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Quality of State Real Estate Cadastre-Maintenance Process Based on Ishikawa Cause-and-Effect Diagram

Abstract: The management of Kazakhstan's Real Estate Cadastre is crucial for ensuring the stability and transparency of its real estate market as well as for the implementation of social and economic programs. The main functions of the cadastre are the protection of rights to real estate and the management of the land fund, which contributes to economic development and legal security. Information technologies are currently being introduced in Kazakhstan to maintain this unified cadastre, including public cadastral maps and geoinformation resources. The study of the quality of maintenance of Kazakhstan's Real Estate Cadastre was conducted using the Ishikawa causal diagram, which allows one to identify and systematize the key factors that influence the quality of any cadastral data. Regulatory legal acts, the methods and means of measurement, the qualifications of personnel, databases, and the technology of the cadastre's maintenance were analyzed. The study applied differentiation of results and comparative analysis methods. The results of the analysis showed that regulations and databases had the greatest influence on the quality of the cadastral data. The technology of the cadastre's maintenance and measurement methods are also significant. The study made it possible to identify control points for improving the quality of cadastral maintenance and propose recommendations for reforming the system. The obtained results can be used for the development and implementation of measures to improve the quality of the cadastral service.

Keywords: state real estate cadastre, cause-effect diagram, inverse series matrix, quality management, real estate

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1. Introduction

In today's world, the effective management of a state's real estate cadastre plays a key role in ensuring the transparency and stability of its real estate market as well as in its implementations of socio-economic programs. Global issues such as urbanization, the insecurity of property rights, land conflicts, and unequal access to land have increased the demand for reliable and up-to-date land information. In order to meet these demands and to guarantee property rights, scientists are advocating for the quality maintenance of official real estate cadastres. To ensure the high quality of any cadastral data, it is necessary to assess the impacts of various factors on the process of its maintenance.

A state real estate cadastre is the main source of information, as was demonstrated by Yesmaganbetova et al. [1]; according to Kirichek and Grianyk [2], this serves the dual function of protecting the rights to real estate and the management of land funds. This system provides comprehensive technical, economic, and legal information on real estate objects while facilitating real estate transactions and mortgage procedures (as was evidenced by the work of Slave and Vizireanu [3]). In essence, a state real estate cadastre serves as a foundation for property rights, taxation, and land management. Its reliability and accuracy are crucial for ensuring legal certainty, promoting economic development, and safeguarding the interests of stakeholders. As emphasized by Mirdjalilova and Ziyayev [4], addressing challenges and maintaining the integrity of the cadastre system's integrity is essential for fostering trust, transparency, and efficiency in land administration. This affects the interests of individuals and legal entities, public authorities, and local executive bodies. It follows that maintaining the quality of a state real estate cadastre system is of a strategic nature and that an entry in a unified cadastre, such as Kazakhstan's, should contain complete information on the characteristics of each object that is included in it.

At present in the Republic of Kazakhstan (as well as in many countries of the world), the system of a unified state cadastre of real estate that is based on the application of information technologies and the provision of electronic services is rapidly developing. A public cadastral map is available to all users; with the help of this, it is possible to obtain reference information on real estate objects. There is an intensive accumulation of geoinformation resources in the republic; most of these use ArcGIS as the main software product. At the same time, the large volume of geodata that is accumulated as a result of the production activities of various enterprises as well as the diversity of their forms, structures, and applied programs complicates and sometimes hinders the processes of using geoinformation. New market demands for information on geographical objects and the development of geoinformation technologies require searches for new solutions or new forms of spatial data organization at the national level.

The current state of maintenance of the state land cadastre in the Republic of Kazakhstan is influenced by the need for the digitalization and standardization

of real estate management (as was highlighted by Kurmanova [5]). This includes the use of modern geoinformation technologies and the creation of a unified state land cadastre. The existing methodology for determining the cadastral value of land in settlements is also a key factor, with Akhmetova and Sekenova [6] noting the importance of zoning approaches and proposing to introduce a new coefficient for commercial purposes.

