Addressing methodological challenges in the mass real estate valuation process, specifically within the context of the Republic of Moldova.

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Abstract: This research investigates the precision of mass real estate valuation models, particularly focusing on the methodology of mathematical value modeling. The discussed challenges are particularly relevant to nations employing an ad-valorem taxation system. The Republic of Moldova's mass appraisal system for real estate serves as an illustrative case. Through a comparative analysis of the performance metrics between existing models and those refined based on the proposed recommendations, the study illustrates the improved efficiency of the advocated methodology.

Key-Words: - real estate, assessment, mass evaluation system, mathematical models, real property taxation, log-linear regression, ratio study, law of diminishing returns

Received: April 14, 2023. Revised: April 19, 2024. Accepted: May 14, 2024. Published: June 10, 2024.

1. Introduction

In both advanced and emerging market economies, the mass real estate assessment system assumes a pivotal role across various dimensions of social and economic domains. It serves as the foundational framework for computing local taxes and establishing a system for calculating economic indicators that gauge the dynamics of national economic development. Accurate assessment is imperative to ensure equitable taxation and streamline the effective collection of tax revenues required for the provision of governmental services [1]. Sound property valuation guarantees that taxpayers contribute taxes commensurate with the actual value of their property, thereby fostering an equitable distribution of the tax burden.

Precision in the extensive valuation of real estate holds crucial significance for urban planning and economic advancement. Local administrations leverage these valuations to identify burgeoning areas, allocate resources, and foster sustainable development. A transparent and well-managed mass evaluation system enhances public trust in the fairness and impartiality of the process, mitigating concerns of corruption or preferential treatment. Additionally, precise valuation is indispensable for the seamless operation of the real estate market, furnishing accurate property value information and facilitating real estate transactions. These valuations cultivate a competitive market environment, offering essential data for banks and financial institutions to assess risks associated with mortgages and secured loans.

Regular updates to the massive appraisal system are imperative to reflect contemporary changes in the economy and real estate market, ensuring accurate and relevant property valuations. Maintaining the accuracy of evaluation results hinges on the type and methodology of mathematical modeling employed. The evolution of legal and economic relations within the real estate market necessitates the adaptation of market value calculation mechanisms. The incorporation of sophisticated contemporary econometric functions in modeling can circumvent certain methodological challenges and enhance the precision of obtained values.

Following their declaration of independence and the transition towards market economies, countries in Central and Eastern Europe embarked on extensive tax system reforms, which included the restructuring of real property taxation. This transformative endeavor has been scrutinized by researchers in several nations, such as Slovenia, the Russian Federation, Belarus, and Lithuania [2].

This case study serves as an illustration for the residential real estate valuation model in the Republic of Moldova. The objective of this research is to pinpoint the primary factors contributing to the inefficiency of the mass assessment models in Moldova, estimate the losses incurred due to their inadequacy, and propose effective strategies for enhancing these models.

The article provides a comparison between linear and nonlinear regressions, focusing on the primary factors affecting real estate value: its size and the age of the building's construction.

2. Problem Formulation

Owing to the heightened dynamics of contemporary methodologies, the existing mass evaluation models established from the ages 2003-2010 for calculating the taxable value in the Republic of Moldova are deemed oversimplified. This is attributed to a limited number of factors utilized in determining property value and the application of simplistic techniques of linear regressions that inadequately capture intricate dependencies influencing market value formation [3]. In most cases, the models represent the linear mathematical equation where the dependent factor (V - Value) is determined by the middle value (VM) and independent factors such as surface area (S), location factor, level, materials, etc., which are introduced as straightforward adjustment multiplication coefficients.

$$V = VM \times \prod_{i=1}^{n} F_i K_i \times S; \quad (1)$$

These models fail to comprehensively represent the many cost factors that influence a property's market value, resulting in frequent changes. Consequently, there is a need to revise real estate valuation methods in accordance with the principles of taking into account various factors and taking into account the nuances of constructing the real estate market.

It is extremely important to recognize that the market value of a subject property is not simply the arithmetic sum of its constituent elements, such as the land and associated improvements. In addition to this shortcoming, the mass assessment system in the Republic of Moldova faces various methodological problems that are typical for other regions of Eastern Europe.

