Deterministic and probabilistic analysis of Ukrainian residential property market evolution in turbulent 2019-2022 years

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Abstract

Purpose – This paper aims to examine the influence of Covid-19, current war and other factors on the dynamics of real estate prices in Ukraine from 2019Q2 to 2022Q4. More specifically, the authors examine the extent of the influence of Covid-19 and war on the real estate market in Ukraine.

Design/methodology/approach – The authors monitor and accumulate information flows from the existing real estate market with their subsequent in-depth math-stat processing to examine dynamics and drivers of Ukrainian real estate prices evolution.

Findings – The study finds that the Ukrainian residential property market has experienced an average growing trend from June 2019 to December 2022, despite the strong influence of pandemic and war. The analysis shows that the impact of these factors varies across different regions and property types, with some areas and property types being more affected than others. The study also identifies the main drivers of the market evolution, including cost-sensitive factors such as floor level, overall area, housing conditions and geographical location.

Research limitations/implications – This research is oriented to analyze evolution of residential property market in Ukraine in 2019-2022 years characterized by influence of such disturbing factors as pandemic and military actions.

Practical implications – Results gained are essential for any type of Ukrainian residential market analytics implementation including but not limited to investment analysis, valuation services, collateral, insurance and taxation purposes, etc. In broader sense, it can be also useful for comparison with same type market development in other geographical areas.

Social implications – Initial data base collected and constantly monitored covers all different regions of the country that gives a broad view on the overall market development influenced by pandemic and war.

Originality/value – The lack of a reliable database of the purchase and sale of residential properties remains one of the biggest obstacles in obtaining reliable data on their market value. This considerably complicates the process of carrying out a valuation and reduces the accuracy and reliability of the results of such work. This is especially important for market which evolves in times of unrest being influenced by such strongly disturbing factors as pandemic and military actions. The originality of the study lies in the development of a complete probabilistic processing of the initial database, which provides a reliable and accurate assessment of the market evolution. The results achieved could be used by various stakeholders, such as property owners, investors, valuers, insurers, regulators and other

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interested customers, to make informed decisions and mitigate risks in the turbulent Ukrainian real estate market.

**Keywords** Residential property, Market evolution, DataBase, Math-Stat processing, Analytical model, Pricing factors, Factor analysis

**Paper type** Research paper

1. Introduction
The future of real estate investing is currently uncertain, much like during the global financial crisis. This new environment poses numerous challenges for investors and other interested parties. As a result, overall deal activity has plummeted, as investors take time to reassess risks and underwrite investments appropriately. While sentiment toward the market is weak, this lack of activity has led to a scarcity of pricing evidence, making it crucial to triangulate data from a range of sources to obtain an accurate picture of the market ([Robson and Green-Morgan, 2022](#)).

The Ukrainian real estate market has been subjected to various economic, political and social disruptions in recent years, particularly the ongoing war in the eastern regions and the COVID-19 pandemic. These disruptions have caused fluctuations in the market, leading to significant changes in housing prices and demand. Despite these challenges, real estate remains a valuable asset class for investors, homeowners and policymakers alike.

However, the lack of reliable and comprehensive data on the Ukrainian residential property market has been a significant obstacle in accurately evaluating the market value of properties. This situation is further complicated by the current turbulent economic and political environment. As a result, there is a need for a robust and accurate analytical approach that can provide insights into the trends and drivers of the Ukrainian residential property market in the current climate.

This study aims to address this knowledge gap by conducting a deterministic and probabilistic analysis of the Ukrainian residential property market evolution from June 2019 to December 2022. Thus, the authors contributed to the creation of an information and analytical database on the Ukrainian real estate market by VERITEX consulting-engineering group, which was used as a data source for this research. Appropriate automated and calculation tools, as well as application program packages, were used to effectively use the database. These tools allowed for the acquisition of comprehensive results in a systematic manner, enabling the identification of modern real estate market trends and the forecasting of priority directions for future development. A noteworthy aspect of this analysis is its fully probabilistic nature, which is crucial in obtaining the most reliable assessment of the evolution of the residential market.

Specifically, this study seeks to examine the extent to which the Ukrainian residential property market is influenced by the COVID-19 pandemic and the ongoing war, as well as other impact factors. Additionally, this study will analyze the features of the supply structure of the secondary real estate market, assess the influence of key price-forming factors on the dynamics and variation of housing prices and provide insights into the market’s evolution.

The study aims to provide a comprehensive understanding of the Ukrainian residential property market during a period of significant turbulence. To achieve this, the researchers have developed a conceptual framework that incorporates both deterministic and probabilistic analysis techniques. By using these approaches, the study seeks to uncover the
underlying factors and dynamics influencing the market’s evolution and to assess the potential future trends and outcomes.

The main motivation behind this study is to address the critical knowledge gap regarding the Ukrainian residential property market’s behavior and performance during the tumultuous period spanning from 2019 to 2022. This period witnessed various economic, political and social challenges that affected the market in significant ways.

The potential contributions of this study include providing valuable insights into the dynamics and drivers of the Ukrainian residential property market, enhancing the methodological analysis of supply and demand formation and improving the accuracy and reliability of valuation and forecasting. These findings could be beneficial to a range of stakeholders, including property owners, investors, valuers, insurers, regulators and other interested parties.

The organization of this paper is as follows: In Section 2, we describe the evolution of the Ukrainian real estate market. Section 3 provides a review of earlier studies. In Section 4, we present an overview of the database and methodology used for calculations and analysis. Sections 5 and 6 describes the data and presents the findings of this study. Finally, in Section 7, we conclude the paper.

2. Overview of Ukrainian real estate market

The Ukrainian property market has been subject to major shocks over the past decade, including the global financial crisis, the COVID-19 pandemic, and the ongoing war with Russia. These events have had a significant impact on the market, resulting in changes to property values, demand and supply.

According to data from the State Statistics Service of Ukraine, real estate prices in Ukraine increased rapidly from 2005 to 2008, with the average price of apartments increasing by around 80% during this period. This was due to strong economic growth, increasing foreign investment and rising demand for housing.