The relevance of this study is due to the development of geoinformation technology, which depends on the level of government support. At present, many new interests in immovable property differ from traditional land titles. As a result, new concepts and definitions of immovable property units are required. In addition, our built environment is becoming increasingly complex; as was demonstrated by Drobež et al. [7], a traditional cadastre cannot meet all of the requirements of modern land use. Taking its main functions and the areas in which it is to be used into account, a cadastre must guarantee security and order – both in terms of the data that it contains and the rights of all individuals. For the rational management of real estate, however, Reczyńska and Hanus [8] emphasized that it was necessary not only to collect information about a cadastre in terms of the temporal data that it contains but also to be able to easily consult archived data that is currently outdated or rights that will be imposed on the property in the future (such as easements, which is a not insignificant factor in cadastre management). A reliable assessment of the quality of the management of the real estate cadastre can be made only on the basis of scientific methods and quality-control approaches. The research solution to this problem is to analyze the quality of a cadastre's management using the Ishikawa causal diagram and to improve the management policy of the state cadastre of real estate in order to ensure the most efficient functioning. The study of the main quality indicators that affect the quality of the management of Kazakhstan's Real Estate Cadastre, their classifications, and the identification of the places of increased control is a way to meet the requirements of the stakeholders. Further systematization, the identification of shortcomings, and their presentation with the help of quality-control tools allow us to observe cause-and-effect relationships more clearly and transparently and determine further steps to eliminate possible discordant situations in advance. Based on this, we define control points as those places where there is an increased occurrence of defects, since the adoption of certain decisions at certain stages of the development of a state real estate cadastre system may affect the final results of its operation. Therefore, a thorough analysis of all subsequent development stages is crucial for evaluating potential options and justifying the optimal path forward for the system. As highlighted by Yesmaganbetova et al. [9], it is necessary to collect information not only on economic indicators but also on social, legal, and environmental indicators for a more detailed analysis of the efficiency of a real estate cadastre system using various sources of information. These results will serve as a basis for the next steps for improving the quality of the maintenance of the real estate cadastre. The originality of the study consists of a comprehensive study of theoretical

approaches to this problem and extensive empirical experience of their applications. The main elements of scientific novelty consist in the developments of proposals and recommendations for further reform of the system of Kazakhstan's Real Estate Cadastre system, based on an analysis of the factors influencing its quality.

The study's hypothesis posits that adopting an innovative management policy for Kazakhstan's Real Estate Cadastre, based on successful examples from other countries, will increase the country's economic efficiency.

The article is structured as follows: the beginning of the article discusses the relevance of the study abroad as well as in Kazakhstan (where the state plays an important role in the development and management of real estate). The article discusses the methods that were used in the study and presents the results of the analysis. The Discussion section explores the relationship between real estate governance and the effectiveness of the governance system, while the Conclusions section highlights the need for a more systematic policy in Kazakhstan and proposes innovative solutions based on successful examples of public real estate governance systems in other countries.

2. Literature Review

The need for research to assess the quality of government cadastral maintenance is justified by several key factors that have direct impacts on service delivery. As noted by Dimova [10], the legal framework serves not only as the basis for the creation of a real estate cadastre but also as the foundation for successful land management. This perspective was reinforced by Mirdjalilova and Ziyayev [4], who emphasized that the system of regulatory documents in the sphere of real estate management constituted a set of interrelated documents that had been adopted by state and self-government authorities at all stages of the real estate management system to protect participants' rights and interests.

However, Buśko et al. [11] demonstrated that frequent changes and inconsistencies in legislation transformed what should be systematic and technical activities into politically dependent processes, while the unsettled state of real estate documentation created legal uncertainty for citizens, investors, and state institutions. Tuleubayeva [12] underscored the necessity for continuous updates to existing provisions and the proper execution of land-legal and administrative-legal statutory acts. Complementing these findings, Jaxybayev [13] provided valuable insights through a historical and comparative analysis of land regulation in Kazakhstan relative to the Commonwealth of Independent States (CIS) and the People's Republic of China (PRC). It is known that the quality of a state real estate cadastre is fundamentally influenced by the availability of an effective information system – a database. As demonstrated by Owusu Ansah et al. [14], this system encompasses all of the simple informal procedures that are performed by individuals or small groups

for identifying properties on small territories and complex spatial data collection and organization at the state level. The extent of the discrepancies in state cadastral databases (including problems of error propagation, their causes, and their correction procedures) was thoroughly examined by Ivanovych and Shtefaniuk [15] and Karabin and Łuczyński [16]. As a result, errors are found in these databases despite the careful preparations of cadastral documents. Lisova and Leiba [17] particularly emphasized the importance of cadastral maintenance and the need for reliable land-quality information. Complementing these findings, Hanus et al. [18] provided a comprehensive analysis of current cadastral databases and documented examples of the most common technical errors in cadastral maintenance practices. A database can also refer to any coordinated and standardized land registry in which a parcel of land serves as a common geographical unit and which, together, provide an integrated methodology for the collection, maintenance, updating, and use of real estate information (as was defined by Sužiedelytė-Visockienė et al. [19]). Building on this concept, Owusu Ansah et al. [14] demonstrated that a well-designed and implemented database not only improved land management and information accessibility but also reduced bureaucracy in cadastral processes. As Sinenko et al. [20] emphasized, the data that is contained in a modern cadastre must maintain adequate quality standards.

