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# Property Valuation in Latvia and Brazil: A Multifaceted Approach Integrating Algorithm, Geographic Information System, Fuzzy Logic, and Civil Engineering Insights

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**Abstract:** This study aimed to predict residential apartment prices in Latvia and Brazil using algorithms from machine learning, fuzzy logic, and civil engineering principles, with a focus on overcoming multicollinearity challenges. To explore the market dynamics, we conducted four initial experiments in the central regions of Riga and Jelgava (Latvia), as well as São Paulo and Niterói (Brazil). Data were collected from real estate advertisements, supplemented by civil engineering inspections, and analyzed following international valuation standards. The research integrated human decision-making behavior with machine learning and the Apriori algorithm. Our methodology followed five key stages: data collection, data preparation for association rule mining, the generation of association rules, fuzzy logic analysis, and the interpretation of model accuracy. The proposed method achieved a mean absolute percentage error (MAPE) that ranged from 5% to 7%, indicating strong alignment with market trends. These findings offer valuable insights for decision making in urban development, particularly in optimizing renovation priorities and promoting sustainable growth.

**Keywords:** property valuation; real estate markets; computational artificial intelligence; fuzzy logic; GIS (geographic information system)

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## 1. Introduction and Background

Real estate appraisal presents various challenges that often hinder the accuracy of traditional statistical models. These models tend to oversimplify the complex and multifaceted nature of real estate data, leading to imprecise property valuations. By combining building inspections with fuzzy logic, this study enhanced valuation accuracy through the integration of human judgment with quantitative analysis. This approach converts technical inspections and subjective evaluations into valuable insights for civil engineering and real estate valuation.

Furthermore, in general, traditional real estate appraisal highlights three major challenges in property valuation. *Model oversimplification*: traditional statistical models tend to oversimplify real estate data, resulting in potential inaccuracies in the statistical model of properties. *Data heterogeneity*: Real estate is characterized by diverse property attributes, such as location, age, and condition. Failing to account for this heterogeneity in models can lead to unreliable valuation estimates. *Variable selection*: the incorrect inclusion or exclusion of variables can significantly affect the accuracy of property valuations, and thus, impact the reliability of the inferential statistics used.

To address these challenges, this paper proposes an innovative framework based on fuzzy logic that integrates civil engineering inspections and building assessments. This approach offers a more accurate and adaptable solution for assessing or simply classifying property values by addressing the uncertainties and complexities inherent in real estate data.

The key advantages of incorporating building inspections in property valuation include the following: *Impact on market value*: inspections help with detecting deferred maintenance and repair needs, allowing for more accurate valuations by factoring in repair costs that might otherwise be overlooked. *Risk mitigation for buyers*: Buyers typically avoid properties that require immediate repairs. Including inspection data in valuations improves the transparency, reduces the buyer uncertainty, and enhances the confidence in the property's condition, which may increase its market value. *Transparency and credibility*: By incorporating technical inspections into valuation models, greater transparency is achieved. This leads to more defensible and accurate market price estimates, as all relevant physical aspects of the property are considered. *Marketability assessment*: properties in excellent condition, confirmed through inspections, tend to sell more quickly and at higher prices, while those with significant defects face challenges in the market.

Moreover, this study emphasized the role of civil engineering inspections in accurately reflecting a property's condition, post-purchase usability, and repair needs. This is particularly important for predicting residential apartment prices using a methodology that evaluates the property's conservation state through fuzzy logic, integrated with association rules derived from artificial algorithms models.

The methodology employed in this study was inspired by the Portuguese approach to property conservation, which converts a five-level property condition coefficient into linguistic expressions suitable for fuzzy logic analysis. The methodology consists of the following key steps: *Data selection*: relevant property and inspection data are gathered. *Preparation of files for association rule generation*: the data are formatted for the generation of association rules. *Rule generation using the Apriori algorithm*: the Apriori algorithm is applied to extract association rules from the data. *Fuzzy inference process*: fuzzy logic is employed to translate linguistic variables into actionable insights. *Interpretation of model accuracy*: the accuracy of the model is evaluated and interpreted.

The combination of the fuzzy logic framework and civil engineering expertise proved to be an effective tool in forecasting property prices. This approach enables more accurate and transparent valuations by addressing the inherent uncertainties of real estate data, making it highly applicable in diverse contexts, such as Latvia and Brazil. This research contributes to the fields of real estate valuation, civil engineering, and artificial intelligence, and the future addition of GIS will provide a security foundation for future applications in property market forecasting.

A focused analysis of Jelgava City that incorporated fuzzy logic and artificial intelligence demonstrated the effectiveness of this approach in forecasting property values based on building condition assessments. This study showed that combining fuzzy logic, an algorithm derived from machine learning, and civil engineering inspections significantly improved the property valuation accuracy. To complement the research, experiments conducted in Brazil showed that the methodology achieved a mean absolute percentage error (MAPE) below 10%, indicating high precision. These results enhance the transparency, accuracy, and reliability of the property valuation process, presenting a robust and adaptable framework for real estate markets in both Latvia and Brazil, withdetails available on https://doi.org/10.22616/rrd.27.2021.041 and https://doi.org/10.22616/j.balticsurveying.2021.14.008 (accessed on 24 September 2024).

## 2. Literature Review

Predicting property prices has become essential for market operators, investors, and professionals as the housing sector evolves [1]. The history of property valuation in Latvia reflects dynamic changes driven by political, economic, and social transformations [2]. Before the Soviet annexation, property values were regulated by Latvian governmental policies. However, during the Soviet era, property valuations primarily served state planning purposes, not reflecting real market conditions. The post-Soviet transition to a market economy marked a critical shift, requiring the standardization of valuation methods to align with a market-driven system [3].

This transition also brought about the development of a new wage system adapted to market conditions [4]. With Latvia's accession to the European Union in 2004, additional influences were introduced in the real estate valuation process. EU directives and regulations promote investment and economic development, and ensure transparency, fairness, and consistency in property values [5]. Therefore, the following topics are of great interest to this research.

### *2.1. Challenges in the Latvian Real Estate Market*

For instance, in Latvia, the average living space per person is significantly smaller than in the EU, with most apartments having 1–2 rooms, compared with the EU's 4–5 room standard. This discrepancy is tied to historical challenges, leading to lower housing quality [6]. Latvia also faces significant issues with housing devaluation, reflecting the poor quality of much of the housing stock.

According to Lukša, Latvian residential buildings, particularly those constructed decades ago, follow a repetitive construction pattern that has not kept pace with modern standards. Many buildings from the late 1950s are nearing the end of their lifespan and building inspections have become crucial [7]. Decree 907 provides guidelines for inspections, maintenance, and energy efficiency in Latvia. Building inspections, conducted by engineers or architects, are critical for identifying deficiencies and potential hazards [8]. Failing to manage these structures can result in substantial costs, particularly if construction standards are not met [9].

### *2.2. Importance of Building Inspections*

Building inspections are vital for identifying construction defects, ranging from minor issues to significant risks that threaten safety [10]. This is especially relevant in densely populated cities, like São Paulo, Brazil, where maintenance lapses in older buildings can lead to severe incidents [11]. Comprehensive inspections evaluate structural, hydraulic, and electrical systems, as well as elements like waterproofing, heating, flooring, and elevators [12].

As Pacheco notes, inspection reports significantly influence property valuations by revealing patterns of deterioration [13]. When property valuations are conducted without proper building inspections, the resulting assessments are often inaccurate [14].