However, the global financial crisis in 2008 had a significant impact on the Ukrainian property market, causing a sharp decline in property prices and demand. Prices continued to fall until 2010, when the market started to stabilize and eventually recover.

From 2010 to 2013, real estate prices in Ukraine increased again, with the average price of apartments rising by around 35%. However, the ongoing conflict with Russia, which began in 2014, had a significant negative impact on the property market, causing a decline in property values, particularly in regions near the conflict zone.

From 2015 to 2018, real estate prices in Ukraine continued to decline, with the average price of apartments falling by around 20%. This decline was also attributed to a slowdown in economic growth and political instability.

Finally, the COVID-19 pandemic has also had a significant impact on the Ukrainian property market. The pandemic led to a slowdown in economic activity, increased unemployment and decreased consumer confidence, which resulted in a decline in property sales and construction activity.

The Ukrainian real estate market from 2019 to 2022 underwent a period of recovery and stability. Following previous economic and political challenges, the market began to rebound, attracting increased attention from investors. Demand for residential properties remained strong, particularly in major cities such as Kyiv, Lviv and Odesa. Property prices varied across regions, with major cities experiencing price increases due to higher demand and limited supply in prime locations. The construction sector saw growth, with developers launching new residential projects to meet the demand. The market also witnessed foreign investment, particularly from neighboring countries and international developers, who were
attracted by the potential returns. Legal reforms were implemented to improve transparency and efficiency in the sector, including measures to simplify registration procedures and enhance property rights protection. The rental market experienced growth, driven by a significant number of students and young professionals in major cities. The commercial real estate sector, including office spaces, retail properties and industrial facilities, also saw growth, supported by business expansions and increasing foreign investments.

Overall, the Ukrainian property market has shown fluctuations in real estate prices over the years, largely influenced by global economic factors and political events. While there have been some challenges, the market started to recover after the crisis, but the full-scale war caused a new wave of uncertainty and instability. It has led to a significant decline in economic growth, a fall in property values and a decrease in demand for property in certain regions.

Some key trends in the Ukrainian property market include the following:

- **Increase in property prices**: Property prices in Ukraine have been rising steadily in recent years, particularly in major cities like Kyiv, Lviv and Odessa.
- **Growth in new construction**: There has been an increase in new construction activity in Ukraine in recent years, particularly in the residential sector. This is due to strong demand for new housing and government initiatives to support construction activity.
- **Increase in rental rates**: Rental rates for residential properties have also been increasing in recent years, particularly in major cities. This is due to rising property prices and increased demand for rental properties.

To gain an overview of the Ukrainian property market, online databases and portals can be valuable resources. Platforms such as the all-Ukrainian unified geographic information system created by Uvekon or online-maps by Olimp-Consulting aggregate real estate listings, market data and analytics specific to Ukraine. These platforms provide access to historical price data and market reports. However, it is crucial to prioritize credibility and reliability by verifying the track record of these sources in delivering accurate and up-to-date information.

The authors recognized this issue and sought an alternative approach by using the database developed by VERITEX. By actively participating in the creation process of this database, the authors were able to ensure a higher level of accuracy and up-to-dateness in the information used for their study. This choice of using a self-created database by the authors demonstrates their commitment to overcoming the limitations of existing resources and providing more reliable insights into the Ukrainian real estate market.

### 3. Literature review

Several studies have focused on analyzing property market and identifying trends and opportunities. For instance, study by Wu et al. (2018) applied a grey correlation degree analysis to identify the key factors driving the residential property market in China. The results of the study showed that there is a strong positive correlation between housing prices and new construction in China. The authors also found that land supply has a moderate positive correlation with housing prices, indicating that the availability of land for development is a key factor in determining housing prices in China.

Another study by Huang et al. (2021) used a dynamic probabilistic model to analyze the housing prices and transactions in China’s real estate market. These studies, among others,
provide valuable insights into the application of deterministic and probabilistic approaches in real estate market analysis, and the factors that drive market evolution.

An extensive examination of the challenges confronting the Ukrainian real estate market can be found in the enlightening study conducted by Kulish et al. (2019). They emphasized the pressing need for effective market analysis to underpin strategic decision-making processes within the industry. By shedding light on these challenges, the study contributes to a deeper understanding of the complex dynamics at play and provides valuable insights into potential solutions and opportunities.

Moreover, Bahriy and Korol (2019) conducted an in-depth exploration of the prevailing trends and patterns in the Ukrainian real estate market. Their research emphasized the crucial role of accurate and comprehensive data in conducting thorough market analysis. By emphasizing the significance of reliable data sources, the study highlighted the importance of using robust information to inform decision-making and foster a more precise understanding of market dynamics.

Additionally, an all-encompassing analysis of the Ukrainian real estate market was provided by Berezivska et al. (2020). Their study delved into key indicators such as supply and demand, pricing fluctuations and market segmentation. Through their comprehensive examination, the researchers offered valuable insights into the various factors influencing the Ukrainian real estate landscape.

Research by Colliers International (2020) shows that despite the pandemic, the Ukrainian real estate market has been able to maintain its stability and that the demand for residential properties has remained relatively high. This finding underscores the enduring strength and attractiveness of the Ukrainian real estate sector, even in times of uncertainty. Meanwhile, a study by Deloitte (2021) notes that the market has seen a decline in prices due to the pandemic, but that there is potential for growth in the long term.

These studies, among others, provide valuable insights into the challenges and opportunities facing real estate market and the importance of accurate and comprehensive market analysis in supporting strategic decision-making. However, despite the wealth of research on the Ukrainian property market, there is still a gap in the literature regarding the analysis of the secondary market, which refers to buying and selling of previously owned properties.

The existing literature on the Ukrainian property market has mainly focused on the primary market, which involves the sale of new properties by developers, while the analysis of the secondary market, which refers to buying and selling of previously owned properties, has been largely neglected. This is particularly problematic given that the secondary market is larger in Ukraine than the primary market. Thus, there is a critical knowledge gap in the literature regarding the analysis of the Ukrainian property market, which must be addressed to gain a more complete understanding of this important sector.