This is particularly important when it comes to the information in the records about the boundaries of a property. Boundaries are attributes that determine the extent of the rights that are attached to a particular property. Their accuracy and reliability have a significant impact on the quality of the other data that is contained in the property cadastre (such as the areas of land parcels). The most widely used methods for determining the dimensions and configurations of real estate were comprehensively described by Quintero [21], who presented both specific theoretical studies and practical measurement examples. The accuracy of the measurement results is significantly impacted by the lack of modern high-precision geodetic instruments and equipment; this was a concern that was raised by Kadaster International [22]. This reduces work productivity and accuracy while potentially compromising measurement outcomes. This issue is directly related to the relationships among spatial uncertainty on cadastral maps, the registry of land-plot areas, and state responsibility (as was thoroughly examined by Yildiz et al. [23]). The dynamics of the technological modernization of multiple systems (particularly through advanced information technologies in our globalized context) deserves special attention – a point that was emphasized by Dawidowicz and Źróbek [24]. Significant improvements in cadastral maintenance quality can be achieved through the optimization of parcel-boundary observations and measurement processes along with the enhanced efficiency in cadastral documentation updates through mapping (as was demonstrated by Zaoralová et al. [25]). Furthermore, attracting qualified specialists and improving their skills as responses to increasing data-quality requirements represents another crucial factor in enhancing cadastral maintenance standards.

Overall, the literature review showed that a systematic approach is required for the maintenance of a national real estate cadastre. Many studies have emphasized the importance of taking local conditions and stakeholder interests into account when developing property-management policies. In addition, the continuous monitoring and evaluation of the quality of cadastral maintenance is recommended in order to ensure that any and all of the policies and practices are delivering the desired results.

3. Materials and Methods

This study used a variety of research methods, including a literature review, an Ishikawa causal diagram, a differentiation of results method, an inverse series matrix, and a comparative analysis to study Kazakhstan's Real Estate Cadastre.

In order to achieve the goal and prove the hypothesis of the study, a qualitative study of the problems and prospects of the maintenance and use of Kazakhstan's Real Estate Cadastre was conducted. The structural sequence of the research consisted of the implementations of the following stages:

The research was based on the method of content analysis of scientific literature. The literature review was focused on an analysis of sources of information on the maintenance of state real estate cadastre – not only in Kazakhstan, but also abroad.

Using the methods of theoretical generalization and comparative analysis, the main indicators of the quality of the maintenance of Kazakhstan's Real Estate Cadastre were determined. The sources were analyzed – the results of which showed that the key factors that directly influenced the quality of the maintenance of a state real estate cadastre were as follows:

- normative and legal acts (hereinafter – NLA);
- measuring instruments and methods;
- personnel;
- database;
- technology.

Based on the identified factors that affected the quality of Kazakhstan's Real Estate Cadastre maintenance, an Ishikawa cause-effect diagram was constructed. This diagram is shown schematically in Figure 1.

The "NLA" component of the cadastre system is fundamentally connected to the legal acts that regulate this sphere; this was extensively documented by Kurmanova [5], Makedonskiy and Kurzayeva [26], and Gavrilova et al. [27]. A wide range of laws and normative legal acts are used to regulate this issue. The main documents that regulate cadastral activities are The Constitution of the Republic of Kazakhstan, the Land Code of the Republic of Kazakhstan, the Order of the Minister of Agriculture of the Republic of Kazakhstan "On Approval of the Rules of

Provision of Public Services in the Field of Land Relations," the Resolution of the Government of the Republic of Kazakhstan (dated October 31, 2011), "On Approval of the Forms of Identification Documents for Land Parcels the Resolution of the Government of the Republic of Kazakhstan" No. 958 (dated September 20, 2003), "On Approval of the Rules of the State Land Cadastre," and other acts of the executive authorities of the Republic of Kazakhstan that are aimed at regulating this sphere.

