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# Investigating the impact of property characteristics, cost of living, and environmental factors on rental prices in Baidoa's climate-affected real estate market: a hybrid approach using hedonic regression and neural networks

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**Introduction:** Understanding the determinants of residential rental prices is crucial for policymakers, investors, and real estate practitioners. This study investigates the influence of property value, property characteristics, cost of living, political stability, essential services, and environmental factors on rental prices in Baidoa city. Additionally, the research compares different modeling approaches to enhance rental price forecasting.

**Methods:** A dual-method approach was employed, integrating hedonic regression analysis and artificial neural network (ANN) models to analyze rental values. The dataset includes key variables such as the number of bedrooms, essential services, cost of living, and environmental conditions. The predictive performance and interpretability of both models were assessed to determine their effectiveness in rental price estimation.

**Results:** The findings reveal that rental prices are significantly influenced by the number of bedrooms, essential services (e.g., electricity), cost of living, and environmental conditions. However, political stability and displacement did not exhibit significant effects. While hedonic regression provided clear, interpretable insights into direct predictors, ANN models captured nonlinear interactions and demonstrated superior prediction accuracy. Nevertheless, the ANN model exhibited mixed performance, with 53% of cases underperforming and 47% exceeding predictions, highlighting the need for improved precision in forecasting.

**Discussion:** The study emphasizes the importance of a mixed-method approach in rental price forecasting. Policymakers should integrate econometric and machine learning models to refine housing policies and ensure fair market regulations. Investors and property owners can leverage these findings to optimize rental pricing strategies, while real estate practitioners can benefit from data-driven decision-making. This research contributes to the real estate valuation literature by bridging traditional econometric analysis with advanced machine learning techniques. The study validates the applicability of hedonic

pricing and information asymmetry theories within an emerging market context, offering a more comprehensive understanding of rental price determinants.

#### KEYWORDS

climate-driven real estate, hedonic regression, artificial neural networks (ANN), rental price forecasting, displacement and political stability

## Introduction

Many factors affect residential rentals, such as property features, standard of living, political stability and the environment. The size, location and facilities available in a building determine how much rent it can attract in addition to tenant preferences and satisfaction (Cai et al., 2024; Li et al., 2021; Nor et al., 2019). Urban areas with good infrastructure, services and security tend to have high rental fees. On the other hand, the cost of living in any given place includes utilities, transportation costs and food stuffs, among others, which also influence rental affordability and demand (Dirie et al., 2024; Makarewicz et al., 2020; Nor and Raheem, 2024).

Political stability plays a major role in the housing market. It interests investors in a stable political environment, thereby affecting rental prices, among others. In contrast, unstable politics often leads to fluctuations, hence reducing property values as well as rental incomes (Chien and Setyowati, 2021; Nor and Moge, 2024). On the other hand, due to climate change, natural calamities are some of the environmental factors that play a significant role in determining rental markets. Risk perception is one of the reasons why flood-prone areas or places susceptible to earthquakes usually have less demand for rents (Chen et al., 2021; Shobande and Ogbeifun, 2023; Soltani et al., 2024; Tu et al., 2023). Therefore, understanding all these factors is important when analyzing residential rental dynamics.

Despite the significant role of residential rental markets in urban economies, existing research has largely examined these markets in a fragmented manner, focusing on isolated determinants such as property characteristics, standard of living, political stability, or environmental conditions (Balota et al., 2023; Shobande and Ogbeifun, 2024a,b). This compartmentalized approach fails to acknowledge the intricate interconnections between these factors, leading to an oversimplification of the mechanisms governing rental pricing and availability. The lack of integrated studies on these variables hinders the formulation of comprehensive policies capable of addressing the complexities associated with rental market dynamics. Furthermore, most studies in this domain have predominantly focused on developed nations, thereby leaving substantial gaps in understanding the housing challenges faced by developing economies. Countries such as Somalia, which experience heightened political instability and environmental vulnerabilities, require localized research that informs effective housing policies. Bridging this knowledge gap is essential to fostering stable and affordable rental markets in such regions.