4. Data and methodology

The choice of methodology for this research was based on the understanding that accurate and comprehensive data is crucial to achieving the desired outcome. Therefore, we implemented several methods, including data collection, data processing and cleaning, descriptive, deterministic, geospatial, cluster and factor analysis. The combination of these methods provided a comprehensive and accurate analysis of the deterministic and probabilistic factors that influence the residential property market evolution in turbulent 2019–2022 years. This methodology is justified, as it provides a basis for probabilistic analysis, which involves using probability theory to model and predict future market behavior. The use of deterministic and probabilistic analysis ensures that both the current
state and future evolution of the real estate market in Ukraine are comprehensively analyzed.

The initial stage of data collection and preprocessing was a primary focus of this research to ensure that subsequent analysis was based on accurate and reliable data. Constant validation and comparison of results ensured that the obtained conclusions were valid and credible.

It should be noted that the Ukrainian apartment market is segmented into two main sectors: the primary and secondary markets. The primary market consists of newly constructed residential properties sold directly by developers or construction companies, whereas the secondary market consists of previously owned residential properties being resold by individuals or companies. This research focuses on the secondary market.

4.1 Primary database and data collection
Market analysis is carried out not just for the sake of it, but rather to inform strategic decision-making based on the results obtained. The accuracy and reliability of the initial information database and its primary processing are crucial for the subsequent analysis of the real estate market and directly impact the overall analysis results. As previously stated, the authors played a key role in developing the VERITEX database on the Ukrainian real estate market.

The creation of the primary electronic database involved scanning and aggregating information flows, followed by in-depth processing using mathematical-statistical methods accompanied by geospatial, cluster and factor analysis.

The main principles on which the information and analytical base is built include the following:

- Maximum coverage of the existing primary information base of the real estate market of Ukraine.
- Application of accurate mathematical, statistical and other modern models and criteria for the analysis of large information arrays at all stages of primary database processing.
- Conducting a full probabilistic and statistical analysis of the primary information base for all categories of real estate to obtain the main parameters of their market state and development evolution.
- Constant checking of intermediate and final results to ensure compliance within the framework of the applied analytical model.
- Constant comparison of the developed analytical apparatus and the obtained results with the most renowned domestic and foreign works of this direction.

This approach aligns with the main goal of providing all interested organizations and specialists with reliable analytics of the state, trends and forecast of the development of the real estate market, with a detailed analysis of the impact of the primary pricing factors.

For any data base collection, a methodology of initial population collection cleaning is essential. The processing of arrays, duplication and outliers of primary data for all three specified blocks of real estate was carried out on a single methodological basis using the analytical tools. This ensures the unification of the methodology itself and the possibility of conducting a comparative analysis of the results for individual real estate groups. Main steps of the processing of arrays of primary data can be identified as follows:
The first one refers to data mining through monitoring and collection of primary information flows from data aggregators available.

The second step includes database initial forming and storage. Here, we are using cloud technologies and platforms, data integrators, main parameters identifications, statistics processing on homogeneity and outliers, data duplication and arrays exclusions being finalized by basic data base formation and storage.

Next step is oriented to data systematization and visualization being based on nearest neighbors and data clustering methods, data visualization, geostatic and cluster–spatial models.

After that database processing stage is progressing, which includes analytical modelling, logic-based, forecasting and predictive modelling techniques and factor analysis.

The final stage goes to results interpretation, optimization and reporting.

At this stage, we use the methods of a statistical analysis of the total amount of available primary information after its initial filtering according to the Romanovsky’s criterion for statistical “outliers”. For exclusion of data duplications appeared in different resources, geographical coincidence criteria was used.

As a result, it was necessary to conduct multiple assessments to determine the level of correspondence or “agreement” between the distributions and well-known theoretical models. Such a check was conducted using one of the most statistically powerful criteria – the Pearson $\chi^2$ test. Through multiple calculations, it was determined that the lognormal distribution of the cost per square meter of living space was the closest theoretical distribution to the obtained statistical set of samples.

This general conclusion is important, as it allows to estimate the parameters of the closest theoretical distribution based on a statistical sampling assessment of the data base population, and because of this, to determine the probabilistic characteristics of the key financial indicator which is cost of 1 sq. m. of residential area of the analyzed premises with any needed level of reliability.

As the analysis was primarily conducted on the most representative statistical sample throughout Ukraine, the lognormal distribution of the cost per square meter of residential apartments was selected as the fundamental basis for further data processing.

To facilitate further processing, the initial data samples were processed as decimal logarithms, based on the characteristics of the distribution. The cost per sq. m. were obtained by the inverse logarithm method of the aggregated values of the obtained statistical distribution law.

Therefore, the obtained results confirmed the validity of using this approach for processing the primary information database and defining the parameters of the log-normal distribution law, which proved to be the closest theoretical model for the entire general population of the information database for the parameter of cost per square meter of housing.

Using the methodological approach described above a generalized information on residential market around of Ukraine for its different regions have been received and systemized.

4.2 Processing of the data
Scope of Data Base covers all 24 regions of Ukraine and requires to be divided into segments to reflects the diverse range of properties available and the needs of different buyers:

- **Unit of apartments**: This segment is further divided into primary and secondary markets (data has been collected since June 2018 till December 2022).
• **Unit of land plots**: It includes land plots that are intended for development, agricultural purposes and industrial use. Land plots for development are often purchased by developers who plan to construct residential or commercial properties. Agricultural land is typically used for farming or livestock production, while industrial land is used for manufacturing or other industrial purposes (data has been collected from 2020 to 2022).

• **Unit of households**: This segment includes both residential properties and the land plots on which they are situated. In some cases, households are separated from the land plots on which they are located, while in other cases they are sold together with the land (timeframe – from 2020 to 2022).

As of December 2022, the database in the context of the secondary apartment market only includes about 1 million 660 thousand unique offers throughout Ukraine. The majority of the market consists of one-, two- and 3-room apartments, which also make up the largest share in terms of value (Figure 1).

The total value of the market is more than US$11.60bn (Figure 1). Two- and three-room apartments account for the largest share, 27% and 32%, respectively, whereas one-room apartments account for 18%. The share of four-room apartments is already 15%, five- (and more) room apartments is 8%.