2.1. The method of obtaining the data used

The prevailing expert-analytical method, upon which the current models in the Republic of Moldova are constructed, revolves around formalizing expert opinions on the interdependence of land market value and various influencing factors. Widely acknowledged at both national and local levels in the Republic of Moldova and the broader Eastern European region, this method is primarily employed for individual evaluations to determine adjustment coefficients for value factors. It is predominantly utilized for assessing real estate in small and medium-sized cities exhibiting standard urban planning characteristics.

However, when applied to large cities or small and medium-sized cities with nonstandard urban planning features (such as satellite cities of district centers/municipalities, settlements with enterprises forming cities, resort cities, etc.), the use of this evaluation model template may lead to significant distortions compared to the actual cost of specific sections of the urban area. This is particularly attributed to the inherent heterogeneity of these assessed cities, necessitating a pre-division into territorial areas that align more closely in terms of cost characteristics. Subsequently, appropriate sub-areas within these cities should be allocated based on their functional purpose. In this methodology, the unit of comparison should not be a hypothetical rated residential area with average city characteristics for key price drivers but specific typical test areas within each selected sub-area with the corresponding functional purpose.

As an alternative to the expert-analytical method, the statistical method does not serve as a universal remedy for the addressed issues. Practical application of the statistical method reveals that the results of statistical analysis do not automatically yield an ideal regression for modeling real estate value. Additional efforts are required to calibrate the model using alternative information sources, including the empirical practices of individual valuation specialists.

2.2. Low linear model elasticity

The employment of simple linear regressions in the model is marked by the model's lack of elasticity. Specifically, the value factors are represented in a linear form within the models and lack the flexibility to accommodate nonlinear functions when manipulating these factors. An illustrative instance is the examination of the surface factor (S), interpreted as a linear function with the value (V) denoted as V=F(S) in current models. The diagrams in Fig. 1 depict both linear and nonlinear functions for the V=F(S) regression. The trend for nonlinear function is presented with log-equation

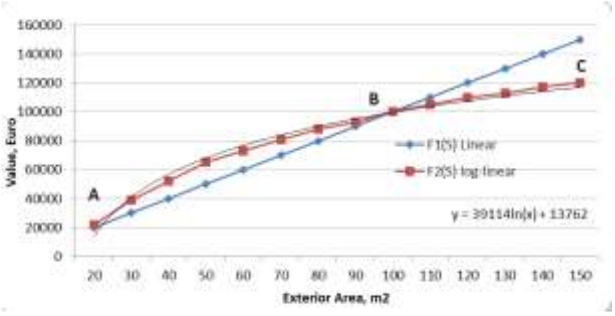

Fig. 1Diagrams of value estimated using linear and log- linear regressions

To address errors arising when the compared functions intersect, transaction prices from the observations in the studied sample were adjusted based on market conditions (sale date: 01.06.2023), location within the region (city and value zone: Chisinau, Center), year of construction (2020), and other technical parameters consistent with a predefined standard object.

The departure of the linear function from the market data, depicted by a nonlinear function, is ascribed to the principle of diminishing returns, initially postulated by Anne Robert Turgot in 1767 [4]. This phenomenon is alternatively recognized as diminishing marginal returns, suggesting that in a production system with fixed and variable inputs, while keeping the fixed input constant, each additional unit of the variable input yields increasingly smaller additional effects [5]. This concept is manifested in the nonlinear correlation between value and the independent variable, notably in terms of measurements derived from statistical analysis of market data. As illustrated in Fig. 1, the parabolic impact of increasing value in relation to the surface area of the object is established, revealing a notable disparity in higher surface values.

The difference between linear and nonlinear regression reflects the undervaluation of small properties (segment A-B in Fig. 1) and the overvaluation of large properties (segment B-C in Fig. 1) by the existent models.

Regarding 1 squire meter (1m2) Value, the difference of model's results is displayed in Fig. 2

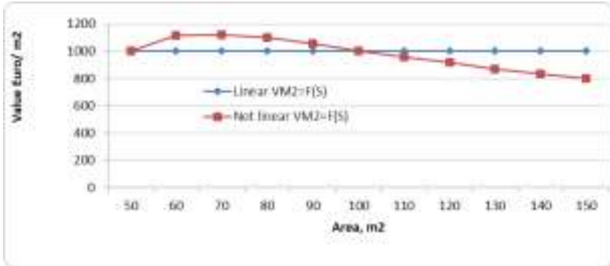

Fig. 2 Diagrams for linear and log-linear regression values per 1 square meter (1 m2)

Using statistical data on apartments as an example, we can calculate approximate losses in the assessment due to a lack of linear functions. It's worth noting that the biased valuation results in the undervaluation of small properties, representing 98% of the total housing stock, and the overvaluation of large properties, accounting for 2%.