The residential rental market in Baidoa city, Somalia, presents a unique case study due to its multifaceted challenges. Factors such as property characteristics, cost of living, Conflict, and environmental conditions collectively shape rental prices and market availability in complex ways. However, existing research has not provided a holistic examination of these interrelated factors, thereby limiting the development of effective policy interventions. This study seeks to address this gap by investigating multiple determinants of residential

rent prices in Baidoa city. By adopting a multidimensional analytical approach, this research aims to generate a comprehensive understanding of rental market dynamics, thereby contributing to evidence-based policy-making that fosters market stability and growth.

This study emerges from the necessity to develop viable housing strategies for urban areas experiencing intricate socioeconomic challenges, such as those observed in Baidoa's rental market. Understanding these dynamics is critical for stakeholders, including policymakers, investors, and residents, to navigate the housing landscape effectively. Additionally, this research contributes to the academic discourse on rental market trends in developing countries by providing empirical insights from Baidoa. The findings are expected to enrich the global knowledge base on housing economics and inform strategies applicable to similar contexts, thereby supporting broader efforts toward enhancing housing stability and affordability in developing regions.

The urgency of this study lies in its potential to address pressing issues in Baidoa's rental market. Conflict and environmental vulnerabilities have contributed to a volatile rental environment, necessitating timely and informed policy responses. This research aims to explore theoretical frameworks governing renter-landlord relationships to develop an evidence-based framework for effective market regulation. Beyond its practical implications, this study also contributes to the theoretical advancement of housing economics by incorporating multidimensional perspectives into the analysis of rental markets. This approach not only enriches the academic literature but also provides practical solutions to real-world challenges in comparable settings.

This research distinguishes itself by offering a comprehensive assessment of residential rentals in Baidoa city. Unlike previous studies that have examined isolated variables, this study integrates multiple dimensions, including property characteristics, cost of living, political stability, and environmental factors, thereby enabling a holistic analysis of rental market determinants. This approach is particularly relevant for understanding the complex and interdependent dynamics shaping rental markets in developing economies. The significance of this research extends beyond its empirical contributions, as it also carries profound policy implications. By providing detailed evidence on the factors influencing rental prices in Baidoa, this study informs targeted policy interventions addressing both immediate and long-term housing challenges. An evidence-based policy framework is essential for developing sustainable housing policies that enhance market stability and affordability.

A review of existing literature indicates a considerable research gap in the integrated study of rental market dynamics in developing nations. The majority of previous inquiries have focused on specific aspects such as property characteristics or political stability, often overlooking the multifaceted nature of rental markets. This fragmented approach does not sufficiently capture the intricacies of rental pricing, particularly in regions like Baidoa, where economic conditions are highly volatile. Additionally, there is a paucity of

academic literature on Somalia's rental market, as most studies have been conducted in developed economies. This study aims to bridge this gap by conducting a comprehensive analysis encompassing various explanatory variables, thereby elucidating the role of property characteristics, essential services, cost of living, political stability, and environmental factors in shaping rental market trends.

The relevance of this study extends beyond the local context of Baidoa city. By offering empirical insights from a developing economy with distinct socioeconomic challenges, this research contributes to the global discourse on rental markets. The framework developed in this study can be adapted to similar contexts, supporting broader efforts to improve housing security and affordability in developing regions. Through a comprehensive analysis integrating diverse variables, this study seeks to generate a nuanced understanding of the forces driving rental market dynamics in Baidoa. The findings will be instrumental in shaping policies that determine rental prices and housing availability. By identifying the key determinants influencing rental markets, this study provides valuable insights for policymakers, investors, and other stakeholders to devise targeted interventions that promote housing security and affordability, ultimately contributing to the socioeconomic transformation of urban areas. Hence, this study aims to investigate the influence of property value, property characteristics, cost of living, political stability, essential services, and environmental factors on residential property rental prices in Baidoa city.

## Literature review

### Global studies on residential rental prices

The global property market is a dynamic interplay of property characteristics, cost of living, political stability and environmental factors that shape residential rental prices. A wide range of literature has shown that property size, age, layout and building facilities greatly affect tenants' WTP since they associate these attributes with quality and convenience (Ghumare et al., 2020; Nor et al., 2019; Olowu et al., 2019). Moreover, the cost of living, including utility bills, real estate taxes and transportation costs, is integrally associated with rent adjustments, indicating wider economic contexts around the existence of such properties (Joshua Adegoke, 2014; Odubola and Adeyeemi, 2017; Vallebueno and Lee, 2023).