This picture is quite natural, as it reflects the structure of the housing stock, the construction of which has been historically formed in recent decades.

Statistical regularities of the distribution of key characteristics and the parameters of these distributions, which allow for their full probabilistic-statistical analysis are important for property valuation and other purposes. The importance of obtaining such parameters of the distribution of value indicators is determined by their nature, which has a probabilistic basis.

The information and analysis unit for the land plot market is divided into three subdivisions based on their purpose: residential and public buildings, agricultural plots and industrial plots. The information base of the land market, as of the end of December 2022, covers around 32,000 unique offers, with 58% being residential plots, 37% being agricultural plots and 5% being industrial plots. The total value of the land market currently stands at US$4.12bn.

For the home ownership market, as of the end of December 2022, the total information base comprises over 22,000 unique offers with a total value exceeding US$5.4bn. The largest

![Figure 1. Volume of the residential property market in Ukraine as of December 2022](image-url)

Source: Authors’ own creation
share of offers for sale belongs to five- and six-room houses, which represent 25% and 21% of the total number of apartments offered for sale, respectively. For four- and seven-room offers, this share is also significant, reaching 20% and 19%, respectively. The remaining 15% of the total number of offers belong to one-, two- and three-room houses.

In terms of monetary value, six- and seven-room offers again make up the largest share at 40% and 24%, respectively, while five-room offers account for 18%. The share of four-room apartments in monetary terms is already 9% and one-, two- and three-room apartments each represent 9%.

When analyzing after pre-processing of primary database the density distribution of most widely used monetary criteria – the cost of 1 sq. m of apartment on the market of Ukraine. In all cases for different regions, we are arriving to not symmetrical pattern with clearly expressed positive skew and right tail as demonstrated in Figure 2. This character is present not only for different regions but also for any separate time fixed points as resulted from serial checks provided.

Figure 3 provides a visual representation of the density distribution of the cost of 1 sq. m. on the secondary apartment market of Ukraine as of December 2022, using the log-normal distribution law.
distribution law. The $x$-axis displays the cost per square meter in US$, whereas the $y$-axis displays the density of properties within each price range.

As shown in the graph, the majority of properties are priced between $823 per m$^2$ and $1,604 per m$^2$, with a peak density occurring around $1,200 per m$^2$. This indicates that the most common price range for properties on the secondary apartment market falls within this range.

The distribution is right-skewed, meaning that there are fewer properties available at higher prices. However, there is a long tail of properties with higher prices, indicating that there is still demand for luxury properties in certain areas.

Overall, the graphs (Figures 2 and 3) provide valuable information about the distribution of prices in the Ukrainian property market and can be used to inform pricing strategies for buying or selling properties.

Some basic data of such analyses as of December 2022 is demonstrated in the Table 1. We can see main parameters of cost distribution 1 m$^2$ of secondary apartment market in regional centers of Ukraine. Kyiv, Odesa, Dnipro, Lviv and Kharkiv are the largest cities in Ukraine in terms of population and economic activity. Paying attention to these five cities is important when analyzing the Ukrainian property market because they are the main drivers of demand for real estate in the country. Therefore, the median prices of apartments in Kyiv, Odesa, Kharkiv, Dnipro and Lviv on the secondary market in December 2022 were $1,800 per m$^2$, $1,000 per m$^2$, $847 per m$^2$, $909 per m$^2$ and $1,218 per m$^2$, respectively. In general,

<table>
<thead>
<tr>
<th>Region</th>
<th>Amount of offers</th>
<th>Median ($\mu$)</th>
<th>Average</th>
<th>$SL_g$ ($\sigma$)</th>
<th>Coefficient of variations</th>
<th>Lower confidence limit interval</th>
<th>Upper confidence limit interval</th>
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<tbody>
<tr>
<td>Ivano-Frankivsk</td>
<td>901</td>
<td>2.88</td>
<td>778.10</td>
<td>2.87</td>
<td>0.12</td>
<td>0.18</td>
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<td>Vinnytsia</td>
<td>2,243</td>
<td>2.97</td>
<td>967.52</td>
<td>2.97</td>
<td>0.10</td>
<td>0.16</td>
<td>586.41</td>
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<tr>
<td>Dnipro</td>
<td>4,381</td>
<td>2.96</td>
<td>1005.45</td>
<td>2.97</td>
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<td>0.25</td>
<td>433.86</td>
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<tr>
<td>Zhytomyr</td>
<td>217</td>
<td>2.91</td>
<td>800.89</td>
<td>2.89</td>
<td>0.12</td>
<td>0.18</td>
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<td>Zaporizhzhia</td>
<td>864</td>
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<td>3.26</td>
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<td>3.28</td>
<td>0.21</td>
<td>0.32</td>
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<td>Kropyvnytskiy</td>
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<td>2.83</td>
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<td>0.20</td>
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<td>3.09</td>
<td>1353.56</td>
<td>3.11</td>
<td>0.14</td>
<td>0.21</td>
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<td>0.13</td>
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<td>3.01</td>
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<td>2.93</td>
<td>900.72</td>
<td>2.94</td>
<td>0.13</td>
<td>0.19</td>
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<td>Sumy</td>
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<td>2.90</td>
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<td>0.19</td>
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<td>Chernivtsi</td>
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<td>898.18</td>
<td>2.94</td>
<td>0.11</td>
<td>0.17</td>
<td>518.70</td>
</tr>
</tbody>
</table>

Notes: The summary table of the parameters of the distribution of this indicator for all the exception of regional centers includes not only the average and median values, but also the level of their dispersion and variation, which fully describes the probabilistic-statistical parameters of these distributions. This table shows the data for the values “mean plus and minus 2 $\sigma$,” which corresponds to the limits of 95.46% of the corresponding distribution.

Source: Authors’ own creation
this indicator for the country is $1,090 per m², thus, we can observe significant differences in the levels of the average cost for different regions, as well as the degree of their volatility. At the same time, obtaining only averaged value indicators for each individual city is not sufficient, considering the geographical location within the country and zoning of value indicators within the cities.