Table 1 The discrepancy in value estimation between linear and nonlinear regression estimation for the apartment example.

Surface m^2	Number of units	Share	Difference per unit, Euro	Difference per group, Euro
<20	19547	4.3%	-2000	-39094000
20-30	32191	7.0%	-3000	-96573000
30-40	73267	16.0%	-5000	-366335000
40-50	104293	22.7%	-6000	-625758000
50-60	80397	17.5%	-5000	-401985000
60-70	90221	19.7%	-5000	-451105000
70-80	27882	6.1%	-5000	-139410000
80-90	13641	3.0%	-3000	-40923000
90-100	7238	1.6%	0	0
100-110	3683	0.8%	5000	18415000
110-120	2434	0.5%	10000	24340000
120-130	1441	0.3%	17000	24497000
130-140	858	0.2%	23000	19734000
>140	1831	0.4%	30000	54930000
Total	458924	100%		-489522000

The data from Table 1 indicates that the residential stock value for apartments in multi-storey buildings is underestimated by approximately 490 billion euros. Consequently, tax revenue losses are estimated based on minimum (0.05%) and maximum (0.4%) tax rates [1], ranging from 0.25 to 2.0 million Euros annually.

DOI: 10.37394/232032.2024.2.12

2.3. Grouping of value factors

An additional limitation is evident in the utilization of multipliers for value adjustment, which has been addressed by aggregating and clustering quantitative variables into segments. This approach resulted in the creation of a value scale that lacks precision in determining fair values between two contiguous quantities. As an illustration, the value function is articulated in relation to the year of construction. Table 1 displays the adjustment coefficients for real estate value based on the year of construction, as per the existing models and alternative coefficients obtained as a result of statistical calculations.

Table. 2 Coefficient of adjustment for building age

Year of construction	KAge, (2003)	KAge, (2023)	(2023)-(2003)	Units rate	WR
1900<>1955	0.65	0,874	-22%	1%	-0,23%
1956<>1965	0.76	0,949	-19%	9%	-1,70%
1966<>1975	0.85	0,988	-14%	20%	-2,82%
1976<>1985	1.00	1,037	-4%	25%	-0,95%
1986<>1995	1.03	1,100	-7%	21%	-1,45%
1996<>2005	1.06	1,179	-12%	3%	-0,33%
2006<>2015	1.08	1,280	-20%	10%	-2,02%
2016<>2022	1.08	1,435	-20%	11%	-3,76%
Total			-133%	100%	-13,2%

Kage, (2003) – represents the adjusted coefficient for age factor used in the current models [6]. The discrepancy in adjusting for the year of construction becomes evident when factors are grouped, as illustrated in Fig. 3. The inconsistency in applying correction factors across these groups results in a disparity between limit values. For instance, in the given example, a property constructed in 1975 is appraised at 15% lower than a property built in 1976, akin to the valuation of a property built in 1985. This calculation approach introduces abrupt jumps between neighboring values and deviates from real market trends. The smoothed trend line is depicted in a logarithmic function for a more accurate representation.

WR - weighted average percentage of cost reduction in accordance with the number of objects in the group (Units rate).

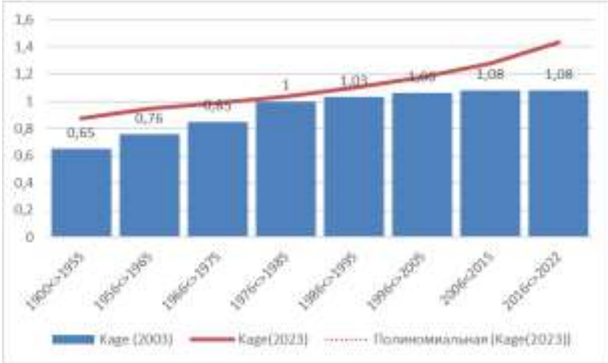

Fig. 3 Diagrams of the current grouped Age coefficient Kage(2003) and the actual adjustment for this factor Kage (2023)

Kage, (2023) – represents the real adjustment coefficient derived from current market data using nonlinear polynomial regression techniques.