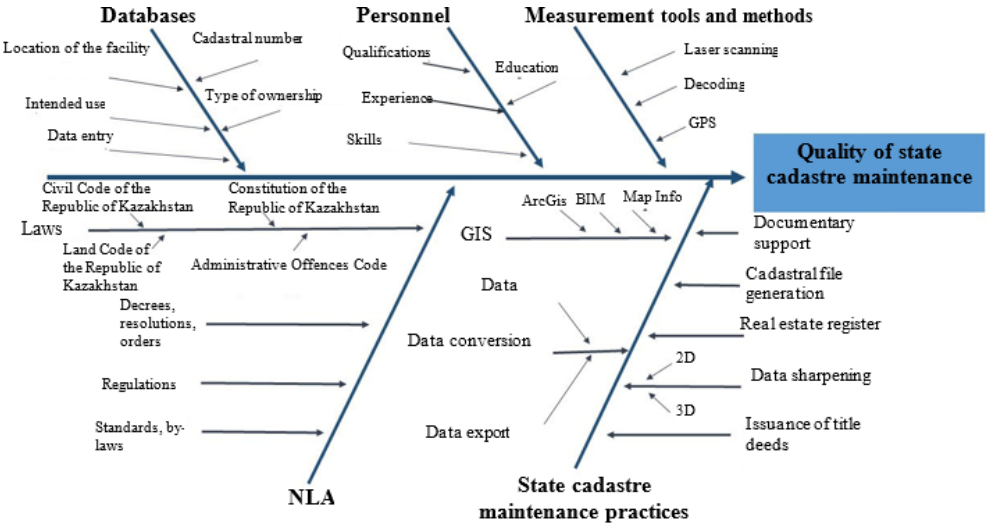

Fig. 1. Analysis of quality of maintenance of Kazakhstan's Real Estate Cadastre using Ishikawa causal diagram

The Land Code [28] regulates land relations on the use and protection of the land, the ways of forming land plots; it also gives basic definitions and concepts in the field of land relations, discloses issues that are related to ownership, and restricts the rights to land plots. An important chapter of the code is the protection of rights to land and the considerations of land disputes, which are often the reasons for cadastral works to clarify the boundaries of land plots. In most cases, an important chapter that serves as a basis for carrying out cadastral works to clarify the boundaries of land plots is the protection of the rights to land and the considerations of land disputes that are regulated by this code; since land management and the maintenance of the state cadastre are regulated by normative legal acts that are approved by executive authorities and local akimats, one of the main indicators of the quality of the maintenance of the state cadastre is the component of the NLA.

The "means and methods of measurement" component includes the methods and means for carrying out the measurements of objects. When creating a state cadastre, each object that is located on the Earth must coincide with the locations of land plots. In order to check whether this is the case, it is necessary to carry out

geodetic surveys. The State Cadastral Service of Kazakhstan carries out several types of topographic surveys for the preparations of land parcel plans; those that are most frequently used are theodolite, tacheometric and leveling surveys. Phototopographic, aerospace, and satellite technologies are also widely used. As was demonstrated by Janteliyev et al. [29], an indispensable source of information for accurate land-use management is data from high-resolution remote sensing; for this, unmanned aerial vehicles are increasingly being used. The specifics of such surveys are closely related to the contents and accuracy of the plans and their presentations as well as to the objects that are surveyed. Cadastral plans and maps reflect the boundaries of land parcels, urban structures, hydrographic elements, communication nodes, green areas, and other objects.

The "personnel" component encompasses factors related to the qualifications, training, experience, and organizational skills of cadastral staff. As the most vital resource of any organization, employees ultimately determine a company's results through their efficiency and productivity. While staff incentives are costly and time-consuming, their impact is significant. Therefore, to achieve optimal outcomes, it is crucial to motivate employees and create the necessary conditions for them to perform their tasks. Furthermore, as Alipbeki and Moldabekov [30] emphasized, the dynamic development of information technologies necessitates properly organizing timely professional development and facilitating the exchange of experience among employees. Moreover, implementing measures for international knowledge exchange directly impacts the quality of cadastre maintenance by enabling the adoption of advanced foreign practices and fostering close cooperation with foreign partners.

The "database" component plays a key role in supporting real estate information in the automating and optimizing processes. Kazakhstan's Real Estate Cadastre is maintained by a single centralized system. This, in turn, is due to the fact that, in order to achieve the maximum economic effect, the normal functioning of the cadastre's database is required. Despite the fact that the updating of the republican base with correct and complete data is ensured, it is necessary to solve many problems:

- organization of data transfer and exchange among automated databases of different departments;
- implementation and maintenance of special automated programs and their improvement;
- creation of unified information and communication space of state cadastral registration, technical inventory, registration of rights to real estate, tax authorities, state administration bodies, etc.