4.3 Price clustering of the information database
To separate the real estate markets of different cities into some certain groups based on the house price grades, the cluster analysis must be used. The goal of clustering is to identify structure in an unlabeled data set by objectively organizing data into more homogeneous groups where the within-group-object similarity is minimized and between-group-object dissimilarity is maximized (Liao, 2005). Various algorithms have been developed to cluster different types of data sets (Guo et al., 2012).

The application of the k-means statistical method proved to be the most effective for determining value clusters within individual cities. The implementation of this method on the example of processing the initial statistical information of the real estate market of Kyiv (Table 2) clearly demonstrates its effectiveness.

Table 2 presents data on the nine main price clusters identified in the Kyiv property market, based on an analysis of real estate prices in the city. The clusters are defined by different price ranges, with Cluster 1 representing the most affordable properties, and Cluster 9 representing the most expensive.

The table provides information on various parameters for each price cluster, including the number of properties analyzed, the median price per square meter. It also includes information on the coefficient of variation and standard deviation in each.

The data in the table is useful for identifying trends in the market. We can see that the coefficient of variation is relatively high for each cluster, indicating that prices are fairly spread out within each range. We can also see that the median price increases as we move up the price clusters, with the highest median price found in the highest price cluster.

As we can see, location significantly affects the cost of apartment in Kyiv which was taken as an example. If we visualize information above using a city map (Figure 4), it is clear that the prices at the city center will be the highest. And the further you move from this area, the lower the average price of apartments in Kyiv are.

Figure 4 provides a visual representation of the price clustering data presented in the previous table. The map shows the location of each price cluster in the Kyiv metropolitan area, with the boundaries of each cluster indicated by different colors.
As the figure demonstrates, the highest prices for real estate in Kyiv are concentrated in the city center, where the prices per square meter are above $1,600, as indicated by the dark red color. Moving away from the city center, the prices gradually decrease, with the lower-priced clusters concentrated in the suburban areas, as indicated by the lighter colors.

This pattern of pricing is consistent with the dynamics of urbanization, where the highest prices are typically found in central locations, where demand is highest and access to amenities is most convenient. As the distance from the city center increases, the demand for properties typically decreases, leading to lower prices.

The data presented in this figure has significant implications for the Kyiv property market. It indicates that location is a crucial factor in determining the price of real estate, and that investors and developers should take into account the spatial distribution of prices when making decisions about investment and development. Furthermore, the data suggests that there may be opportunities for investment in the suburban areas of Kyiv, where prices are lower and demand may be growing as the city expands.

5. Dynamics of real estate prices in Ukraine
For getting a grounded basis for the prices forecasting in real estate market, it is reasonable to analyze the available historic data and trace evolution of apartment prices for that period.

First, it should be noted that prices in real estate markets in each region are formed under the influence of general trends throughout the country, price increases/decreases in one of the market segments inevitably cause corresponding price changes in others. It should also
be mentioned that initially the increase in purchasing power responds to the demand for residential properties. At the same time, the processes on the real estate market in different cities and in different market segments are developing in a similar way but with additional influence of local particulars. That is why, to see the general picture of the country’s real estate market development, it is advisable to consider the prices evolution both in terms of specific cities and the whole of Ukraine. Figure 5 presents analysis of price evolution on the secondary market of apartments in Ukraine over the period 2019–2022.

The results of the data processing are presented in the form of time series displayed on corresponding graphs with a given frequency. Figure 5 illustrates the dynamics of changes in prices for apartments in the secondary market of Ukraine in US$ equivalent. A similar trend is also shown in national currency, the hryvnia, using the official rate of the National Bank of Ukraine.

The first conclusion that can be drawn from the graph is that between crises, the prices on the real estate market of Ukraine generally grow monotonously. There are, however, short-term intervals where the trajectory of price movement changes direction. These directly correspond to the COVID-19 pandemic period for Ukraine and the Russian military invasion.

In general, analyzing the graph and events characteristic of the corresponding time period, several stages can be distinguished:

- Until the end of 2019, the continuation of earlier periods’ trends was observed, which were characterized by relative stability.
- The impact of the coronavirus was most noticeable in the first few months of 2020, from January to May, when the market experienced shocks caused by the energy crisis, the reduction of purchasing power and the growth of inflationary expectations, among other factors.
- However, from June 2020, the market adapted and buyers began to realize delayed demand. The indicators returned to pre-quarantine levels with further stable growth.
- 2022 was very unpredictable for objective reasons, being directly connected to the start of a full-scale war. There was a rather sharp increase in prices in April, which could be attributed to increased demand due to the influx of refugees, leading to a price increase. However, in the following period, this abnormal growth leveled off and the market returned to relatively stable growth.

**Figure 5.** Evolution of the average price of an apartment on the secondary real estate market of Ukraine for June 2019 to December 2022

Source: Authors’ own creation
Moreover, this trend in 2022 is not the same for all cities. For Kharkiv which is a front-line city that terribly suffers from shelling, market reacted accordingly by lowering prices and demand. On the other side cost of square meters has increased significantly in the western regions of the country including such cities as Lviv, Ivano-Frankivsk, Ternopyl and others. Such a situation is quite reasonable, because this is where most of the temporarily displaced and evacuated persons were directed. A similar picture was observed in Kyiv after the liberation of the region and the cessation of the offensive on the capital.

Some regions such as Dnipro city located not so far from the zones of active hostilities still demonstrated market prices increase. Again, this is connected with immigrants. People chose relatively safe regions, but which are closer to their native homes. Increased demand provoked an increase in prices for such regions. Such cities as Odesa located at Black Sea coastline with recreation orientation have not undergone significant residential market changes because of their continuous attractiveness.

Thus, the study of the general evolution of real estate prices for June 2019 to December 2022 shows an overall upward trend, which is stimulated by an increasing demand for residential square meters. This is consistent with the global trend in residential market evolution for different countries (Robson and Green-Morgan, 2022). At the same time such turbulences caused by COVID-19 pandemic and military situation in a country had a serious impact on residential market evolution. At the same time influence of these disastrous factors is uneven around of the country which is caused by specific social elements like people migration aside from active military actions regions.