### *2.3. Methodologies in Property Valuation*

In real estate, the direct comparative method of market data is commonly used for property valuation [15]. However, this method encounters challenges, such as managing multicollinearity, where variables overlap and provide redundant information [16]. Failing to address these issues can make the mathematical model infeasible. Therefore, alternative statistical strategies are necessary to reduce redundancy and improve the model accuracy [17]. These strategies often involve a series of mathematical tests to ensure theoretical rigor [18–20]. While numerous valuation methodologies exist, not all are capable of handling heuristic, imprecise, and subjective variables, especially when combined with civil engineering inspections [21]. The increasing demand for models capable of working with limited or scattered data highlights the need for innovative solutions in property valuation [22].

Analyzing properties collectively, rather than individually, helps with understanding behavioral patterns in buildings. This reveals the strong impact of building conditions on the property value [23–27]. From this behavior pattern, fuzziness exists, where there are no sharp boundaries to the exact interval, i.e., a fuzzy set occurrence [28]. Thus, the fuzzy set can be better adapted to market value predictions since the price market trend is not exact.

*2.4. Fuzzy Logic and Property Valuation*

Given the inherent uncertainty and subjectivity in property valuation, fuzzy logic presents an effective approach for handling these complexities. Fuzzy logic, developed by Lotfi Zadeh [29], was specifically designed to address problems involving imprecision by allowing variables to take intermediate values between true and false, representing uncertainty more accurately. This contrasts with traditional binary logic, which only recognizes absolute values.

Fuzzy logic operates through the use of fuzzy sets, where elements can belong to varying degrees of membership, ranging between 0 and 1. This flexibility allows for a more nuanced representation of real-world conditions, making it especially valuable in property valuation, where factor fuzzy logic systems translate subjective real estate characteristics into quantitative values. This system is vital for capturing the qualitative nuances of property features that are typically challenging to quantify, such as the condition of the building and subjective assessments that play critical roles. The fuzzy logic model can be mathematically formulated as

$$Y = \sum_{t=1}^{n} Wi \times uAi(Xi) \tag{1}$$

where **Y** is the fuzzy logic output, **Wi** are the weights assigned to each parameter, and ***uAi*** are the membership functions and **Xi** are the input variables.

In a fuzzy inference system, property attributes, such as the age, condition, and location of a building, can be translated into linguistic variables (e.g., "good", "fair", or "poor"), and fuzzy rules are applied to determine the overall market value. The process involves three key steps: fuzzification (converting inputs into degrees of membership), rule evaluation (applying fuzzy logic rules), and defuzzification (producing a precise output, such as a property value). The Mamdani fuzzy inference method is particularly useful in this context, enabling the mapping of input variables to the corresponding output variables, facilitating decision-making and control processes in property valuation [28,30–33].

By incorporating fuzzy logic, property valuation models can capture the subjective nuances and uncertainties that conventional models often overlook. This leads to more reliable and accurate predictions, as evidenced by experiments where fuzzy-logic-based approaches achieved a mean percentage absolute error below 10%.

*2.5. Artificial Intelligence/Machine Learning and the Apriori Algorithm*

The Apriori algorithm, a fundamental tool in data mining and machine learning, is used to discover frequent item sets in large datasets. It belongs to the realm of artificial intelligence and machine learning, specifically in association rule learning, where meaningful patterns and relationships are uncovered from data [34].

The algorithm begins with individual items and progressively combines them to form larger sets using a support threshold to determine the minimum frequency at which item sets are considered frequent. This method is useful for decision making and uncovering behavioral patterns [35–39].

*2.6. Geographic Information Systems (GISs)*

A GIS (geographic information system) incorporates geographic information to assimilate, maintain, and interpret geographic data in property valuation. It includes additional datasets, such as maps, satellite imagery, and people databases, making it suitable for urban development, environmental studies, and more [40–42]. The use of a GIS in the real estate field improves the market value determination by providing a spatial representation of data and geographically correlating variables [43].

### 2.7. Real Estate Dynamics between Latvia and Brazil

An independent study recently compared the real estate markets of Latvia and Brazil. The research was carried out using data from the World Bank Data (The World Bank Organization–Data and Projects by Country); The Organisation for Economic Co-operation and Development (OECD); Global Property Guide–Brazil; Global Property Guide–Latvia (Latvia Residential Real Estate Market Analysis 2024); Eurostat Latvia Housing Data; IBGE Real Estate Data for Brazil; Colliers Real Estate Reports; and Knight Frank Global Reports. Table 1 is particularly useful for presenting the contrasts of different factors that influence the real estate markets in both regions, including the market size, regulatory aspects, and cultural factors.

**Table 1.** Comparative real estate dynamics between Latvia and Brazil. Source: author.

| Aspect | Latvia | Brazil |
|---|---|---|
| Population size | ~1.9 million | ~214 million |
| Territorial area | ~64,589 km$^2$ | ~8.5 million km$^2$ |
| Housing demand | Stable with moderate growth | High with large regional variations |
| Economic context | Stable economy, strongly influenced by EU policies, with controlled inflation and moderate economic growth. | High economic volatility, frequent inflation, income inequality, and complex socioeconomic challenges. |
| Annual transaction | Relatively low | Very high in large cities |
| Growth factors | Internal migration or urban modernization | Urbanization, expansion of the middle class, government programs (e.g., “Minha Casa Minha Vida”) |
| Real estate market maturity/size | Mature market, with structured legal and regulatory frameworks aligned with EU directives. Small and focused on urban areas like Riga and Jelgava. | Developing market, characterized by rapid urbanization and inconsistent regulatory oversight. Extensive and diverse with major centers, like São Paulo, Rio de Janeiro, and Brasilia, and coastal regions. |
| Housing supply and demand | Limited supply in urban areas, with high demand due to rising living standards and EU-related migration patterns. | A significant housing deficit, especially in urban centers, with government initiatives to increase the affordable housing supply. |
| Construction standards | High construction standards influenced by EU regulations, with emphasis on energy efficiency and sustainability. | Varying construction standards, with newer developments adhering to modern codes, but older buildings often suffer from maintenance issues. |
| Property valuation methods | Predominantly market-driven and influenced by EU transparency and standardization regulations. | Valuation methods are more variable, with a mix of market-driven assessments and state subsidies affecting pricing in certain regions. |
| Building lifespan | Many buildings, especially Soviet-era constructions, are nearing the ends of their service lives, requiring frequent inspections and repairs. | Buildings vary widely in quality; newer constructions meet higher standards, while older ones require substantial maintenance or renovation. |
| External investment | Moderate | High, with growing interest from foreign investors |

**Table 1.** *Cont.*

| Aspect | Latvia | Brazil |
| --- | --- | --- |
| External investment | Strong foreign investment, particularly from EU countries, driven by stability and consistent legal frameworks. | Foreign investment fluctuates, influenced by Brazil's economic instability, currency depreciation, and political uncertainty. |
| Urbanization patterns | Urbanization has plateaued, with Riga being the primary hub; slower growth in other cities. | Rapid urbanization, especially in cities like São Paulo and Rio de Janeiro, leading to infrastructural challenges and housing shortages. |
| Government initiatives | EU-backed programs focused on energy efficiency, sustainable development, and housing affordability. | Government initiatives like Minha Casa, Minha Vida aimed at reducing the housing deficit, though often constrained by economic challenges. |
| Market trends | A steady rise in property values, particularly in urban areas, though moderated by EU market regulations. | Fluctuations in property values, influenced by inflation, interest rates, and political instability. |
| Financing options | Competitive mortgage markets with low interest rates due to EU monetary policies and banking regulations. | Higher interest rates and more restricted mortgage access, especially for low-income groups. |
| Cultural influences | Emphasis on stability and home ownership as a cultural value, encouraged by a tradition of secure investment in property. | Home ownership is viewed as a symbol of social status, with diverse cultural influences shaping the approach to property ownership. |

## 3. Materials and Methods

### *3.1. Materials*

The research was conducted on a DESKTOP-ER0LAP5 computer with the following specifications: Intel Core i7 processor, 64-bit architecture, Windows 10 operating system, and a SanDisk SSD PLUS 240 GB. All software employed was open source, permitting modification and redistribution. The primary software tools utilized in the analysis included the following:

- Notepad++ v8.6.2 (64-bit): for text editing and file preparation.
- Weka Software version 3.8.3 (c) 1999–2010—The University of Waikato—Hamilton, New Zealand: for machine learning tasks, including association rule mining.
- InFuzzy Software version V.01—Registration with INPI protocol 020110031632 on (25 March 2011): as a computational modeler for fuzzy logic applications.
- LibreOffice 7.2: for data documentation and reporting.