One of the main conditions for the creation of Kazakhstan's Real Estate Cadastre system is the need to create and maintain a central cadastral database for the subjects of the Republic of Kazakhstan and a republican database. The necessity to create a central cadastral database of the peripheral stations of the administrative

districts significantly affects not only its structure but also the relationships among the elements of the system and the entire environment (economic, ecological, natural, social, etc.).To date, the Republican Centre of the Automated Information System of Kazakhstan's Real Estate Cadastre (hereinafter, AIS SRC) has been established to implement, maintain, collect, systematize, and maintain the database of the cadastre. The transition to an automated mode of maintaining Kazakhstan's Real Estate Cadastre is based on the application of geographic information system (hereinafter, GIS) technologies; on the basis of these, the AIS SRC was created. It was designed to automate the processes of maintaining the cadastre in order to increase the efficiency of the work, to increase the volume and quality of the services that are provided, and to provide prompt responses to inquiries that are submitted in the forms of references using Internet technologies. AIS SRC is maintained at various territorial levels; i.e., republican, regional, and district. The automated information system of land and urban cadastre at the district level is the main element of the entire AIS SRC system, as it is here that the work on the initial and ongoing registration of real estate, primary processing of transactions, maintenance of current records, reporting, and provision of information is carried out. Information on the condition and use of land parcels as well as their areas, locations, economic, and qualitative characteristics are entered into the AIS SRC system in accordance with SRC documents. The data (SRC documents) are formed on the basis of land-survey data, the information that is provided by the right holders of land plots, and the results of various studies and surveys (including topographic-geodetic, cartographic, monitoring, cadastral, soil, and geological-geomorphological works) as was established by Ministerial Order No. 68 [31]. When optimizing the work, it should be noted that the systematization of cadastral information has a significant impact on the acceleration of the processes that are carried out. When optimizing the work, it should be noted that the systematization of the cadastral information has a significant impact on the speeding up of the processes that are carried out. As Mirdjalilova and Ziyayev [4] demonstrated, those countries that have successfully implemented databases for land management (particularly, developed nations like the Netherlands) have shown how such systems can provide universal access to geographical data while increasing transparency and facilitating individual real estate choices.

It is evident from the initial data that a technological process is defined as an ordered sequence of interconnected actions that are meticulously designed to achieve a specific objective. Consequently, each technological process can be conceptualized as a constituent element of a multifaceted process that are comprised of a series of fundamental (elementary) technological processes. As demonstrated in the research that was conducted by Akishev and Daribaeva [32], Kiran [33, pp. 21–37], and Coccia [34], the probability of achieving quality services is contingent upon the execution of each technological process in the correct sequence.

Considering the maintenance of a state cadastre as a production process, it can be seen that the maintenance of the state cadastre is a system that is a unity of two

closely related subsystems: documents and activities (process). The subsystem of the state cadastral documentation includes the following groups of documents:

- basic (unified state cadastre, cadastral maps, cadastral files);
- auxiliary (document registers, registers of transferred information, catalogues of coordinates of points of reference boundary network);
- derivative tools (list of republic's lands, republic and municipal property, reports on state and use of land resources, statistical reports, analytical reviews, derivative cadastral maps, reference, and analytical documents).

Consequently, the process of carrying out an SRC includes the main technological activities that are included in the "technology" component:

- preparatory works;
- creation and accounting of immovable property;
- creation and accounting of territorial zones;
- valuation of real estate;
- preparation of reports on use of real estate and provision of cadastral information.

The next stage of the study was to evaluate those factors that were identified in the process of constructing the Ishikawa causal diagram. Expert analysis was used to obtain quantitative values for the identified factors.

The expert analysis was carried out by ranking the factors based on the opinions of the experts. In order to obtain objective and reasonable results, two independent groups of experts were formed: property owners, and specialists from the state corporation "Government for Citizens." Assessments of the influence of the factors on the quality of cadastral data were carried out by each group of experts.

The use of two independent groups of experts made it possible to verify a consensus among the different opinions and assess the degree of agreement regarding the influence of different factors on the quality of cadastral data.

In order to identify the importance and influence of the quality factors, it was decided to determine the degree of the influence of each factor on quality based on the expert analyses that were performed. The degrees of the influence of the factors were determined using two different methods of differentiation:

A method of graphical analysis that included data visualization, which allowed us to visualize the weight shares of the components that influenced the quality of the inventory factors. The experts in the first group evaluated the weight shares of the components using a 100-point system. The main factors (such as the regulations, databases, technology, measurement methods and instruments, and personnel) were rated.