Additionally, political stability has become a major determinant of fluctuations in housing markets at the global level. A more stable political environment attracts greater investments in real estate, leading to competitive rental prices in robust markets (Jover and Cocola-Gant, 2023; Nor and Raheem, 2024). Conversely, regions characterized by political turmoil tend to experience depressed property values and rental rates due to increased risks and reduced investor confidence (Collins and Senhadji, 2003; Hromada et al., 2023). In this way, politics can have both direct and indirect effects on housing markets that range from returns on investment to local affordability.

Furthermore, environmental aspects play a critical role worldwide in regard to determining residential rentals. Climate change issues, among other factors such as environmental degradation and the risks of natural disasters, may affect living conditions, hence causing variations in rental pricing. For instance, those buildings that adopt sustainable model designs coupled with siting them in less risky zones experience better rental prices, which shows tenants' growing

preferences for sustainability plus security (Albsoul et al., 2023; Mironiuc et al., 2021; Van De Wetering, 2018). Conversely, areas that are highly vulnerable to environmental threats often experience a decrease in rental value, which calls for urban resilience planning and development (Anelli et al., 2024; Seewald et al., 2023; Shin et al., 2024).

The combination of these factors shows a complex space where global trends intersect with local specifics to form the residential rental market. Therefore, urban economists and policy makers must understand these worldwide influences when trying to improve housing affordability and market stability. With growing urban populations globally, there is therefore a need for a comprehensive understanding of these different yet interconnected factors that affect housing markets (Raco et al., 2022; Rodríguez-Pose and Storper, 2020).

### Regional studies on residential rental prices

Regarding the context of East Africa, regional studies provide deeper insights into how similar factors impact the real estate industry. Rapid urbanization in cities such as Nairobi Addis Ababa and Dar es Salaam indicates how migration within towns and the building of infrastructure change rental markets (Henderson and Liu, 2023; Shobande and Asongu, 2022; Woldeamanuel, 2020). These cities usually receive large influxes of people from rural areas that result in increased demand for housing and hence rising rental prices, especially in town centers as well as connected suburbs.

At the regional level, economic policies have significant effects on the housing sector. For example, government interventions such as housing finance subsidies or property ownership regulations can either help alleviate or contribute to more pressure on rent markets. A study by Tanzania and Uganda shows that the introduction of favorable government policies on housing often leads to reduced fluctuations in rentals, thereby making it more affordable for lower-class citizens (Mutero et al., 2010). However, inconsistent policies can cause market instability and unaffordability (Onduko, 2023).

The sustainability and resilience of the environment are increasingly prominent in regional urban planning due to the recurrent drought and flooding in East Africa, which affects livability and hence rental markets. For example, urban areas that integrate flood defenses and sustainable water management systems are more attractive because they influence rents (Beltrán et al., 2019; Mutlu et al., 2023). In regions where climatic variability can greatly interrupt daily life and economic stability, such environmental considerations are essential (Thaler et al., 2023; Yi and Choi, 2020).

Regional real estate dynamics are also affected by security concerns, often tied to political stability. Higher property valuation is observed in locations with strong government control and low crime rates, indicating a safety/stability premium (Goodfellow, 2012; Manea et al., 2023). This correlation underscores the significance of effective governance and law enforcement as necessary elements for developing a stable real estate market in the region (Mwau and Sverdlik, 2020; Soyeh et al., 2021).

### Somalia-specific research

The Somali real estate market is peculiarly influenced by market forces compounded by its post conflict status as well as ongoing recovery

efforts. Historical land policies and sociopolitical upheavals have significantly shaped Somalia's housing market. In the 1970s, tight rules were placed on land ownership and distribution during that era, forcing an urban focus in land registration through the Land Law of 1973 (Nor et al., 2019). After this, there was another Land Law of 1975 that gave power over any kind of land to the state since it was guided by the communist ideology at that time (Leeson, 2007; Nor et al., 2019). The Munisibaale Agreement facilitated permanent residential allocations, while Damanyaale offered temporary residency with options to buy land alongside (Roth et al., 1994; Samatar, 1987). These policies endorsed urbanization and affordable housing with leasehold titles for up to 50 years (CAHF, 2017; Wily, 2011).