### *3.2. Methodology Overview*

This study employed a comprehensive methodology that integrated machine learning, fuzzy logic, and aerial data analysis, with each contributing uniquely to the property valuation process.

### *3.3. Data Collection and Experimental Design*

This research focused on residential apartments located in central areas of Jelgava (Latvia), Niterói, and São Paulo (Brazil). This selection offered diverse perspectives on real estate valuation, with samples drawn in 2018/2019 from online advertisements by real estate agencies within the study region, such as https://www.city24.lv (accessed on 24 September 2024) and http://www.arcoreal.lv/en/ (accessed on 24 September 2024), websites that are still fully active in the region, as verified on recent access.

The samples were inspected personally by the researcher using the standardized civil engineering inspection form. The analysis adhered to a consistent engineering inspection protocol across all locations, despite the variations in sample sizes: large in Jelgava, medium in Niterói, and small in São Paulo. Detailed documentation in the complete thesis allowed for replication with adjustments tailored to the specific realities of each location.

***Preliminary experiments***: Four initial experiments were conducted to understand the real estate market dynamics within the study regions:

***Initial experiment in Riga:***

- Traditional statistical methods were applied in the central area, addressing multicollinearity through regression analysis.
- The chosen model for price forecasting was an ANCOVA model, yielding a fit of less than 58%.
- The regression equation was determined as Price = 430 + 12.58 $\times$ Area. Detailed statistical results are available in the published article (https://doi.org/10.22616/rrd.25.2019.022) (accessed on 10 October 2020).

***Second experiment in Jelgava:***

- Traditional statistical methods facilitated property evaluations.
- Regression analysis was conducted without multicollinearity, revealing subjective uncertainties in appraisals.
- The incorporation of fuzzy logic improved the valuation accuracy, resulting in an estimated score of EUR 747.50/m$^2$ within an 80% confidence interval.
- For comprehensive statistical details, refer to https://doi.org/10.22616/j.balticsurveying.2020.007 (accessed on 11 July 2021).

***Third experiment in Riga with fuzzy logic:***

- A comparative analysis was performed between the regression analysis and fuzzy logic.
- Linguistic expressions were utilized to represent building conditions, illustrating the impact of heuristics on valuation.
- The fuzzy logic approach resulted in a 15% score difference, confirming the influence of the building conservation status.
- More details can be found in the poster presented at the second Multidisciplinary Conference for Young Researchers (29–30 November 2021, Sumy, Ukraine). To consult, see page 62, available at

(1) https://agrisci-ua.com/conferences/ (accessed on 6 March 2022).
(2) https://czuvpraze-my.sharepoint.com/personal/chladova_ftz_czu_cz/_layouts/15/onedrive.aspx?id=%2Fpersonal%2Fchladova%5Fftz%5Fczu%5Fcz%2FDocuments%2FBOOK%20OF%20ABSTRACTS%5F2021%2Epdf&parent=%2Fpersonal%2Fchladova%5Fftz%5Fczu%5Fcz%2FDocuments&ga=1 (accessed on 6 March 2022).

***Fourth experiment, which applied fuzzy logic and heuristics in Jelgava:***

The objective of this paper was to take the first steps towards developing a real estate evaluation model based on the Heuristic view using a civil engineering inspection form associated with artificial intelligence and Fuzzy logic. Details available in https://downloads.editoracientifica.com.br/articles/210303732.pdf (accessed on 8 April 2021).

The researcher gained valuable insights into the behavior of the real estate market in the study region through four experiments. Building on this understanding, the researcher applied the proposed method to the city of Jelgava in Latvia. The scope of this study was expanded to include two additional cities in Brazil: Niterói and São Paulo. In all three cities, the civil engineering inspection, based on the Portuguese construction inspection method, led to improvements in the real estate evaluation methodology. This approach used fuzzy logic instead of statistical inference and helped to mitigate the occurrence of multicollinearity.

In this sense, the city of Jelgava was chosen because it had residential buildings with very similar characteristics. Jelgava, located in Latvia, was significantly devastated during

World War II. It suffered extensive damage, particularly in 1944, during the battles between the German and Soviet forces. Much of the city's historical architecture was destroyed, including Jelgava Palace, which was heavily bombed.

Following the war, Latvia was incorporated into the Soviet Union, and Jelgava was rebuilt largely under Soviet rule. The reconstruction of the city reflected Soviet architectural styles and urban planning, replacing many of the original structures with utilitarian Soviet-era buildings. This post-war reconstruction transformed the city's appearance, with many of the older, historical buildings lost to the destruction and the subsequent Soviet modernization.

The similarity between residential buildings can cause multicollinearity issues when using traditional statistical methods for property evaluation. To address this, the researcher selected Jelgava as a case study to detail a new methodology designed to minimize the effects of multicollinearity.

By the way, the results from São Paulo and Niterói have also been published. They can be explored further in the provided https://doi.org/10.22616/rrd.27.2021.041 (accessed on 24 September 2024) and Niterói can be seen in https://doi.org/10.22616/j.balticsurveying.2021.14.008 (accessed on 24 September 2024).

Subsequently, in Jelgava, the researcher worked on the scattered data from property markets, particularly 1-, 2-, and 3-room residential apartments, which were collected from online sources and inspected. For Jelgava city, 48 samples from 2019 were used, which included scattered data from website. In the thesis, there are some other address examples.

1. https://www.ss.com/lv/real-estate/flats/jelgava-and-reg/all/fDgQeF4S.html (accessed on 2 September 2019).

That being said, civil engineering inspection techniques adapted from the Portuguese MAEC method were used to assess the apartment characteristics. The gathered data, along with selected heuristic variables, were compiled for the analysis. Therefore, the proposed model was based on the constrained optimization of dispersed data.

From this, the research methodology focused on predicting the apartment market prices by assessing 37 functional elements of the properties. These elements were evaluated for anomalies using a scale, and weightings were assigned to determine their relative importance in the overall assessment. The researcher chose two-bedroom apartments as a sample for evaluation in Jelgava City (Latvia), allowing for flexibility to adjust the method according to each location's reality.

Hence, the proposed method evaluated properties in Jelgava, Niterói, and São Paulo using civil engineering inspections, adhering to Portuguese criteria, and converted the conservation status indexes into heuristic variables applied following the fuzzy logic. We followed rigorous Portuguese criteria for civil engineering inspection.

Therefore, this approach ensured a comprehensive analysis, ultimately leading to more informed and effective decision making. In this way, when integrating GIS data into future endeavors, these sophisticated geospatial solutions will empower residents with advanced tools, enabling them to visualize and analyze information with enhanced clarity and precision.

The research methodology framework consisted of several key steps:

***In-depth understanding****:* a thorough understanding of the Portuguese inspection form used for assessing residential properties was gained, including criteria for evaluating the conservation status.