An inverse series matrix method involved the use of expert judgement to calculate the factor weights. The experts in the second group rated the factors on a scale of 1 to 5 points, where 1 point indicated a minimum impact and 5 points indicated a maximum impact. Based on these assessments, the inverse series matrix was

calculated according to Formula (1), and the weights for each factor (W) were determined:

$$W = a_{i,j}^{(n_{\max}+1)-a_{i,j}} \tag{1}$$

where $a_{i,j}$ is the j-th expert assessment by expert a for the i-th criterion (as was described in the studies by Makedonskiy and Kurzayeva [26], Gavrilova et al. [27], and Kurzayeva [35]).

The total scores were obtained from the inverse degree matrix and plotted by category.

Both methods aimed to determine the importance and influence of the quality factors but used different approaches to evaluate and calculate the weighting factors. On the basis of the results that were obtained with the two different methods of differentiation, a comparative analysis was carried out. The comparison of the results made it possible to check the consistency of the data that was obtained by the different groups of experts and assess the degree of the agreement of the influences of the different factors on the quality of the cadastral data.

4. Results

Graphical analysis method: the experts of the first group evaluated the weight shares of the components according to a 100-point system. Each factor received a certain number of points that reflected its importance and influence on the quality of cadastral data. The results of the expert evaluations are presented in Table 1.

Table 1. Results of expert evaluation

Factors that affect quality	Expert evaluation					Average value
	1	2	3	4	5	
NLA	30	24	20	25	26	25
Measuring instruments and methods	18	18	20	19	20	19
Personnel	16	16	18	14	11	15
Database	20	22	19	22	22	21
Technology	16	20	23	20	21	20
Total	100	100	100	100	100	100

According to the results of the expert assessments, the distribution of the influence of the factors by the score indicators was determined in ascending order as a share of the total accumulation of the share of each factor (Table 2).

Table 2. Degree of influence of factors on event through share of component totals

Factors	Score [points]	Share of accumulation totals [%]
NLA	25	25
Database	21	46
Technology	20	66
Methods and means of measurement	19	85
Personnel	15	100
Sum	100	–

"Regulatory acts" received the highest score of 25 points, which represented 25% of the total impact; this highlighted the importance of the legal and regulatory framework in maintaining a quality cadastre.

"Database" received 21 points, thus indicating the importance of a reliable and up-to-date database for an effective cadastre.

"Measurement technologies and methods" received 20 and 19 points, respectively, thus highlighting their critical roles in ensuring the accuracy and reliability of cadastral data. "Personnel" received 15 points, also highlighting the importance of skilled professionals in the field.

The component proportions were visualized using a histogram and a marker chart in order to provide a visual representation of the distribution of the weight proportions (Fig. 2).

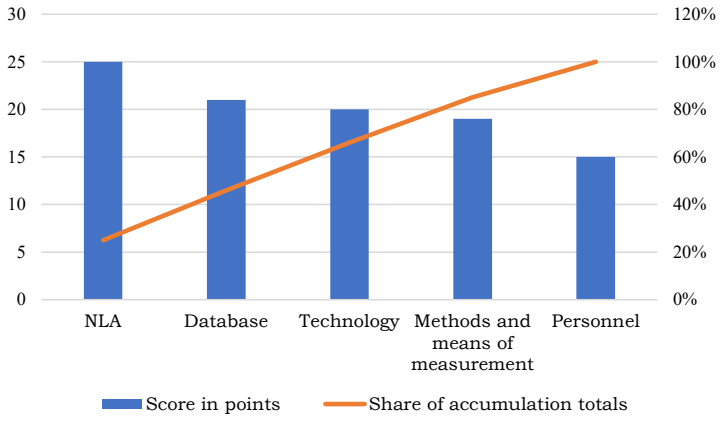

Fig. 2. Quality of state cadastre maintenance

The histogram and marker chart that are presented in the study visualize the distribution of the weight shares of the components. It is clear from the graphs that the main efforts should be focused on improving the legal framework, the database, and the technology, as these have the greatest impacts on the quality of a cadastre. This method makes it easy to identify priority areas for improvement.

Inverse series matrix method: the second group of experts ranked the factors on a scale of 1 to 5. This method of ranking the factors allowed us to assess the degree of the influence of each factor based on the experts' opinions. Then, the inverse series matrix was calculated using Formula (1), where each $a_{i,j}$ score was used to calculate weight index *W*. Based on the data that was obtained, weight indicators were determined for each influence factor; these were then summarized and expressed by category (Table 3).