The volume of the residential market in Ukraine for the period of 2021–2022 appeared to be even more indicative as shown in Figure 6.

Figure 6 shows that the drop in market proposals for residential apartments during the pandemic constituted approximately 10%. However, with the start of the war, this market shrank for the country as a whole by 60% to the pre-war period, followed by a gradual increase to approximately half its size before the military invasion. The country’s general situation of uncertainty and instability makes many owners cautious, and these factors can be attributed as the main reasons for the strong decrease in the residential market size. The most significant drop in the residential market size was observed in April 2022, two months after the start of the military invasion.

The complete probabilistic analysis of the residential property market database also made it possible to analyze the evolution of the scattering parameters of this market (Figure 7).

Figure 7 shows the dispersion and coefficient of variation of the cost of 1 m² on the secondary housing market in Ukraine from 2021 to 2022. The dispersion measures how much the prices of real estate vary around the mean value, while the coefficient of variation shows the degree of variation of a set of data relative to its mean. The graph represents the changes in these parameters over time, with the x-axis representing the time period from 2021 to 2022 and the y-axis representing the values of dispersion and coefficient of variation.

The figure indicates a high level of data deviation, meaning that the prices of real estate in Ukraine were widely spread around the mean values during this period. This situation is expected for developing economies without a well-established system of sales contract registration. Additionally, the level of deviation increased since the beginning of 2022, which may be attributed to the growing economic, political and social instability and uncertainty in Ukraine.

The coefficient of variation is more stable in its level over time than the standard deviation, especially during the year 2022, despite the remarkable changes in market size.
The quarterly indicators of the land market size in Ukraine for the period of 2021–2022 dynamically characterize the overall picture being influenced by various factors that restrain or, on the contrary, encourage market activity (Figure 8). As shown in Figure 8, the land market experienced significant fluctuations during this period, reflecting the impact of key events and trends on the market.

In particular, the figure demonstrates that the opening of the agricultural land market from July 1, 2021, had a significant impact on the size of the land market, with a rapid growth in the number of land plots available for sale. This growth continued through the first quarter of 2022, as more landowners entered the market and demand remained strong.

However, the market evolution in the second quarter was largely influenced by the outbreak of a full-scale war, which caused a shock situation and a significant drop in market size both in terms of quantitative and monetary results. The figure illustrates this drop in activity, with a sharp decline in the number of land plots available for sale in Q2 2022. Despite this setback, the third quarter has shown a tendency to recovery, as the market
begins to stabilize and confidence returns. The figure demonstrates this trend, with a slight increase in the number of land plots available for sale in Q3 2022.

The secondary household market volume trend in Ukraine for the period 2021-2022 demonstrates similar pattern to apartments market evolution (Figure 9).

According to the Figure 9, since the beginning of 2022, there has been a slow decline associated with political and economic instability in the country. April 2022 in this respect has become the most critical month for the market size diminution, both in terms of offers quantity and their total cost. It is obvious that the reason for that was the beginning of a full-scale war, which shook the market. Currently, relative stabilization is observed, although the indicators are still far from the pre-war level being below by 2 times approximately. This is in line with the overall residential apartments market drop underlined and discussed above.

The information database of the real estate market is constantly replenished and updated, which allows expanding its analytics using modern methods of mathematical and statistical processing of results and obtaining the most reasonable and reliable parameters of this market and its evolution with the determination of the influence of a wide range of individual price formation factors.

6. Real estate prices and their underlying determinants

Factor analysis is a cornerstone in the processing of large data sets. It allows to predict and simulate the impact of several factors on the target indicator. Without the collection of systematized market information and its in-depth analysis, studying the impact of individual factors does not seems to be realistic being at least less reliable and trustable.

Table 3 presents the results of factor analysis that examines the impact of the floor level on the cost per square meter of residential property, in various locations across the country and for buildings of different total number of stories. One interesting finding is that first floor apartments in big cities (Kyiv, Dnipro, Lviv, Odessa, Kharkiv) demonstrate a discount expectation that is over two times higher than the same apartments located on higher floors in multi-story buildings, with an average discount

![Diagram](image-url)

**Figure 7.** Evolution of dispersion and coefficient of variation of the cost of 1 m² on the secondary housing market in Ukraine, 2021–2022
of 28%. This difference is less significant in other cities where number of sky-scrappers is not so big.

As shown in Table 3, the cost of residential property is affected differently depending on the location and type of building fund, particularly the number of floors in the building and the floor level of the apartment. In new buildings, apartments on the top floor typically have a higher cost due to their panoramic views, while apartments on the top floor of older buildings do not have this advantage, resulting in a lower value. Therefore, the last floor is generally more expensive than the first in new buildings, while the opposite is true for old buildings, especially up to five-story buildings with no elevators. In such cases, the cost of the first and last floors of old

Source: Authors’ own creation

<table>
<thead>
<tr>
<th>Data collection period, year.quartal</th>
<th>Number of offers (in general)</th>
<th>Number of offers (agricultural purpose)</th>
<th>Number of offers (residential purpose)</th>
<th>Number of offers (industrial purpose)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2021.02</td>
<td>24,955</td>
<td>5,013</td>
<td>39,756</td>
<td>6,014</td>
</tr>
<tr>
<td>2021.03</td>
<td>12,036</td>
<td>3,423</td>
<td>13,093</td>
<td>2,502</td>
</tr>
<tr>
<td>2021.04</td>
<td>6,014</td>
<td>1,717</td>
<td>3,075</td>
<td>817</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Data collection period, year.quartal</th>
<th>Total value of the market, billion $</th>
<th>Value of the market (residential purpose), billion $</th>
<th>Value of the market (agricultural purpose), billion $</th>
<th>Value of the market (industrial purpose), billion $</th>
</tr>
</thead>
<tbody>
<tr>
<td>2021.02</td>
<td>2,395</td>
<td>0.43</td>
<td>0.83</td>
<td>0.46</td>
</tr>
<tr>
<td>2021.03</td>
<td>1,809</td>
<td>0.42</td>
<td>0.82</td>
<td>0.41</td>
</tr>
<tr>
<td>2021.04</td>
<td>1,325</td>
<td>0.41</td>
<td>0.80</td>
<td>0.40</td>
</tr>
</tbody>
</table>

Figure 8.
Evolution of the volume of the land market in Ukraine, 2021–2022
buildings in the largest cities are in approximate parity, which is in line with the results of the factor analysis presented in Table 3.