K=Exp*(Int+AxKage+A^2xKage2+A^3xKage3); (2)

Where Int - denotes the intercept of the regression, A - signifies the age of construction, and Kage - represents the polynomial regression value indicators for A, A^2 and A^3.

The financial losses incurred due to the utilization of an incorrect grouping system, using the age coefficient of buildings as an illustration, are computed and displayed in Table 2. As per the statistics, the adjustment for age results in the loss of over 13,2 % of the tax value.

2.4. Ratio Study

As a part of the statistical analysis, the author performed the ratio study for the values generated by the existing models for some of the previously evaluated residential urban categories and the accumulated market data. The results of the rate study are presented in Table 3

Table. 3 Current models ratio study

Indicator	Apartments	Family houses
Num. of observations	1710	7693
RM	0.41	0.24
COD	108.26	128.32
PRD	1.78	1.69
R^2	0.14	0.07

The interpretation of the quality indicators on the existing models indicates a series of problems

related to the compatibility of the old methodology with the prices on the current market real estate:
Median Rate (RM) – this value is the middle rate when arranged from low to high. Confidence intervals are calculated around the RM. According to the International IAAO, the RM confidence interval should overlap with the suggested assessment level range (0.90 – 1.10) [7]. RM is preferred over the mean (or average) rate because it is less likely to give misleading results if extreme outliers (i.e., very high or very low) are in the sample. The low level of the medians on the studied categories indicates the underestimation of the values obtained according to existing models.
Coefficient of Dispersion (COD) – this value provides an estimate of how much rates spread or disperse around the RM. Lower CODs are desirable over higher ones as they indicate less variation and greater precision/consistency. The IAAO recommends COD thresholds based on property type, jurisdiction size and market activity, which range from 5-20% for residential properties [7], as well as local standards [8]. COD values above 100.5% for the old models notify about the enormous dispersion of the results as a result of the low prediction of the old models.
Price Related Differential (PRD) – this value provides an estimate of how much rates fluctuate between lower, mid and higher priced properties. PRD is centered on 1.0, with values above 1.0 suggesting regressive vertical inequity (higher priced properties enjoy lower rates) and values below 1.0 indicating progressive vertical inequity (lower priced properties enjoy lower rates) [9].
The IAAO rate study standard recommends PRD values to be between 0.98 and 1.03 [7]. When the sample size is small or the weighted average is heavily influenced by several extreme values of selling prices, the PRD may become an insufficiently reliable measure of vertical disparities. Under the representativeness hypothesis, high PRDs generally indicate low valuations for high-priced properties. In case of insufficient representativeness, extreme selling prices may be excluded from the PRD calculation. Similarly, for very large samples, the PRD may become too insensitive to highlight small areas where there is significant vertical inhomogeneity.
Price related injury (PRB) and coefficient of variation (COV) are additional values not used in this report. PRB is not included because unpublished research has shown it to be a highly flawed and misleading measure of vertical inequity [10] COV is not included because COD is viewed as a more appropriate measure of dispersion, which is less likely to give misleading results if there are extreme outliers in the sample.

3. Problem Solution

Combining the statistical and expert-analytical methods in the development of mass real estate valuation models is an effective approach, as both methods have their advantages and can complement each other. In the same vein, combined methods rectify mutual shortcomings caused by external and internal factors. Thus, the errors caused by the application of the expert-analytical method in the development of primary models are solved by the application of complex regressions, deduced from the statistical processing of market data. At the same time, the errors caused by the lack of data, the reduced level of data transparency, as well as the invalidity of some existing statistics, are brilliantly rectified by applying the methodology based on empirical practice through the expert-analytical approach. A series of measures is proposed below by the author in order to solve the problems addressed.