***Data collection and preparation****:* A market analysis was conducted to identify the recent sales of comparable properties. The collected data were verified to ensure adherence to the relevant market segment.

**Building inspection data**: detailed information was gathered on the physical condition, structural integrity, and esthetics of the properties.

***Conversion to linguistic expressions***: linguistic variables representing various conservation levels were defined, facilitating fuzzy logic analysis.

***Fuzzy logic implementation***: InFuzzy software was utilized to develop a fuzzy inference system (FIS) that connected linguistic expressions to price predictions. Association rule mining using Weka Software was applied to identify the relationships within the dataset.

***Model validation and optimization***: The model was validated using a dataset of known conservation coefficients and corresponding property prices. The model performance was assessed through metrics such as the mean absolute error (MAE) and root-mean-squared error (RMSE).

***Integration of GIS data:*** Future research may explore the integration of geographic information system (GIS) data to enhance the spatial modeling and improve property valuation methodologies. This multidisciplinary approach will leverage advancements in geodesy and geoinformatics, facilitating more accurate real estate assessments.

On one hand, the inclusion of GIS in our research is still open. On the other hand, currently, the innovative methodology proposed in this study combined experimental building inspection and computational algorithms to predict apartment prices based on civil engineering principles.

It presents a robust framework for real estate valuations, enabling enhanced decision-making capabilities for urban planners and real estate professionals. The proposed model offers flexibility for adaptation in various locations, allowing for the incorporation of additional relevant variables.

The uniqueness of this methodology lies in its pioneering integration of experimental building inspection with computational tools and algorithms, aiming to predict apartment prices based on association rules rooted in civil engineering knowledge.

Consequently, in the near future, the fusion of GIS and this research will enhance the capacity for archiving geospatial data, particularly in the context of building diagnostics, aligning perfectly with the price per square meter forecasts. Land development planners, empowered by this fusion of technologies, will experience a substantial improvement in their capabilities.

This data will be seamlessly included in files created using Notepad++ and saved with the ARFF extension, ensuring a standardized and accessible format for the later creation and analysis of new association rules based on Weka Software's "a priori" algorithm.

Hence, the current model design that involved the methodology proposed in the thesis can be divided into five stages: selecting scattered data; preparing files for association rules; generating association rules; the fuzzy inference process; and interpreting the precision of the experimental model.

1. **Step 1: Selecting scattered data**

The researcher randomly selected a sample of forty-eight apartments, ranging from one to three rooms, from online real estate listings in the central area of Jelgava City, Latvia. The sizes of the apartments varied between 23 and 84 square meters. The building inspections were conducted according to the Methodology for Assessment of the State of Conservation of Buildings (MAEC), which is based on the Process of Assessment of the State of Conservation of Buildings, as established by the Ministry of Public Works, Transport, and Communications of Portugal [44,45].

While the inspection form was slightly modified for the Latvian context, the scoring criteria remained unchanged. Any fields from the Portuguese form that were irrelevant to the Latvian or Brazilian context were excluded to streamline the assessment process. The MAEC evaluates 37 functional elements of a building (Table 2), encompassing both the interior and exterior aspects. Visual inspection enables a qualitative analysis that identifies inconsistencies in the functional elements of the building and the apartments.

**Table 2.** Functional elements—variables involved in the inspection (Pedro et al., 2008) [44].

| | **Building** | **Weight** |
|---|---|---|
| 1 | Structure | 6 |
| 2 | Coverage/roof | 5 |
| 3 | Facade elements | 3 |
| | Other common parts of the building | Weight |
| 4 | Walls | 3 |
| 5 | Floor coverings | 2 |
| 6 | Ceiling | 2 |
| 7 | Stairs | 3 |
| 8 | Windows and doors | 2 |
| 9 | Fall protection devices | 3 |
| 10 | Water supply system | 1 |
| 11 | Sanitary drainage system | 1 |
| 12 | Gas distribution system | 1 |
| 13 | Electrical and lighting systems | 1 |
| 14 | Telecommunications and security systems | 1 |
| 15 | Elevator systems | 3 |
| 16 | Fire protection systems | 1 |
| 17 | Waste disposal facility/household waste/garbage disposal | 1 |
| | Flat/Apartment | Weight |
| 18 | External walls | 5 |
| 19 | Interior walls and partitions | 3 |
| 20 | Exterior floor finishes | 2 |
| 21 | Interior floor finishes | 4 |
| 22 | Ceiling finish | 4 |
| 23 | Internal staircase | 4 |
| 24 | External windows and doors | 5 |
| 25 | Internal windows and doors | 3 |
| 26 | Window safety devices | 2 |
| 27 | Fall protection (upper story guardrails/balustrades) | 4 |
| 28 | Sanitary fixtures | 3 |
| 29 | Kitchen fixtures | 3 |
| 30 | Water supply installations/and sanitary installations | 3 |
| 31 | Wastewater disposal system | 3 |
| 32 | Gas supply installation | 3 |
| 33 | Electrical system | 3 |
| 34 | Communication and security systems | 1 |
| 35 | Ventilation system | 2 |
| 36 | Heating, ventilation, and air conditioning (HVAC) systems | 2 |
| 37 | Fire protection system | 2 |

These functional elements are classified based on their importance: (a) highly important elements are weighted as 5 or 6; (b) important elements are weighted as 3 or 4; and (c) less important elements are weighted as 1 or 2. This weighting reflects the significance of each functional element in the context of the overall building inspection.

The building inspections were therefore tailored to the expertise of civil engineers or architects, facilitating a qualitative analysis of each abnormality encountered. These irregularities were classified into five levels of severity (Table 3). The assessment process categorized structural inconsistencies into five main types, which were assigned scores according to the applicable standards [44].

**Table 3.** The scale of the anomalies (Pedro et al., 2008) [44].

| Too Low (Excellent) | Low (Good) | Medium (Average) | Critical (Bad) | Very Critical (Terrible) |
|---|---|---|---|---|
| 5.00 ≥ IA ≥ 4.50 | 4.50 > IA ≥ 3.50 | 3.50 > IA ≥ 2.50 | 2.50 > IA ≥ 1.50 | 1.50 > IA ≥ 1.00 |

2. **Step 2: Preparing files for association rules**

The results of step 2 are not automatically generated. At this stage, the ARFF file required for use in Weka Software was manually created. Notepad++ was utilized to structure the file, with particular attention paid to organizing the data related to the price per square meter ratio. This process aided in describing the variable characteristics.

The variables used in the experiment included the price per square meter for each inspected property, the area of each property in square meters, and the indices derived from the inspection sheet for the variables "consv_ap" and "consv_build". The "price" variable was categorized using linguistic terms: low, medium, and high.

3. **Step 3: The generation of association rules**

Weka Software, developed by the University of Waikato, New Zealand, was employed as the computational tool for generating the optimal association rules. The "Apriori" algorithm was selected from the (associate) menu, though not all resulting algorithms could yield the desired outcomes. To achieve this, Agrawal proposed a mathematical model where the generated association rules must meet the minimum support and confidence levels set by the decision-making agent [34].

In this context, "support" refers to the frequency with which certain patterns appear in the dataset, representing the percentage of data that include both the antecedent (X) and the consequent (Y). "Confidence" is a measure of the strength of the rule, indicating the percentage of cases where the antecedent (X) is followed by the consequent (Y).

The minimum support (minsup) ensures that the union of items in both the antecedent and the consequent is present in at least a small percentage (s%) of transactions. The minimum confidence (minconf) ensures that at least a certain percentage (c%) of transactions satisfying the antecedent also satisfy the consequent. Association rule mining seeks to identify frequent if–then patterns within the dataset. Out of the twenty-three rules generated, seven were manually selected, focusing on cases where "price" was the consequent variable. These seven rules had a confidence level of at least 50% (MinMetric) and were further analyzed using InFuzzy software.