The collapse of the military government in 1991 left the Land Law of 1975 worthless, as it led to the loss of land registries and title deeds (Nor et al., 2019). Consequently, land administration became decentralized and largely informal, with local authorities and traditional mechanisms taking precedence (CAHF, 2017; Nor et al., 2019). The adjudication of land disputes transitioned to Islamic Courts and later civil courts; however, corruption and enforcement issues have made many people depend on records that existed before the civil war for proof of ownership (Nor and Raheem, 2024). Despite this interest by the government in land reform, major strides have failed due to capacity constraints, leaving issues related to land tenure and ownership unresolved (Nor and Raheem, 2024).

Since then, Somalia's housing sector has experienced significant privatization since 1991 as a result of population growth, improved security conditions, diaspora investments and internal displacement (Ingiriis, 2020; Nor and Raheem, 2024). However, high price levels remain an obstacle for most Somali citizens. Housing finance in Somalia lacks a conventional mortgage market that relies more on family savings or nonmortgage financing options (Nor and Raheem, 2024; Uwayezu and Vries, 2020). Global financial markets and banking services have not been accessible since 1991 but only recently with the revival of the banking industry through new banks licensed by the Central Bank of Somalia (Nor and Masron, 2019; Nor et al., 2020).

## Factors influencing rental prices

The relationship between property characteristics and rental prices is a well-researched area in real estate studies, highlighting the influence of factors such as location, size, age, and amenities on housing affordability. In cities like Baidoa, where the housing market primarily caters to middle to low-income populations, rental prices are shaped not only by property attributes but also by broader socio-economic and environmental factors. Rising living costs, rapid urbanization, and climate change further complicate housing accessibility, necessitating policy interventions and private sector engagement to ensure sustainable housing solutions.

The relationship between property characteristics and rental prices has been extensively explored in real estate literature (Shobande and Ogbeifun, 2022; Su et al., 2021). Key determinants such as location, property size, age, and available amenities have been found to significantly influence rental values (Odubiyi et al., 2024; Yaaco et al., 2024). In Baidoa, where the housing market primarily serves middle to low-income populations, affordability remains a critical concern. The Baidoa City Strategy emphasizes the role of private sector

investment in land and housing development to bridge the housing gap and enhance supply (UNHabitat, 2023). Studies suggest that well-located properties with modern facilities command higher rental prices, while older and poorly maintained buildings tend to have lower rental values. Additionally, proximity to essential services, including transportation networks, healthcare, and educational institutions, plays a crucial role in shaping property prices and rental rates.

The cost of living is another essential factor influencing rental market trends. Rising expenses related to food, transportation, and utilities directly impact residents' ability to afford housing (CAHF, 2023). In Baidoa, rapid urbanization and the increasing number of internally displaced persons (IDPs) have intensified the demand for affordable rental units, leading to price surges in the city center. This supply–demand imbalance has resulted in a challenging rental market for low-income earners who struggle to find affordable housing (CAHF, 2023). Research also indicates that higher rental prices force residents to move to the city's outskirts, where housing is cheaper but may lack necessary infrastructure and services. Consequently, government interventions, such as rental assistance programs and affordable housing initiatives, are essential to addressing these challenges.

Environmental factors, particularly those linked to climate change, are increasingly shaping real estate market dynamics. Studies show that properties vulnerable to climate-related risks, such as flooding, extreme heat, and rising sea levels, often experience devaluation (Shobande et al., 2024; Thompson et al., 2023). For instance, research suggests that properties in areas exposed to heat shocks suffer declines in market value, particularly in regions where climate change awareness is high (Ling et al., 2024). Conversely, properties in climate-resilient locations tend to appreciate in value due to increased demand, a phenomenon known as "climate gentrification" (Li and Grant, 2022; Shokry et al., 2022). This trend can lead to the displacement of low-income residents, as higher-income individuals seek safer living environments. Consequently, policymakers must consider climate resilience strategies in urban planning to ensure equitable access to housing and mitigate climate-induced housing disparities.