Cost of one sq. m. residential apartment area is widely used as a main financial indicator of residential market. At the same time, this parameter may depend on the overall apartment area size. To reflect such dependence, different approaches are used, including linear and power dependence. Direct factor analysis of such dependence for the Ukrainian residential property market demonstrates a quite interesting picture. According to the Figure 10, analysis of this indicator for one-, two- and more-room apartments shows that the average cost per m² is quite stable up to the total apartment area of about 70 m². Starting from this size of total apartment area, there is a significant increase in the cost per sq. m.
Such dependence, which has been revealed, could be explained by some social-related factors influence. Apartments with a total area under 70 sq. m. are quite modest and normally are owned by low-income groups of people. With further increase in the total living area, the ownership gradually moves to the groups of the population that can afford more...
comfortable and modern apartments, which is directly linked with their area unit cost growth.

The influence of the apartment’s housing condition on the cost indicator was analyzed in five categories: suitable conditions, just built, cosmetic repair, euro-standard and author’s design. The results of this analysis are presented in Table 4, which clearly demonstrates the significant role of the apartment’s condition in determining its price. The table shows that apartments with author’s design renovation can cost up to twice as much as an apartment in suitable or just built conditions. On the other hand, the euro-standard level corresponds to an intermediate price range between these extreme categories of apartment quality.

These findings suggest that investing in high-quality renovations and designs can significantly increase the value of an apartment. Moreover, it highlights the importance of considering the housing condition factor when evaluating the value of residential properties. This information can be particularly useful for real estate investors and developers who seek to optimize their investment strategies and maximize their profits.

<table>
<thead>
<tr>
<th>No. of floors at the building</th>
<th>Location</th>
<th>Category of housing condition</th>
<th>Median cost, $ per m²</th>
<th>Absolute difference with the baseline, $ per m²</th>
<th>Relative difference from baseline, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above 9 floors</td>
<td>Ukraine as a whole</td>
<td>Suitable condition</td>
<td>815</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Just built</td>
<td>1,042</td>
<td>227</td>
<td>27.89</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cosmetic repair</td>
<td>978</td>
<td>163</td>
<td>19.99</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Eurorenovation</td>
<td>1,319</td>
<td>505</td>
<td>61.93</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Author’s design</td>
<td>2,000</td>
<td>1,185</td>
<td>145.46</td>
</tr>
<tr>
<td>The biggest cities*</td>
<td></td>
<td>Suitable condition</td>
<td>994</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Just built</td>
<td>1,203</td>
<td>209</td>
<td>20.98</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cosmetic repair</td>
<td>1,000</td>
<td>6</td>
<td>0.59</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Eurorenovation</td>
<td>1,500</td>
<td>506</td>
<td>50.88</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Author’s design</td>
<td>2,243</td>
<td>1,249</td>
<td>125.63</td>
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<tr>
<td>Other cities</td>
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<td>Suitable condition</td>
<td>631</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Just built</td>
<td>748</td>
<td>117</td>
<td>18.54</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cosmetic repair</td>
<td>820</td>
<td>189</td>
<td>30.03</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Eurorenovation</td>
<td>1,049</td>
<td>419</td>
<td>66.39</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Author’s design</td>
<td>1,178</td>
<td>547</td>
<td>86.80</td>
</tr>
<tr>
<td>Up 9 floors</td>
<td>Ukraine as a whole</td>
<td>Suitable condition</td>
<td>455</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Just built</td>
<td>769</td>
<td>315</td>
<td>69.23</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cosmetic repair</td>
<td>763</td>
<td>308</td>
<td>67.84</td>
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<tr>
<td></td>
<td></td>
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<td>1,016</td>
<td>562</td>
<td>123.59</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Author’s design</td>
<td>1,413</td>
<td>959</td>
<td>210.95</td>
</tr>
<tr>
<td>The biggest cities*</td>
<td></td>
<td>Suitable condition</td>
<td>902</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Just built</td>
<td>841</td>
<td>−61</td>
<td>−6.75</td>
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<tr>
<td></td>
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<td>Cosmetic repair</td>
<td>876</td>
<td>−26</td>
<td>−2.90</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Eurorenovation</td>
<td>1,200</td>
<td>298</td>
<td>32.98</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Author’s design</td>
<td>2,057</td>
<td>1,155</td>
<td>127.99</td>
</tr>
<tr>
<td>Other cities</td>
<td></td>
<td>Suitable condition</td>
<td>386</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Just built</td>
<td>720</td>
<td>334</td>
<td>86.55</td>
</tr>
<tr>
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<td></td>
<td>Cosmetic repair</td>
<td>694</td>
<td>308</td>
<td>79.85</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Eurorenovation</td>
<td>930</td>
<td>544</td>
<td>141.02</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Author’s design</td>
<td>1,100</td>
<td>714</td>
<td>185.00</td>
</tr>
</tbody>
</table>

Note: *Kyiv, Dnipro, Lviv, Odessa, Kharkiv

Source: Authors’ own creation

Table 4. Change of the median cost of 1 m² depending on apartment quality category for different geographical location
To carry out a comprehensive analysis of the home ownership market in Ukraine, it is necessary to determine the median price per square meter depending on the type of home ownership and location (Table 5).

The median cost of home ownership was studied in relation to the distance from the nearest city in Ukraine. Table 5 summarizes the dependence of the median cost on the category of home ownership and the distance to the nearest city. The study found that home ownership within 10 km of a city had a median cost that was 72.28% higher than the national baseline. However, home ownership located between 10 and 50 km from a city had a median cost that was 5.08% lower than the national baseline. Furthermore, the median cost of home ownership in central agglomerations was 56.54% higher within 10 km of a city compared to the national baseline. Conversely, the median cost of home ownership located between 10 and 50 km from a city in central agglomerations was 24.32% lower than the national baseline. Finally, the median cost of home ownership in the periphery within 10 km of a city was 78.36% higher than the national baseline. However, home ownership located between 10 and 50 km from a city in the periphery was 29.13% lower than the national baseline.