Figure 1 displays the seven association rules selected based on their relevance to the price variable, which serves as the consequent in each rule. These rules were generated through data analysis and reflected relationships between the property characteristics and price outcomes. The use of price as a consequence demonstrated the model's capacity to predict property values based on the various influencing factors identified in the dataset, providing a structured approach to real estate valuation.

Let's break down these rules similarly to understand their meaning. Then, in Figure 1, for example, in rule 1: the [2] here means that the rule conclusion (i.e., price?=expensive) is observed 2 times in the dataset, regardless of the conditions in the premise. In short, the [2] indicates that the rule conclusion part (i.e., "price is expensive") is true in 2 instances within the dataset. The same is true for the other rules related to items [6], [5], [3] on those structures generated by Weka Sofware.

In the case of rule 8, item [6] indicates that the conclusion "price?=average" occurs 6 times in the data set, regardless of the premise (apartment condition being average). As an example, in the case of rule 12, item [5] indicates that the conclusion "price?=average" appears independently 5 times in the data set.

Finally, [3] indicates that the conclusion "price?=average" occurs independently 3 times in the data set, regardless of the building condition. Therefore, [2], [6], [5], and [3] in the image are not reference citations. They are parts of the structure of the rules generated by Weka Software.

| Rule number | Rules |
|---|---|
| 1 | cons_ap=good cons_build=renew 5 ==> price?=expensive 5 <conf:(1)> lift:(2.09) lev:(0.05) [2] conv:(2.6) |
| 5 | cons_build=renew 7 ==> price?=expensive 6 <conf:(0.86)> lift:(1.79) lev:(0.06) [2] conv:(1.82) |
| 8 | cons_ap=medium 17 ==> price?=average 14 <conf:(0.82)> lift:(1.8) lev:(0.13) [6] conv:(2.3) |
| 9 | cons_ap=medium cons_build=old 16 ==> price?=average 13 <conf:(0.81)> lift:(1.77) lev:(0.12) [5] conv:(2.17) |
| 12 | cons_ap=good 23 ==> price?=expensive 17 <conf:(0.74)> lift:(1.54) lev:(0.12) [5] conv:(1.71) |
| 17 | cons_ap=good cons_build=old 14 ==> price?=expensive 9 <conf:(0.64)> lift:(1.34) lev:(0.05) [2] conv:(1.22) |
| 22 | cons_build=old 37 ==> price?=average 20 <conf:(0.54)> lift:(1.18) lev:(0.06) [3] conv:(1.11) |

**Figure 1.** Seven selected association rules with price variable as consequence. Source: author.

## 4. Step 4: Fuzzy inference process

In this step, the InFuzzy software was used to apply fuzzy logic, as shown in Figure 2. The researcher manually incorporated the association rules from step 3, with input variables including the residential building preservation index, the property's area in square meters, and the building conservation index.

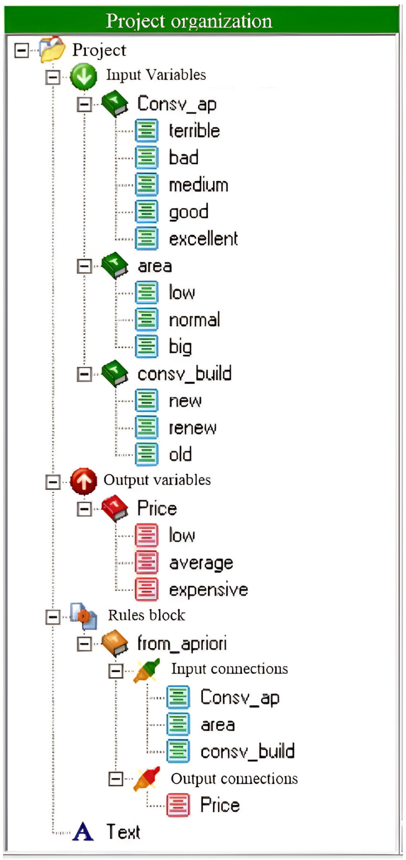


**Figure 2.** Overview of the project organization screen for the fuzzy system. Source: author.

The output variable was the price per square meter. The fuzzy inference process involved fuzzification, rule evaluation, and defuzzification, with the results determined using the center of gravity method. Step 4 involved running fuzzy modeling using the open-source InFuzzy software.

InFuzzy manages the entire simulation process, which includes predicting property prices. The project organization screen (Figure 2) allowed the researchers to analyze the system, including the input variables that affected the "price" output. The researcher also assessed deviations caused by poorly formulated rules during the simulation.

5. **Step 5: Interpreting the precision of the experimental model**

This step focuses on improving the accuracy of the experimental model by comparing the predicted apartment prices from this step with the results from step 3. Error metrics, such as the root-mean-square error (RMSE), mean absolute error (MAE), and mean absolute percentage error (MAPE), were used to evaluate the predictions. Emphasis was placed on the MAPE due to its intuitive interpretation of relative error without relying on a percentage scale.

$$\text{MAPE} = \frac{1}{n}\sum_{\text{t}=1}^{n}\left(\frac{Y_t - \bar{Y}_t}{Y_t}\right)^2 x100 \tag{2}$$

This study emphasized the importance of translating building inspection criteria into linguistic terms, offering a practical approach to real estate appraisal. This methodology interpreted the outcomes of building inspections, integrating human subjectivity to provide additional insights relevant to civil engineering. The primary focus was on the conservation status of buildings. However, an initial evaluation of the sample size and sampling error was required to ensure that the sample size was sufficient for an accurate analysis.

## 4. Results

Civil engineering inspections were conducted in Jelgava (Latvia), Niterói, and São Paulo (Brazil) using the standardized Portuguese criteria for building inspections. These inspections provided comprehensive indices that reflected the conservation statuses of the evaluated properties. The results offer valuable insights for individuals navigating the real estate markets in these areas.

The experiment utilized a standardized inspection form from Portugal, adapted for use in Jelgava, São Paulo, and Niterói. The inspection process covered 37 construction elements, allowing for a detailed assessment of the conservation state of the properties. The model developed identifies both intrinsic characteristics and extrinsic factors—such as location and construction quality—that influence the property value. Moreover, the inspections contribute to predicting future maintenance needs, transforming scattered data into actionable knowledge.

*Experiment in Jelgava*

The framework for the Jelgava experiment was based on the Portuguese civil engineering inspection criteria. A total of 48 apartment samples from real estate listings in Jelgava were inspected, with the analysis involving multiple engineering disciplines. The inspection addressed 37 construction elements, producing an accurate index of the conservation status for each property. The key findings from the Jelgava experiment included the following:

- Approximately 48% of the apartments required some form of maintenance. Among these, 13% of the properties had significant maintenance issues that would require extensive labor. Severe issues were identified in 6% of the properties, posing safety risks due to poor conditions in essential facilities. These results offer a strategic framework for prioritizing repairs based on severity.
- The market price of apartments was found to vary based on their conservation status. Buildings that required substantial repairs were less attractive to buyers and took longer to sell, as the cost of the necessary renovations was a deterrent. Several

properties had severe conservation issues, contributing to urban decay and aesthetic deterioration in the city.

