sources
Expert project review	Professional assessment of the rationality of the decision, alternatives, and proportionality	AI, PESI, DCI	only partially	approval authorities, internal control of the executor

Control method	Essence of the method	What it checks	Can it be algorithmized?	Where it can be implemented
Post-project audit	Analysis of refusals, disputes, corrections, and repeated preparation	PSI, PPSI, RRI	yes, if integrated data are available	State Land Cadastre, State Register of Property Rights, court analytics, management dashboards
Field verification	On-site inspection	actual existence of objects, boundaries, and structures	partially	mobile applications, control authorities
Anomaly analytics	Search for atypical configurations and suspicious recurring scenarios	corruption and technological risks	yes, increasingly	analytical modules, risk-oriented control systems

Note: developed by the authors.

The last method - anomaly analytics - is of particular importance. Most illegal or manipulative practices in the land sphere do not necessarily appear as a gross technical error. They often appear as statistically atypical behavior: repeated small buildings used as a basis for initiating large land parcels; identical templates in document configurations; excessive concentration of approvals among particular entities; or typical sequences of registration actions leading to circumvention of competitive procedures. It is at this intersection that space emerges for new digital-control tools.

For land management practice, it is important to move beyond the notion of quality as the “internal soundness” of a document. Documentation quality is also a measure of public trust in it. High-quality documentation reduces the number of disputes, reduces the need for repeated applications, lowers transaction costs for the state and private persons, prevents some corruption manipulations, and increases the predictability of the circulation of land rights. Therefore, it is also appropriate to consider it in terms of risk: a document is high-quality to the extent that it reduces the probability of future uncertainty regarding boundaries, regimes, title, permissible use, and spatial conflict.

This leads to an important methodological thesis: in the modern land management system, not only error control but also risk control should be central. An error is an already identified deviation. Risk is the probability that a defect will manifest later. Therefore, indicators of post-project stability, conflict potential, repeated preparation of documentation, or an array of refusals in similar cases are no less important than indicators of accuracy or file validity.

Separate attention should be paid to assessing the prospects for using artificial intelligence (AI) to control the quality of land management works. The issue of using AI in land administration is already directly recorded at the level of the UN system. UN-GGIM materials for the 14th session of the Committee of Experts state that the expert group is analyzing the potential application of AI in future systems of land administration and land management; at the same time, OECD documents on public governance emphasize that trustworthy use of AI depends on high-quality data and proper data governance [10; 22]. Thus, for land management, AI cannot be a "superstructure" built over a low-quality information base; on the contrary, it is possible only where the quality model of data, sources, and procedures has previously been brought into order.

In the authors' opinion, the most promising areas for the use of AI in quality control of land management works may be grouped into five categories:

1) The first is intelligent document analysis. Natural-language-processing models can compare textual provisions of an explanatory note with regulatory requirements, identify omitted mandatory elements, search for contradictions between text and graphics, and automatically generate a preliminary list of risks and non-conformities. This does not replace a lawyer or land surveyor, but it radically strengthens preliminary control.
2) The second is anomaly detection in geospatial and procedural data. AI can learn from arrays of already processed cases and identify atypical combinations of features: unusual ratios between land-plot area and building area; recurring configurations of cadastral contours; atypical temporal sequences of registration actions; and unusual clusters of

refusals or, conversely, “too smooth” passage through procedures. It is precisely here that technology can become an early-warning tool not only for technical risks but also for corruption risks.

3) The third is computer vision for verifying the actual existence of objects. Where lawful integration with orthophoto plans, satellite images, aerial-survey materials, and field photo-recording results is available, AI can help verify whether a declared building exists, whether it has not been demolished, whether its contour corresponds to the actual condition, and whether a capital construction object has not been replaced by a small or temporary element. In the context of schemes in which legal title to land is built through a dubious reference to an immovable-property object, this is of particular significance [17].
4) The fourth is assistance in project decision-making. AI can propose alternative configurations, automatically account for restrictions, analyze access, servitudes, and overlaps of regimes, compare alternatives against several criteria, and generate explanatory notes on spatial compromises. Here, it performs an advisory rather than a public-authority function.
5) The fifth is self-learning quality control. If the system accumulates data on reasons for refusals, typical comments, court disputes, corrections, resubmissions, and verification results, AI can continuously refine documentation risk profiles and improve the rules of primary control.

At the same time, the limits of permissible AI use must be clearly defined. In the field of land management, it is impermissible to fully and automatically substitute professional and public-authority decision-making where legal assessment, determination of the balance of interests, assessment of proportionality of restrictions, or final establishment of legal consequences is involved. AI should operate as a decision-support system, not as an independent bearer of public authority. In other words, for land management, the most promising model is that of an “explainable digital assistant”, not an “autonomous digital expert”.