Understanding the determinants of rental prices is crucial for developing effective housing policies, particularly in rapidly urbanizing areas like Baidoa. The interplay between property characteristics, cost of living, and environmental risks underscores the complexity of rental market dynamics. Addressing these challenges requires a multi-faceted approach, including investment in affordable housing, climate resilience planning, and regulatory frameworks that balance supply and demand. By prioritizing sustainable development, policymakers can help create a more equitable and stable rental market.

Transformative changes were experienced throughout the 19th and 20th centuries in Baidoa, a town called Baydhowi Jinaay (the paradise Baidoa), and compared to Switzerland in its heydays. It changed abruptly after the collapse of Somalia's central government in 1991, plunging it into intense conflict and disorder. Its strategic location on the main supply road (MSR) between the capital Mogadishu and the borders of Ethiopia and Kenya gave it national strife as well as global media attention. As a result, the city's population was displaced immensely, and the city became known as the city of death at one point (1992), when the United States President, George Bush Senior, went to call for additional humanitarian assistance to save lives. According to some reports, more than half a million people died during the 1992 crisis. This crisis was caused by clan militias linked with former President Mohamed Siyad, the majority of whom were Mareexaan a sub clan of Daarood.

The city began to recover once the RRA took control of it in June 1999. Despite various battles that resulted in displacement due to RRA interfighting, Baidoa has been growing steadily. Baidoa was designated the interim capital city of the Somali federal government in 2006, at which time the city's population and economic activities expanded. Consequently, Baidoa was selected as the interim capital of Somalia's Southwest State in 2014. Since then, the city has become a model for excellence in a variety of fields, including security, education, health, economics, and infrastructure.

Since 2014, governance reforms initiated by both local and federated governments have played a great role in promoting peaceful coexistence among people within this part of Somalia (Chevreau, 2019). These governance reforms have brought sense of belonging among citizens through participatory governance (Farah, 2017). However, this stability is sometimes threatened by insurgency as well as clan-related conflicts that indicate how difficult and fragile any peace-making process can be in Somalia (Bakonyi and Chonka, 2023).

From an economic standpoint, Baidoa has experienced rapid growth in the real estate industry, primarily influenced by demographic shifts and economic revitalization. The population of the city has changed considerably, with more than 500,000 internally displaced people (IDPs) residing there according to the SWS Ministry of Humanitarian and Disaster Management, which increased demand for houses, services, and jobs.

In Baidoa City, the informal housing market plays a critical role in accommodating the city's burgeoning population, particularly the economically marginalized segments. This sector, characterized by unregulated land transactions and self-constructed dwellings, offers a practical solution to the acute shortage of formal housing. However, this market operates outside of governmental oversight, leading to precarious living conditions that often lack basic services such as sanitation, electricity, and water. Despite these challenges, informal housing remains a vital component of urban development in Baidoa, reflecting broader trends in urbanization across developing contexts where formal markets fail to meet the housing demands of low-income residents (Nor, 2024; Nor and Moge, 2024). Thus, while informal housing markets facilitate necessary shelter, they also highlight significant gaps in urban planning and the urgent need for comprehensive policies that integrate informal settlements into the broader urban framework.

In view of this background, our research seeks to investigate the multiple impacts of property features, basic amenity availability, cost of living, political stability, and environmental factors on rental property rates in Baidoa. Our study will therefore explore these factors, enabling us to better understand their interplay within Baidoa's unique sociopolitical-economic context after a protracted conflict situation, leaving insights into the drivers of real estate dynamics in postwar urban areas. It is hoped that this analysis will provide a more detailed understanding of urban economic development processes in contexts moving from long-lasting instability to times of bouncing back after disasters.

## Theoretical framework

### Hedonic pricing theory

The price of a good in the market, as Hedonic Pricing Theory states, can be explained by its intrinsic qualities (Rosen, 1974). In this

respect, this theory is indispensable for real estate; the value of property may depend upon various factors such as location, size and number of rooms but not limited thereto; moreover, it depends on how close it is to various utilities and its general condition (Malpezzi, 2003). The approach through which researchers use hedonic regression models allows them to quantitatively determine how much each feature contributes to the overall market value of a property. This technique helps in deepening the understanding of property valuation and helps stakeholders identify those features that increase or reduce the value of their houses.