- Error metrics were used to compare property values predicted by the fuzzy model with observed market data. The mean absolute percentage error (MAPE) ranged between 9% and 10%, indicating a high level of accuracy. A MAPE below 10% is considered excellent, while values below 20% are deemed good in this context.
- The defuzzification process, which converts fuzzy values into a precise numerical result, was applied to forecast apartment prices. For example, for a 48 $m^2$ apartment, the defuzzified price was estimated at EUR 416.67 per square meter, compared with the market average of EUR 522 per square meter. These estimates aligned closely with real estate prices provided by local agencies.

Although the real estate websites consulted did not disclose the conservation statuses of listed properties, direct interactions with real estate agents revealed that discounts of 15% to 20% were common for poorly maintained properties. This discounting practice, often arbitrary, was explained scientifically by the fuzzy logic methodology used in this study, which tied price reductions directly to the condition of the building.

The predicted values generated by the fuzzy model were based on indices derived from civil engineering inspections. This approach has significant potential for property valuation within the field of civil engineering, offering clear linguistic terms that facilitate understanding and application. Given the urgency of renovations in most Jelgava apartments, the fuzzy logic model provides highly reliable price estimates, far surpassing traditional statistical methods, which may be affected by multicollinearity.

This inspection-based approach offers a scientific justification for the price discounts applied by realtors (real estate agents). By aligning the property pricing with objective engineering criteria, the model increases transparency and buyer confidence, potentially leading to more efficient sales.

The proposed method offers a novel approach to property valuation, minimizing the impact of multicollinearity and emphasizing the use of linguistic terms, which are more suitable for real estate appraisals. This methodology provides an accurate representation of the real estate market, focusing on prediction rather than statistical behavior.

Additionally, this method incorporates a technical perspective from civil engineering, unlike traditional valuation methods that primarily focus on market trends. The model inspects 37 building elements, converting the observed degradation into scores that are expressed through fuzzy logic linguistic terms.

In the case of Jelgava, the behavior of the calculated property values predicted by the fuzzy model was consistent with the observed data (Table 4). In this context, the metrics were used to verify whether the method behaved according to expectations based on the hypotheses. Therefore, the value presented depended on the extent of anomalies identified in the civil engineering inspection report based on Table 2.

**Table 4.** The simulation output in EUR (the value is per square meter). Source: author.

| **Input (Variable)** | | | **Output (Price) EUR** |
|---|---|---|---|
| **Index: consv_ap** | **Area ($m^2$)** | **Index: consv_build** | |
| 1.50 | 48.00 | 3.00 | 416.67 |
| 3.10 | 38.00 | 3.00 | 416.67 |
| 2.40 | 44.00 | 3.00 | 416.67 |
| 2.70 | 30.00 | 3.00 | 416.67 |
| 1.20 | 23.00 | 3.00 | 416.67 |
| 2.70 | 46.10 | 3.00 | 416.67 |
| 4.30 | 62.00 | 3.00 | 693.26 |
| 1.50 | 52.00 | 3.00 | 416.67 |

**Table 4.** *Cont.*

| Input (Variable) | | | Output (Price) EUR |
|---|---|---|---|
| **Index: consv_ap** | **Area ($m^2$)** | **Index: consv_build** | |
| 3.80 | 43.00 | 3.00 | 737.32 |
| 3.20 | 52.40 | 3.00 | 416.67 |
| 3.61 | 42.00 | 3.00 | 623.87 |
| 3.65 | 33.00 | 3.00 | 660.05 |
| 3.70 | 40.30 | 3.00 | 693.26 |
| 3.20 | 48.00 | 3.00 | 416.67 |
| 1.30 | 55.40 | 3.00 | 416.67 |
| 2.60 | 56.00 | 3.00 | 416.67 |
| 2.50 | 36.00 | 3.00 | 416.67 |
| 3.30 | 48.30 | 3.00 | 416.67 |
| 4.70 | 61.00 | 2.00 | 887.31 |
| 4.30 | 83.30 | 3.00 | 693.26 |
| 4.31 | 56.00 | 3.00 | 687.42 |
| 4.34 | 58.00 | 3.00 | 667.58 |
| 3.20 | 40.40 | 3.00 | 416.67 |
| 1.80 | 54.00 | 3.00 | 416.67 |
| 4.80 | 41.00 | 3.00 | 416.67 |
| 2.80 | 46.00 | 3.00 | 416.67 |
| 3.20 | 30.01 | 3.00 | 416.67 |
| 2.58 | 40.00 | 3.00 | 416.67 |
| 4.20 | 84.00 | 3.00 | 737.32 |
| 3.90 | 48.02 | 2.00 | 887.31 |
| 2.60 | 69.00 | 3.00 | 416.67 |
| 2.52 | 31.00 | 3.00 | 416.67 |
| 3.60 | 42.18 | 2.00 | 887.31 |
| 3.68 | 58.01 | 2.00 | 887.31 |
| 3.30 | 58.02 | 2.00 | 881.03 |
| 3.87 | 41.00 | 2.00 | 887.31 |
| 4.30 | 68.70 | 2.00 | 887.31 |
| 4.40 | 30.02 | 2.00 | 887.31 |
| 4.50 | 63.00 | 1.00 | 600.00 |
| 4.30 | 92.00 | 1.00 | 879.95 |
| 4.20 | 54.01 | 1.00 | 882.42 |
| 4.10 | 66.00 | 3.00 | 765.63 |
| 4.00 | 33.01 | 3.00 | 785.70 |
| 4.00 | 48.03 | 3.00 | 785.70 |
| 2.60 | 52.01 | 3.00 | 416.67 |
| 3.60 | 52.02 | 3.00 | 612.90 |
| 2.80 | 50.00 | 3.00 | 416.67 |
| 2.70 | 28.00 | 3.00 | 416.67 |

To illustrate the findings from the defuzzification process outlined in Table 4, we selected a 48 $m^2$ apartment as a representative sample. The defuzzification analysis was conducted across all 48 inspected apartments. This analysis provided a scientifically grounded explanation of the market property prices, offering valuable insights into the discounts frequently and arbitrarily applied by real estate agents. Based on official data released for the average value of typical residential apartments in 2019, which was EUR 525 per square meter (see Figure 3), this served as our reference point.

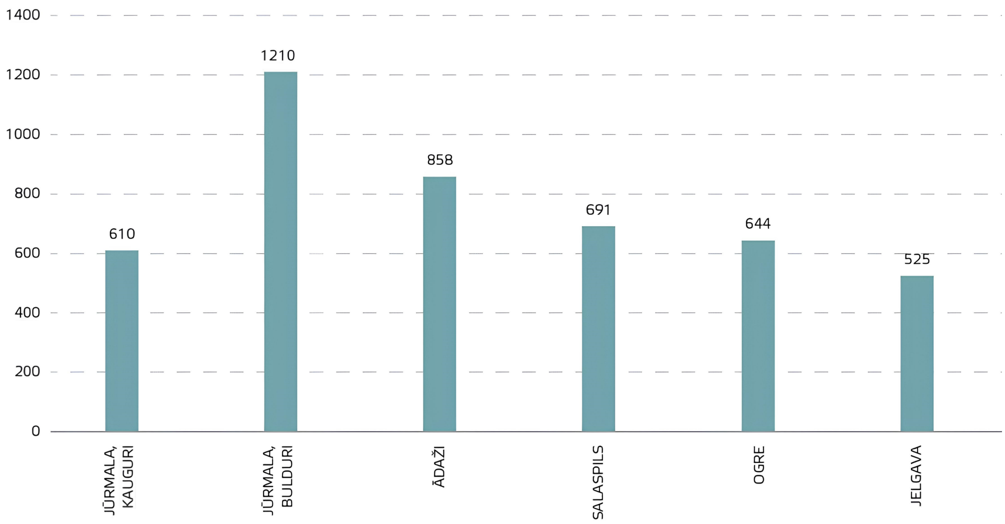


**Figure 3.** Average prices of serial apartments in Jelgava, EUR/$m^2$. Source: https://www.arcoreal.lv/files/Prezentacijas/2019_gada_parskata_prezentacija.pdf (accessed on 24 September 2024).