3.1. Implementation of log-linear models

Following research and examination of market data, for residential real estate (Apartments in multi-storey blocks, Individual houses in urban and rural localities in the municipalities of Chisinau, Balti, Individual garages, Orchard lots with/without constructions and Apartments on the ground) by the author the type of log-linear model is proposed:

$$\mathrm{Ln(V)} = Int + \sum_{i=0}^{n} \mathrm{K_i a_i^x}; \qquad (3)$$

Where:
Ln(V) – The natural logarithm of the estimated value of the real estate (lei);
Int – Intercept of the math function. It presents the free (constant) term of the model;
i – value factor indicator;
n – the number of value factors in the model;
K_i – the constant coefficient of the value factor;
a_i^x – value factor (independent variable) to the x power (for nonlinear regression).
The advantages of the optimized model consist in raising the elasticity of the nonlinear regression between the dependent variable (V) and the value factors. Log-transforming the variables in a regression model is a very common way to handle situations where there is a nonlinear relationship between the independent and dependent variables. Using the logarithm of one or more variables

instead of the equation of the line makes the effective relationship nonlinear while keeping the model linear.

Logarithmic transformations are also a convenient means of transforming a highly skewed variable into one that is more approximately normal. In fact, there is a distribution called log-normal distribution defined as a distribution whose logarithm is normally distributed but whose untransformed scale is skewed [11]. Log-linear models have several advantages in real estate valuation:

• Log-linear models take into account the logarithmic relationship: In most cases, real estate prices have a logarithmic (nonlinear) relationship with various factors such as area, number of bedrooms, distance from the center, etc. Using logarithms allows taking into account this dependence in an equation, making the model more accurate.

• Increasing regression elasticity: Thanks to the use of the logarithmic equation, regressions between dependent and independent variables become sensitive and can be predictable for situations of extreme values, which is very important for massive evaluation with a wide range of specific objects.

• Scale clustering inference for numerical independent variables: This fact reduces the distortion of marginal factor evaluation results from group-based classifiers.

• Stability of estimates: Using logarithms of the data makes them less sensitive to outliers and skewed distributions. This reduces the influence of unusual observations and can improve the stability of the estimates.

• Interpretability: Logarithms can make the interpretation of model coefficients more intuitive. For example, in the case of a linear model, a one-unit increase in one of the factors can be interpreted as an increase in the percentage or proportion of change in the dependent variable.

• Improving hypothesis fit: Many statistical methods, including regression, assume normal error distributions. Taking logarithms can make the distribution closer to normal, which improves the fit of the model to the established assumptions.

• Reducing multicollinearity: Using logarithmic equations in the model reduces multicollinearity between factors, making the estimate more stable.

3.2. Quality effect

In order to analyze the level of optimization of the methodological framework regarding the effect of raising the quality of the models, the quality indicators of the modified models were calculated by the author. This made it possible to compare the degree of efficiency of the new methodology proposed by the author. International best practices recommend evaluating model accuracy, uniformity, and equity through ratio studies. Extreme observations were adjusted based on the IAAO Standard on Ratio Studies using the IQRx1.5 methodology. In this approach, the model calculates a valuation estimate for each sale, dividing it by the sale price to determine an assessment-to-sale price ratio. These ratios are then categorized into quartiles, ranging from lowest to highest. The "interquartile range" or "IQR" is computed by subtracting the first quartile from the third quartile. Ratios beyond the third quartile ratio+(1.5*IQR) or below the first quartile ratio-(1.5*IQR) are considered "extreme observations" or "outliers" and are recommended to be trimmed following IAAO standards. The Fig. 4 below illustrates the distribution of ratios.

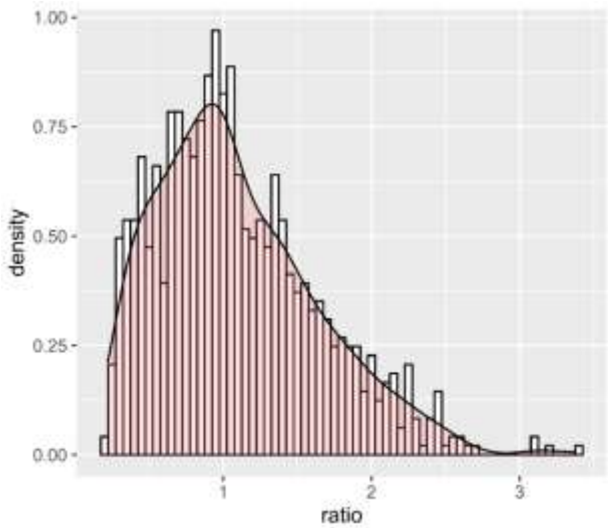

Fig. 4 Distribution of ratios for log linear regression

Table 4 shows comparison reports of quality indicators for old and new models, formed according to the new methodology.