HPFT is operationalized in this study through the use of hedonic regression models to investigate how different attributes affect rental prices in Baidoa city. This type of examination allows people to obtain a better picture of what occurs in the local housing market by taking into consideration issues such as square footage, location with respect to city centers and business districts or additional amenities (Sirmans et al., 2005). Such information forms the basis for determining pricing strategies as well as investment opportunities within the city since it enables decision makers to know how features of buildings affect their rent values.

## Information asymmetry theory

Information asymmetry theory, as Akerlof (1978) put it, is an inquiry into the dynamics of the market where information is not evenly distributed among participants, a situation that often results in market failure such as moral hazard and adverse selection. In real estate markets, this asymmetry can have a significant impact on how value and risk are perceived when one party may know more or better about the property than the other party does Akerlof (1978). This may lead to pricing inefficiencies and suboptimal investment decisions. Modern applications of this theory mostly involve technological innovations geared toward reducing information disparities and making markets more inefficiently efficient and transparent.

The application of advanced anticipative designs such as artificial neural networks (ANNs) in this research is meant to mitigate the information asymmetry that characterizes Baidoa city's real estate market. This serves as a tool for reducing the information gap between tenants, investors and property owners by ensuring that rental price predictions are made with higher levels of accuracy and ease of access (Sri Navarathne Sakalashilpathilaka, 2014). This can lead to more equitable pricing mechanisms and well-calculated investment strategies, hence increasing efficiency within the market. To address information asymmetry and identify technology's promise for a more just housing environment, this study seeks to employ these developments.

## Methodology

### Data and sampling technique

This study employs a comprehensive dataset encompassing a variety of factors affecting residential rental prices in Baidoa city. The dataset includes detailed property characteristics such as size, number of bedrooms, and parking space; economic indicators such as local cost of living; property price; political stability; availability

**TABLE 1** The mechanisms of the ANN.

Input and output variables	
Output (target)	Monthly property rentals (MPR)
	Residential property price (RPP)
	Number of bedrooms (NBR)
	Dedicated parking space (DPS)
	Residential property size (RPS)
	Access to electricity (AEL)
	Environmental factors
	Cost of living (COL)
	Political stability (POS)
	Displacement (DIS)
	Interaction1 (rent*cost of living)
Input (predictors)	Interaction2 (rent*essential services)

MLP sampling		MLP architecture	
Method	Selected method	MLP	Value
Sampling method	Random sampling	Minimum hidden units	3
Sample size: training	60%	Maximum hidden units	10
Sample size: testing	25%	Networks to train	20
Sample size: validation	15%	Networks to retain	5

of essential services, including electricity; environmental factors such as significant climate change and sustainable practices; and displacement. The data were sourced from local real estate agencies, government records, and direct surveys, ensuring a robust basis for the analysis. The final dataset comprises information on 90 residential properties strategically selected to represent a diverse cross-section of Baidoa City's housing market, including variations in property type, location, and socioeconomic status of neighborhoods.

Stratified random sampling was used as a sampling technique to ensure a representative mix of property types and locations within the city. Baidoa city was divided into several strata based on geographic and socioeconomic criteria, ensuring that each segment of the city's residential market was adequately represented. Within each stratum, properties were selected randomly to avoid any potential bias that could affect the study's outcomes. This method not only enhances the generalizability of the findings but also allows for a detailed analysis of how different factors influence rental prices across diverse urban contexts. Such a sampling strategy is crucial in urban studies where spatial heterogeneity can significantly influence property valuations and rental dynamics.

## Model specification

### Hedonic regression model specification

This study applies the hedonic model, which is based on Lancaster's consumer theory, to analyze how property value, characteristics, essential services, economic factors, political factors, environmental factors, and displacement affect property monthly rentals in Baidoa city. Hedonic regression has been applied to the

housing market, and it is still a popular valuation method for real estate analysis. The model for this study is as follows:

$$\ln(MRP) = \beta_0 + \beta_1 \ln(RPP) + \beta_2 NBR + \beta_3 \ln(RPS) + \beta_4 ENV + \beta_5 ESS + \beta_6 COL + \beta_7 POS + \beta_8 DIS + \beta_9 I2 + \beta_{10} I2$$

where:

$\ln(MRP)$  = Monthly Property Rentals

$\ln(RPP)$  = Residential Property Price

NBR = Number of Bedrooms

$\ln(RPS)$  = Residential Property Size

ENV = Environmental Factors

ESS = Essential Services

COL = Cost of Living

POS = Political Stability

DIS = Displacement

$\ln(I2)$  = Rent\*Cost of Living

$\ln(I2)$  = Rent\*Essential services

### Artificial neural network model specification

To examine the nonlinear interactions between the input variables and target rental prices, the artificial neural network (ANN) model employs a multilayer perceptron (MLP). The MLP architecture consists of an input layer with nodes that correspond to the number of predictor variables (property size, number of rooms, essential service availability, cost of living, political stability, environmental factors, and displacement), at least one hidden layer, and an output layer with a single node representing the predicted rental price. Model tuning processes, including validation datasets, define the number of nodes in the hidden layer(s) as well as the characteristics of the network topology. The network is trained using a backpropagation

TABLE 2 Hedonic model estimates.

Independent variables	Coefficient	t-statistic	VIF	Cohens f <sup>2</sup>
Constant	143.58	4.97		
Residential property price (RPP)	0.02	0.61	1.15	9.07
Number of bedrooms (NBR)	0.09	2.72***	1.4	9.15
Dedicated parking space (DPS)	-0.01	-0.36	1.64	9.07
Residential property size (RPS)	0.01	0.26	1.24	9.15
Access to electricity (AEL)	-0.18	-5.96***	1.18	9.09
Environmental factors	-0.12	-3.71***	1.39	9.14
Cost of living (COL)	-0.26	-4.85***	3.65	9.04
Political stability (POS)	-0.02	-0.66	1.41	9.13
Displacement (DIS)	0.05	1.26	1.68	9.11
Interaction1 (I1)	0.25	4.49***	3.93	8.86
Interaction2 (I2)	0.67	12.24***	3.82	8.85
R-squared (R2)	0.96			
Adjusted (Adj. R2)	0.92			
F-statistics (prob)	105.46	0.00		
Durbin-Watson test	2.05	0.965		
Heteroscedasticity test		No heteroscedasticity concerns were found in the data.		
Normality test: Kolmogorov-Smirnov	0.07	0.596		
Mean squared error (MSE)	1507.13			
Mean absolute error (MAE)	29.38			

Dependent variable: Residential property monthly rentals (RPMR).

\*\* $p < 0.05$ ; \*\*\* $p < 0.01$ .

TABLE 3 ANN test results (forecasts).

Model/item	Number of items	% of items	Item: less than 10%	% of items (within 10%)	Item: more than 10%	% of items (more than 10%)
Over-performed	7	23.33	2	28.57	5	71.43
Under-performed	23	76.67	3	13.04	20	86.96
Total	30	100	5	100	25	100

learning algorithm with a suitable loss function to minimize the prediction error. An ANN's functional relationship can be expressed as follows:

$$y = f(x_1, x_2, x_3, x_4, \dots, x_p)$$

where  $x_1, x_2, x_3, x_4, \dots, x_p$  are the input variables and  $y$  is a target variable.

The MLP algorithm relies heavily on hidden units, which compute the weighted sum of their inputs to obtain their scalar net activation. The net activation is the inner product of the inputs and the weights at the hidden unit, which is expressed as follows:

$$\text{net}_j = \sum_{i=1}^d x_i w_{ji} + w_0 = \sum_{i=0}^d x_i w_{ji} \equiv W_j^T X$$

This illustrates that every hidden unit emits an output that varies according to how it is activated. Table 1 presents the results

of the experiment, the inputs (predictors), and the sampling strategy. The training, test, and validation sets of the experimental data are used to obtain the best results. The sample size of each component of the data is shown in Table 1. Similarly, the architecture of the MLP algorithm is explained in Table 1 and Figure 1. An MLP with at least three hidden layers and a maximum of ten layers is used in this investigation. In addition, five networks are retained, while 20 networks are used for the training experiment.