The value comparison is presented in Table 5. It includes data from the website https://arcoreal.lv (accessed on 24 September 2024), typical market practices (with random discounts of 15% to 20% per EUR/$m^2$), and insights from scientific research, incorporating Fuzzy Logic models supported by civil engineering inspections.

**Table 5.** Value comparison. Source: author.

| Latvian (https://arcoreal.lv) (EUR $m^{-2}$) | The Real Estate Market Practices Random Reduction without Scientific Research as Support (15% or Even 20% Off in EUR $m^{-2}$) | With Scientific Research as Support (Fuzzy Logic Plus Inspection) (EUR $m^{-2}$) |
|---|---|---|
| 525 | 446.25 or even 420.00 | 416.67 |

Another important point to note is that when deviations occurred, the relationship between the predicted and observed values remained proportional, indicating the model's reliability (Figure 4). This figure presents the comparison between the observed data and the values predicted by the model based on civil engineering inspections conducted in Jelgava, which incorporated various indices related to the conservation status of the inspected properties.

These results demonstrate that the fuzzy model performed consistently across different datasets, supporting its applicability in real estate valuation. The alignment between the observed and predicted data highlights the model's effectiveness in forecasting property conditions and market values. This validation supports the model's use in real estate valuation and decision-making processes and eliminates bad practices, providing good practical solutions [46].

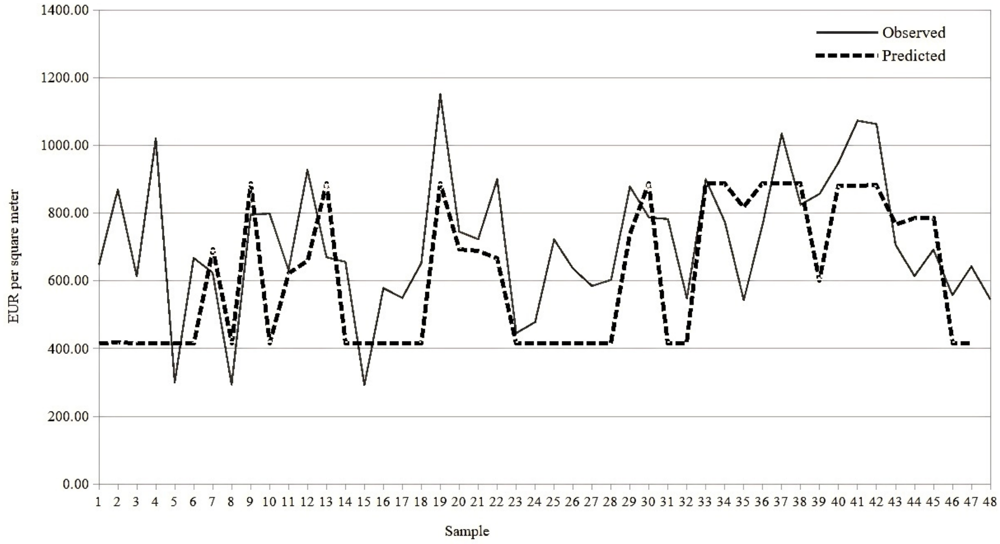


**Figure 4.** Observed vs. predicted data from civil engineering inspections in Jelgava. Source: author.

## 5. Discussion

The proposed method integrates the results of building inspections with factors like human subjectivity, transforming these inputs into valuable insights for civil engineering applications. By employing this approach, civil engineering inspections provide a technical basis for justifying the reductions in property value due to building degradation. This contributes to the advancement of civil engineering inspections, extending their scope beyond routine maintenance and anomaly detection to produce a more comprehensive property valuation.

We will go through each rule individually, providing a detailed explanation of the measurements involved. Rule 1: Is one of the strongest rule, if an apartment is in good shape and building is getting rebuilt it means this market price has gotten high up to(100%). Rule 5: A strong rule demonstrating that modifiers renovated buildings mean greater (more expensive) cost, with a confidence of about 86% Rule 8 (the next strongest of all the rules) conveys that when medium-condition apartments come in, expect standard pricing upwards to average prices about four-fifths with an abiding confidence interval value around high values standing close by at just above three-quarters. Rule 9: This is also a good rule and shows that medium-condition old apartment will likely have an average price (81% confidence). Rule 12: A moderately strong rule suggesting that well-maintained apartments are likely to be priced higher (74% confidence). Rule 17: A weaker rule, showing that the prices of good apartments in old buildings are expensive around 64% percent of the time but again no very strong association. Rule 22: This is a fairly weak rule, showing that older buildings tend to have average prices 54% of the time, though the association strength is low.

The findings support the hypothesis outlined in the PhD thesis of this researcher. This study demonstrated the feasibility of using civil engineering inspections in combination with fuzzy logic and artificial intelligence to develop association rules for property evaluation. Furthermore, it established a strong correlation between inspection-based assessments and actual market values.

Table 6 contrasts the proposed methodology with traditional inferential statistical approaches for property evaluation, highlighting key differences.

The proposed methodology highlights the advantages of incorporating civil engineering assessments and fuzzy logic into property valuation. It enables more accurate and nuanced insights into building conditions, contributing to both public policy and real estate market decisions. This approach is more robust and adaptable compared with traditional statistical methods.

**Table 6.** Comparison of traditional vs. fuzzy-logic-based property evaluation methods. Source: author.

| Characteristic | Traditional Method | Fuzzy Logic Method (Physical-Condition-Based) |
|---|---|---|
| Strategy | Relies on inferential statistical analysis. | Uses a computational algorithm and fuzzy logic. |
| Data handling | Focuses on statistical techniques and numerical data. | Uses linguistic terms and rules based on human behavior. |
| Technical assessments | Limited incorporation of civil engineering inspections. | Integrates civil engineering inspections for more accurate valuations |
| Insights into property conditions | Primarily focuses on numerical data. | Provides detailed insights into physical anomalies, informing policy decisions and sustainable improvements. |
| Prediction | May be affected by multicollinearity. | Avoids multicollinearity, ensuring accurate predictions. |
| Behavior of predicted values | Statistical methods may miss nuances. | Fuzzy model ensures proportional and consistent predictions. |
| Consistency in data processing | Depends on statistical methods' reliability. | Processes data consistently across groups. |
| Adherence to standards | Follows widely accepted statistical standards. | Aligns with international predictive tool standards. |
| Integration of subjective elements | Limited consideration of subjectivity. | Emphasizes the integration of subjective factors in assessments. |

Building inspections are the responsibility of engineers and architects, ensuring the accurate documentation of anomalies. This paper provides a comprehensive view of building issues and suggests creating a national database to track building conditions over time, informing public policies. This method also translates civil engineering inspections into terms suitable for the property market.

Historically, Latvia's property valuation evolved from government-regulated values to market-driven processes after the Soviet era and EU accession. This new method, combining civil engineering knowledge with artificial intelligence and fuzzy logic, improves property evaluation by emphasizing the importance of the building condition for price prediction.

Hence, the hypothesis was confirmed: visual inspections, when combined with algorithms from machine learning and applied to fuzzy logic, provide reliable property price predictions by converting dispersed data into technical knowledge.

***Challenges and future directions***: Challenges include regional valuation disparities and the need for better data. Future integration of geographic information system (GIS) data could improve the analysis, enabling more precise property evaluations and better-informed decisions.