Table 4 Quality effect of proposals

Indicator	Apartments	Rate	Family Houses	Rate
RM	1.03	↑56%	1.03	↑73%
COD	37.28%	↑70.98%	42.45%	↑85.87%
PRD	1.19	↑59%	1.28	↑41%
R^2	89%	↑75%	84%	↑77%

Explanation of the data from the comparison table of indicators from Table 4:

Median rate (RM): Compared to the median of the old models, the given indicator is improved (↑) for the studied examples by 56% in the category of apartments and by 73% for urban houses.
Coefficient of Dispersion (COD): The dispersion indicator improved (↑) by 70.98% for apartments and by 85.87% for townhouses.
Price Related Difference (PRD): PRD is centered on 1.0, with values above 1.0 suggesting regressive vertical inequity (higher priced properties benefit from lower rates) and values below 1.0 indicating progressive vertical inequity (lower priced properties get lower rates). Although the indicator of price differentiation remains with regressive inequity, optimization (↑) qualifies with 59% for apartments and 41% for urban houses. The coefficient of determination R^2 has improved for both categories, indicating a heightened level of predictability for the new models.

4. Discussions

The results of the study were integrated into project reports and are intended to develop new models for mass valuation of real property for tax purposes in the Republic of Moldova. These recommendations go beyond the Moldovan valuation system and provide targeted solutions consistent with modern mass real estate valuation systems, especially for former socialist countries, which adapt to market dynamics and ensure accurate valuation.
The practice of mass assessment has long been focused on complex mathematical algorithms and does not refer to primitive linear regressions based only on the area of the assessed object. Moreover, not only qualitative assessment factors are carefully considered, but also the psychology of real estate market participants. Governments of countries with developed real estate markets use modern theories such as triangular theory of fuzzy numbers (VIKOR), rough set theory [12], cost tolerance ratio, fuzzy logic [13] and genetic algorithms [14]. Significant attention is also paid to the use of artificial intelligence in the development of new mass assessment models.
However, modern technology is based on accurate information about real estate transactions, extensive investment in scientific research and a wide range of guarantees. Thus, the critical demands facing developing countries require the application of cutting-edge science, supported by a reliable financial infrastructure, information security and insurance guarantees.
Moreover, mass valuation of real estate for tax purposes entails certain social reactions and necessitates simplifying the model for discussion with taxpayers and reducing its complexity. However, future research will focus on improving valuation methodology and increasing the accuracy of mass real estate valuation results by incorporating modern mathematical modeling theories while maintaining reasonable restrictions on their applicability and effectiveness.

5. Conclusion

Implementation of recommendations based on these studies can lead to significant improvements in the quality of real estate market data, the methodology used in mass valuations, and the accuracy of the results obtained. Compliance with the proposed recommendations in the real estate value modeling methodology will contribute to the development of operational processes and optimization of efficiency in the field of mass real estate valuation. Refining the quality indicators of models developed in accordance with the proposed methodology emphasizes the real goal of developing the field of mass real estate valuation. A comparative analysis of the quality indicators of existing models and the models proposed by the author of the study highlights the effectiveness of the proposals, reinforcing the hypothesis that the use of mathematical tools developed to formulate methodologies for mass calculation of real estate values increases the accuracy and predictability of calculation models.
The identified shortcomings of the current system of mass valuation of real estate for tax purposes in the Republic of Moldova can be quickly eliminated by improving the regulatory and methodological framework governing the calculation of the cadastral value of real estate with relatively small resources.

Declaration of Generative AI and AI-assisted technologies in the writing process

I hereby confirm that all ideas and innovations in this article belong to the author and not to other persons or to AI engines

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Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

The author contributed in the present research, at all stages from the formulation of the problem to the final findings and solution.

Sources of Funding for Research Presented in a Scientific Article or Scientific Article Itself

In the research, author used the date, presented by The Project of Land registration and Assessment from the Republic of Moldova (2018-2024), Implemented by the Department of Cadaster from the Public Services Agency.

Conflict of Interest

The author has no conflict of interest to declare that is relevant to the content of this article.

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