Table 3. Calculation of degrees of influences of factors on event by inverse series matrix

Experts	NLA	Databases	Methods and means of measurement	Technology	Personnel
1	2^4	1^5	4^2	5^1	3^3
2	1^5	2^4	3^3	5^1	4^2
3	1^5	4^2	2^4	5^1	3^3
4	2^4	5^1	1^5	4^2	3^3
W	18	12	14	5	11
Weight score	0.3	0.2	0.23	0.09	0.18

From Table 3, it can be seen that the NLA factor received a weighted score of 0.3, thus confirming its importance. "Methods and means of measurement" received a score of 0.23, also confirming its importance, while "Databases" and "Personnel" received scores of 0.18 and 0.2, respectively. "Technology" received the lowest weighted score – 0.09.

Comparative analysis was used to compare the obtained results using the two methods of data differentiation. The results of the assessments of the degrees of influence of the factors on the quality of the maintenance of a real estate cadastre according to the two different methods are presented in Table 4. These methods can help prioritize resource allocation and policy focus in cadastre management.

This table indicates that both analytical approaches demonstrated high degrees of agreement in identifying the most critical factors that influence cadastre quality:

- NLA;
- Database;
- Methods and means of measurement.

Table 4. Assessments of degrees of influence of factors on quality of Kazakhstan's Real Estate Cadastre maintenance

Evaluation criteria	Degree of influence of criteria on event through share of accumulation totals	Calculation of degree of influence of causes on event by inverse series matrix	Interpretation
NLA	25	0.30	consistently ranked as most influential
Database	21	0.20	strong agreement on its high importance
Methods and means of measurement	19	0.23	slightly higher impact in matrix method
Technology	20	0.09	considered important (but less so in matrix method)
Personnel	15	0.18	lower overall impact (but not negligible)

This convergence underscored the foundational role of NLA and database systems in maintaining cadastral accuracy, with methods and means of measurement emerging as a key operational determinant.

While a consensus was reached on the most significant factors, differences of opinion emerged in the evaluations of the lower-priority components. These discrepancies were indicative of methodological sensitivities and the subjective weighting that are inherent in expert-driven assessments:

- Technology: the graphical analysis positioned technology in third position out of five, thus indicating its moderate influence based on the cumulative expert input. Conversely, the inverse series matrix assigned it a normalized weight of 9% (fifth out of five), thereby implying a relatively lower significance when accounting for non-linear interdependencies and comparative normalization.
- Personnel: the two methodologies identified personnel as a less dominant factor; however, the inverse series matrix attributed a notably higher influence (18%) as compared to its last-place rank in the graphical method. This finding indicated that, while not leading, human factors may have carried a greater relative importance when assessed within a standardized quantitative framework.

The dual-method analysis served to reinforce the primacy of NLA, database, and methods and means of measurement in determining cadastral quality. Furthermore, it emphasized the necessity of avoiding an exclusive reliance on a solitary analytical instrument. The graphical analysis provided intuitive clarity and ease of interpretation, while the inverse series matrix yielded estimates that were more nuanced and quantitatively precise.

5. Discussion

The analysis of the factors that influence the quality of state cadastral maintenance in Kazakhstan revealed a high degree of agreement between the ranking methods on key factors such as regulations, databases, and cadastral technology. Both methods emphasized the critical importance of the regulatory framework for cadastral operations. As demonstrated in the ISO 19152 standard that was developed by ISO/TC 211 [36], international studies by Lemmen et al. [37] confirmed that such standardization helped to harmonize and improve land administration by ensuring that the legal framework was updated in line with international standards. These findings were consistent with Tulenova and her colleagues' [38] recommendations that Kazakhstan's legislation needed to be brought in line with international standards in order to improve the quality of the territory's cadastral registration.

The creation of a centralized and integrated database is the next important step in improving the quality of the cadastral data. International experience – particularly, in those countries with developed cadastral systems – shows that such databases improve access to information and interaction between government agencies when supported by geographic information systems (GISs). These systems can significantly improve data transparency and accessibility for citizens and businesses. As demonstrated by Kaidarova et al. [39] in their study of land-resource management in Kazakhstan, the introductions of a unified state land cadastre and regional geographic information systems contribute to marked improvements in the efficiency of cadastral registration.