A GIS is a valuable tool for spatial analysis and decision making. Its applications include informed decisions: guiding renovation and development; policy making: improving safety and sustainability policies; resource allocation: prioritizing renovations; risk assessment: identifying vulnerable structures; and sustainable development: supporting environmentally friendly improvements. Lastly, apartment inspections are critical for understanding property conditions, benefiting both buyers and sellers by facilitating informed decisions and successful transactions. It is possible to incorporate the comparative real estate dynamics between Latvia and Brazil into the concept of GIS, where this integration will provide a robust analytical framework for understanding the complexities of real estate markets in both countries. Here is how a GIS can assist with each aspect:

***Economic context***: A GIS is useful in displaying statistical areas overlaid with economic factors, such as GDP, inflation, or unemployment for different countries, such as Latvia and Brazil. This type of representation allows one to examine spatial economic differences relating to property and its value.

***Researching the real estate market development***: A GIS can help to depict changes in development within the real estate market by presenting historical information. It is useful as households in downtown, suburban, and rural areas of Latvia and Brazil are at different stages of property development.

***Housing supply and demand***: A GIS can also present the existing housing stock and the demand for such housing in a spatial manner. Population, housing, and rents are different layers of information that when used together can show the deficits and excesses of needs in both countries.

***Construction standards***: the mapping of specialist area construction techniques, local building laws, and the quality of buildings and materials will also expose variations in standard practices.

***Property valuation methods***: A GIS can analyze property value differences as relative to the distance from amenities, environmental elements, or even socio-economic conditions. By synthesizing approaches apparent in Latvia or Brazil, one might perceive how certain location-based characteristics affect property evaluation.

***Building lifespan***: A GIS is useful for containing seniority and maintenance records of structures so as to help estimate the average lifespans of buildings within a particular country in relation to the types of materials used, the individual climatic conditions, and the building standards.

***External investment***: as a subject of national importance, investment flows of foreign countries to the real estate market can also be visualized in terms of the effectiveness of particular regions or cities and these trends can also be overlapped on real estate market behavior.

***Urbanization patterns***: Analyzing the urban sprawl growth rate, density, and other characteristics can be achieved well with a GIS. The observation of urban populous growth expansion regions in Latvia or Brazil can be used to determine the effects of urbanization on the real estate sector.

***Government initiatives***: Supportive amenities to citizens, such as housing subsidy programs, taxation schemes, or zoning ordinances, can be plotted and observed. This allows for the evaluation of how these initiatives affect the geospatial distribution of the real estate market in each country.

***Market trends***: The application of historical geographical information systems (GISs), coupled with the assessment of development of the real estate market in various properties, allows for evaluating the rate of change patterns in the real estate price indices over time for the Latvia or Brazil real estate market. Predictive GIS models can forecast future market behaviors based on past trends and other spatial factors.

***Financing options***: mapping regions where different types of financing (e.g., mortgages, subsidies, foreign loans) are most prevalent provides insights into the accessibility of home financing options in each country and their geographic distributions.

***Cultural influences***: Cultural factors, like preferences for types of housing (e.g., apartments versus detached homes), can be mapped to reveal geographic patterns in residential demand influenced by cultural differences.

In addition, another relevant aspect is the advantages and disadvantages related to the method presented in this article compared with traditional property valuation. Table 7 illustrates some of them.

**Table 7.** Some advantages and disadvantages related to the methods discussed. Source: author.

| Criteria | Fuzzy-Logic-Based Property Appraisal | Traditional Property Appraisal |
|---|---|---|
| Nature of data | Scattered data deal with imprecise, vague, and uncertain data (e.g., property conditions, neighborhood quality, building status, etc.). | Relies on accurate and detailed data, such as property sizes, locations, and recent sales. |
| Methodology | Uses fuzzy set theory, which allows for degrees of truth rather than binary (true/false) evaluations. | Deterministic models are based on established formulas and have clear input–output relationships. |
| Handling of subjectivity | Effectively incorporates subjective judgments (e.g., "good neighborhood" or "poor condition") through diverse linguistic variables. | Struggles may arise in heterogeneous or volatile markets, where conditions change frequently and unpredictably. |
| Adaptability to complex markets | More adaptable to complex and uncertain market conditions, especially when precise data are unavailable. | Struggles in heterogeneous or volatile markets where conditions change frequently and unpredictably. |
| Calculation complexity | More complex tasks may require designing membership functions and fuzzy rules, which can be computationally intensive. | Embraces the simplicity, wide usage, and ease of understanding; this solution is not computationally complex. |
| Accuracy and precision | Provides a more detailed and adaptable method, enhancing precision in uncertain or ambiguous situations. | High accuracy is achievable in stable and well-understood markets, especially when good data are available. |
| Transparency | Understanding fuzzy logic might seem challenging for laypeople at first because it relies on subjective reasoning. However, using algorithms to generate association rules simplifies and speeds up the fuzzy logic process, ultimately delivering effective results. | "Transparent and easy to interpret because it follows clear, predefined models". |
| Scalability | At first, it is less easily scalable due to the complexity of designing and maintaining fuzzy rules and membership functions. However, using association rules from the Apriori algorithm makes it easy. | Easily scalable and applicable to large datasets; suitable for mass-appraisal methods. |
| Error sensitivity | Fuzzy logic is more robust to errors from uncertainty or missing data, as it handles degrees of variability and avoids issues like multicollinearity. | Errors may occur when inputs are incomplete, inconsistent, or when subjective factors play a significant role. |
| Applicability | Best suited for heterogeneous or emerging markets where qualitative factors and subjectivity play a greater role in the decision. | This is most suitable for uniform markets with distinct, measurable variables and data. |

## 6. Conclusions

This groundbreaking study advances our understanding of the real estate market dynamics by introducing an innovative valuation method and successfully applying it in three diverse cities in Europe and South America. This research effectively predicted property prices by combining fuzzy logic with civil engineering techniques and linguistic terms. This approach addresses subjective uncertainties and discounts related to building degradation, providing a reliable alternative to traditional statistical models. This study emphasized the importance of human decision making in property valuation linked to building inspections and demonstrated that the proposed method aligns with international standards for property valuation. It can also be used as a predictive tool for market prices.

Overall, the findings confirm that a visual technical analysis, which assesses the conservation state of properties through artificial intelligence and fuzzy logic, can establish strong relationships for predicting property prices. Notably, 5% to 10% of the price variations announced by real estate brokerages can be attributed to discounts due to building degradation. The civil engineering inspection serves as a crucial technical basis for adjusting property values based on observed conditions, challenging conventional realtor practices and emphasizing the need for technical assessments to accurately represent the property status.

Future work will integrate geographic information systems (GISs) to further enhance this approach. Thus, incorporating these dynamics into a GIS framework allows for a spatial comparison of real estate markets, offering visual insights and data-driven analysis to better understand how location influences each factor across Latvia and Brazil.

**Author Contributions:** Conceptualization: V.S.; methodology: V.S.; software: both are open search.; validation: V.S., I.A. and V.P.; formal analysis: V.S.; investigation: V.S.; resources: V.S.; data curation: V.S.; writing—original draft preparation: V.S.; writing—review and editing: V.S.; visualization: V.S., I.A. and V.P.; supervision: V.P. and I.A.; project administration: V.S.; experiments: V.S.; original idea: V.S.; study design: V.S.; data collection: V.S.; data analysis: V.S., V.P. and I.A.; manuscript preparation: V.S.; funding acquisition: no funding acquisition. study design: V.S.; data collection: V.S.; data analysis: V.S., V.P. and I.A.; manuscript preparation: V.S. All authors read and agreed to the published version of this manuscript.

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