The pandemic and ongoing war have significantly impacted the preferences of the population in terms of household location. A noticeable trend has emerged wherein people are moving away from cities that are subject to military attacks and towards safer countryside areas. However, the rising cost of automobile fuel and lower personal income has created a barrier for those looking to move further away from their workplaces in the cities. This has led to a market balance in housing location choices that affect the decision on the place of residence. Another contributing factor is the increased level of remote work, which has led to a growing interest in suburban householding. This trend is reflected in the growth of price indicators for residential properties located up to 10 km away from the cities.

In this scenario, the demand for housing will depend on the residents’ assessment of the reliability and safety of the property. Therefore, the prices in safer areas and neighborhoods will be higher than in those where the risk of attacks is higher. The factor analysis presented in the previous section has proven to be an efficient tool in uncovering market behavior peculiarities and getting quantitative parameters of price forming factor influence on property overall cost. However, such analysis requires an initial and updated database, which is most crucial during the period of market unrest.

### Table 5.
Dependence of the median cost on the category of home ownership

<table>
<thead>
<tr>
<th>Sample</th>
<th>Distance to the nearest city</th>
<th>Median cost, $/m²</th>
<th>Absolute difference from the baseline, $/m²</th>
<th>Relative difference from baseline, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole Ukraine</td>
<td>All</td>
<td>346.22</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>From 10 to 50 km</td>
<td>328.64</td>
<td>–17.58</td>
<td>–5.08</td>
</tr>
<tr>
<td></td>
<td>Up to 10 km</td>
<td>566.18</td>
<td>237.54</td>
<td>72.28</td>
</tr>
<tr>
<td>Central agglomerations</td>
<td>All</td>
<td>351.14</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>From 10 to 50 km</td>
<td>265.76</td>
<td>–85.38</td>
<td>–24.32</td>
</tr>
<tr>
<td></td>
<td>Up to 10 km</td>
<td>416.03</td>
<td>150.27</td>
<td>56.54%</td>
</tr>
<tr>
<td>Periphery</td>
<td>All</td>
<td>176.68</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>From 10 to 50 km</td>
<td>125.22</td>
<td>–51.465</td>
<td>–29.13</td>
</tr>
<tr>
<td></td>
<td>Up to 10 km</td>
<td>223.34</td>
<td>98.12</td>
<td>78.36</td>
</tr>
</tbody>
</table>

Source: Authors’ own creation
including the current situation in Ukraine with the shocking influence of pandemic and military action.

7. Concluding remarks
The developed methodological approach, which is based on the accumulation of an initial database and its in-depth mathematical-statistical analysis, has led to the possibility of a detailed analysis of the Ukrainian residential property market evolution during the turbulent years of 2019–2022, with a particular emphasis on the influence of the COVID-19 pandemic and military actions. The approach’s main particular feature is its full probabilistic description, which allows for obtaining results of the market evolution with any required level of reliability.

The study conducted a comprehensive analysis of the general dynamics of the real estate market from June 2019 to December 2022, demonstrating an average growing price trend. The most evident influence of disturbing factors, such as the pandemic and war, was demonstrated by the market size squeezing, which decreased by more than two times of its pre-war period level.

Factor analysis, jointly with cluster analysis, was used to analyze the accumulated data base, providing insight into the character of influence of several price forming factors such as geographical location, type of building, floor level and housing overall area. Furthermore, the analysis led to the quantitative parameters of such influence. The methodology developed can be further implemented in other residential property markets to provide a more general view of the broader applicability of the results achieved in this investigation.

The conceptual framework used in the study incorporates deterministic analysis techniques to understand the cause-and-effect relationships within the residential property market. This approach allows the researchers to identify key variables, such as economic indicators, policy changes and market conditions, that have a direct impact on the market’s behavior. By examining these deterministic factors, the study aims to provide a clear understanding of the forces driving the market’s evolution during the turbulent years under investigation.

In addition to the deterministic analysis, the study also incorporates probabilistic methods to assess the uncertain and unpredictable nature of the real estate market. By utilizing probabilistic models, the researchers can capture the inherent uncertainties and risks associated with the market, enabling them to forecast potential future scenarios and evaluate their likelihoods. This probabilistic analysis adds a crucial dimension to the study, allowing for a more comprehensive understanding of the Ukrainian residential property market’s evolution during the turbulent years under examination.

In conclusion, the developed methodology provided a comprehensive analysis of the Ukrainian residential property market’s evolution in turbulent years, highlighting the influence of the COVID-19 pandemic and military actions. The results of the study contribute to a better understanding of the market’s behavior, including the factors affecting the price formation process. The application of this methodology to other residential property markets can further enhance our knowledge of the real estate industry.

The results obtained in this study provide evidence that the secondary market in Ukraine’s residential property market is significant and deserves further attention.

Additionally, the methodology developed in this study can be used to conduct further research on the secondary market, providing a more comprehensive understanding of this
important aspect of Ukraine’s residential property market. Therefore, this study contributes to filling the knowledge gap regarding the analysis of the secondary market in the Ukrainian property market.

Overall, the study provides insights into the factors that influence the Ukrainian residential property market, such as the impact of the pandemic and military conflict on the population’s preferences for housing location. This information can be useful for real estate developers, investors and other stakeholders in the industry to make informed decisions about where to invest their resources and how to adjust their strategies based on market trends.

Furthermore, the study’s factor analysis approach provides a quantitative understanding of the factors that influence the pricing of residential properties, such as location, distance to the city and quality of housing condition. This information can be valuable for real estate agents and appraisers to accurately evaluate the value of properties, set reasonable prices and negotiate deals. Findings can help stakeholders in the Ukrainian residential property market to make informed decisions, adapt to changing market conditions and improve their overall performance.

It should be noted that the practical application of the results achieved in the Ukrainian residential market is limited to the current turbulent times. Therefore, their generalization requires a comparison with similar market tendencies in other countries and regions.

References
Further reading

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