The utilization of cadastral technologies (encompassing digital maps, blockchains, and mobile applications) is of paramount importance in guaranteeing the precision and promptness of cadastral registration. The implementations of these technologies have been demonstrated to markedly expedite the process of data updating, diminish the potential for human error, and enhance the precision of information that pertains to land plots. In light of these considerations, it becomes evident that these technologies are particularly pertinent in the context of Kazakhstan's ongoing modernization of its cadastral registration system and the imperative to enhance the quality of its public services.

The discrepancies in the methodology between the graphical analysis and the inverse series matrix in the evaluations of the less significant factors can be attributed to disparate analytical approaches and the subjectivities of the experts. The graphical analysis method was demonstrated to be an effective approach for visualizing structures of factors and their interactions, which is a crucial aspect in the initial stages of decision-making. Conversely, the inverse series matrix offered more-comprehensive quantitative estimates, thus rendering it more suitable for comprehensive analysis and intricate calculations.

6. Conclusions

In conclusion, the findings of this study underscored the necessity for a comprehensive reform of Kazakhstan's Real Estate Cadastre system. The updating of the regulatory framework to be in accordance with international standards (such as ISO 19152) represents a crucial step in ensuring the accuracy and transparency of cadastral registration. The implementations of these standards will eliminate legal inconsistencies and enhance the public's confidence in the accuracy of its cadastral data; this will have a positive impact on the development of Kazakhstan's economy. For instance, the implementation of digital land-management systems (such as Digital Land Management) is advised in order to enhance administrative procedures and enhance transparency.

It is recommended that the legal and regulatory framework be updated and the legislation of Kazakhstan be reviewed and updated to take the ISO 19152 international standards into account. This will facilitate the standardization of the cadastral registration processes, enhance land management, and bolster confidence in the cadastral data among national and international investors (as was demonstrated in the work of Lemmen et al. [37]).

The centralized database must be improved. It is imperative that the centralized and integrated database be enhanced with the incorporations of contemporary technologies such as geographic information systems. This will facilitate interdepartmental collaboration and enhance the accessibility of the cadastral data. The implementation of such systems has already demonstrated their efficacy in land management, as was evidenced by Kaidarova et al.'s [39] studies that were conducted in the Pavlodar region.

The utilizations of blockchain technologies, mobile applications, and remote sensing will facilitate the processes of registration and the registrations of land plots. This will enhance the transparency and accuracy of the data while simultaneously reducing the potential for human error.

One strategy for enhancing the efficacy of personnel is to elevate the caliber of their training and qualifications. The success of the introduction of innovative technologies in the cadastre is contingent upon the qualifications of the specialists, therefore making it crucial to devise training and professional-development programs for civil servants who are engaged in land-related matters, with the objective of ensuring their capacities to effectively utilize new tools and approaches.

It is crucial to implement state digitalization programs such as Digital Land Management with the objective of simplifying the processes and enhancing the transparency in land management (as was highlighted by Tulenova et al. [38]). This initiative will facilitate Kazakhstan's transition to a new phase of land management, thus enhancing its efficiency and sustainability.

These proposals are based on an analysis of the best practices on the international stage and are informed by a number of studies on land-governance reforms.

The practical results of the study demonstrated that the implementations of these recommendations will result in notable enhancements in the quality and reliability of the cadastral data, improvements in land management, and assurances of economic growth and Kazakhstan's attractiveness to foreign investors. The experience of other countries and the adaptations of advanced technologies and standards may serve as pivotal drivers of cadastral reform in Kazakhstan – a conclusion that has been supported by the findings of both theoretical and practical research.

These findings have underscored the necessity for further research into the incorporations of international standards and technologies into cadastral systems as well as the formulations of methodologies for staff development in this domain. This will permit Kazakhstan to not only enhance its extant cadastral registration system but also serve as a model for other countries that are in the process of reforming their land-management systems.

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CRediT Author Contribution

A. Y.: conceptualization, investigation, data curation, writing – review and editing, visualization.

S. I.: methodology.

B. R.: software.

D. D.: validation, writing – original draft preparation, project administration.

O. D.: validation.

G. S.: formal analysis.

All of the authors have read and approved the published version of the manuscript.

Declaration of Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

No new data were generated, collected, or analyzed in the course of this theoretical study. All conclusions and analyses presented are based exclusively on previously published scientific literature, official legislative and normative documents, and publicly available information, which are fully cited in the references section of this article.

Use of Generative AI and AI-Assisted Technologies

No generative AI or AI-assisted technologies were employed in the preparation of this manuscript.

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