Conclusions. Modern quality management of land management works should move from the logic of after-the-fact error checking to the logic of designing quality into the very architecture of documentation and digital procedures. This requires at least four steps. The first is to approve a sectoral model of land management documentation quality that is not limited to regulatory compliance, but covers completeness of surveys, accuracy, project substantiation, and risk safety. The second is to form mandatory digital source profiles and checklists for each type of documentation. The very idea of such a unified list of questions, despite the non-adoption of Draft Law No. 10095, reflects an objective need of the system for more standardized control [16]. The third is to integrate qualimetric indices similar to those proposed in this article into CAD systems, the State Land Cadastre, the urban planning cadastre, and related systems, with acceptability thresholds and automatic generation of quality protocols. The fourth is to develop risk-oriented control and the use of artificial intelligence where it can strengthen the detection of hidden defects, anomalies, and manipulations without substituting professional judgment.

Prospects for further research are primarily related to deeper development of sectoral qualimetry of land management, that is, a system of scientifically substantiated indicators, weighting coefficients, and threshold values for different types of land management documentation. The methodology for quantitatively assessing the completeness of land-management surveys and the evidentiary substantiation of the project decision requires separate elaboration, since these components are currently least susceptible to formalization but at the same time significantly influence the legal stability and practical value of documentation. Another important direction for further research is the development of models for integrating such metrics into computer-aided design systems, the State Land Cadastre, the urban planning cadastre, and related public information resources, as well as defining the limits and principles of AI application for detecting defects, anomalies, and risks in land management documentation without replacing professional and public-authority discretion. It is on this basis that a new quality of land management can be formed - as a sphere in which reliability, evidentiary

substantiation, and digital verifiability become the foundation of legal certainty and sustainable spatial development.

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Л.А. Гунько, А.Г. Мартин, І.Г. Колганова, О.В. Захаренко

УПРАВЛІННЯ ЯКІСТЮ РОБІТ ІЗ ЗЕМЛЕУСТРОЮ: СУТНІСТЬ, ІНСТРУМЕНТИ, МЕТРИКИ

Анотація. *У статті досліджено якість робіт із землеустрою як складну багатовимірну категорію, що не зводиться до формальної відсутності помилок, дотримання встановленої форми документації чи її мінімальної відповідності нормативно-правовим вимогам. Обґрунтовано, що в сучасних умовах цифровізації земельно-кадастрових, реєстраційних і планувальних процедур якість документації із землеустрою має розглядатися як інтегральна властивість професійного результату, яка поєднує повноту землевпорядних вишукувань, точність топографо-геодезичної основи, обґрунтованість проектного рішення, нормативну коректність, а також здатність документації мінімізувати ризики набуття, підтвердження та реалізації прав на землю. Показано, що чинна практика контролю в Україні історично найбільшою мірою зосереджена на перевірці технічної валідності електронних документів, топологічної зв'язності, логічної узгодженості та форматної придатності геоданих, тоді як питання повноти вишукувань, доказовості проектного рішення та післяпроєктної стійкості правового результату залишаються методологічно значно менш розробленими. Метою дослідження є теоретико-методологічне обґрунтування сутності якості робіт із землеустрою, формування системи її структурних елементів, розроблення кваліметричного підходу до оцінювання документації із землеустрою та визначення інструментів управління якістю, придатних для професійного, адміністративного й автоматизованого цифрового контролю. Методологічну основу становлять системний, структурно-функціональний, формально-юридичний, порівняльно-правовий та кваліметричний підходи, а джерельну базу - законодавство України, міжнародні стандарти якості географічної інформації, документи у сфері адміністрування земель, а також чинні процедури електронної валідації землевпорядної документації. Запропоновано модель якості документації із землеустрою, що включає п'ять*

взаємопов'язаних вимірів: повноту вишукувань, точність геодезичних робіт, обґрунтованість проектного рішення, нормативну відповідність і практичну придатність до досягнення правового результату. Розроблено систему кількісних метрик та інтегральний підхід до оцінювання якості, придатні для впровадження у системах автоматизованого проектування, Державному земельному кадастрі, містобудівному кадастрі та суміжних державних інформаційних ресурсах. Окремо обґрунтовано перспективи використання штучного інтелекту для інтелектуального аналізу документації, виявлення аномалій, перевірки фактичного існування об'єктів, підтримки проектних рішень і побудови ризик-орієнтованого контролю, за умови недопущення підміни ним професійного та владного розсуду. Практична цінність статті полягає у формуванні концептуально цілісної та інструментально придатної рамки для переходу від формального контролю документації до системного управління якістю робіт із землеустрою в Україні.

Ключові слова: *якість робіт із землеустрою; документація із землеустрою; управління якістю; кваліметрія; метрики якості; Державний земельний кадастр; геопросторові дані; топологічна зв'язність; повнота землевпорядних вишукувань; обґрунтованість проектного рішення; цифровізація землеустрою; штучний інтелект.*