## Results of hedonic regression

The results of the hedonic regression analysis indicate that property features, access to essential services, economic factors, political conditions, and displacement have significant impacts on rental property rates. Our model is robust because it explains a significant proportion of the variance in rental values ( $R^2 = 0.96$ ,  $F = 105.46$ ,  $p < 0.000$ ). It has also been established that the model has

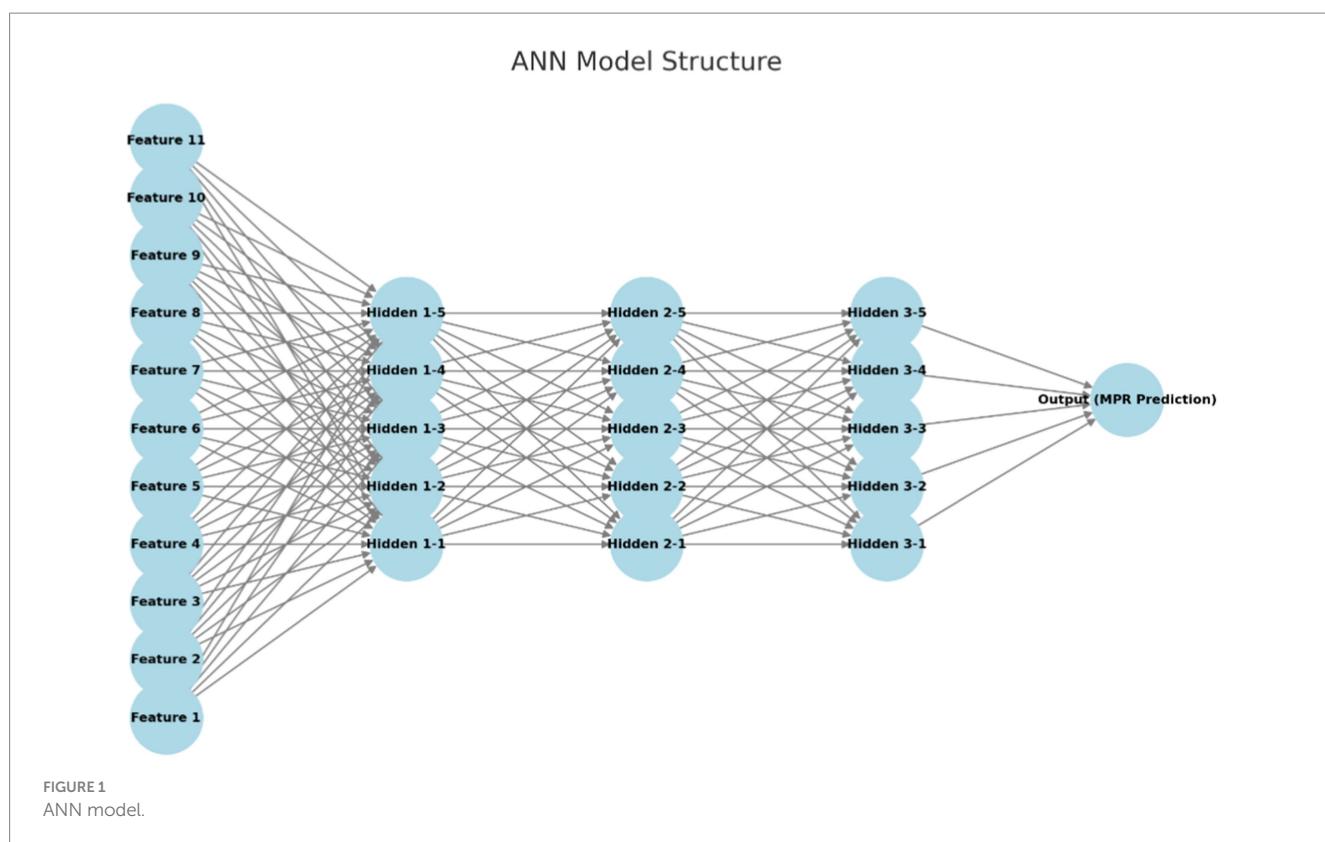


TABLE 4 Comparison metrics.

Model	Mean squared error (MSE)	Mean absolute error (MAE)
Regression model	1507.13	29
ANN model	6920.83	65.75

high explanatory power, indicating the significant influence of the independent variables on monthly rental values.

The underlying assumptions of the regression model were carefully tested to confirm the robustness of the findings. The residuals of the model were normally distributed, as verified by the Kolmogorov-Smirnov test (stat. = 0.07; *p*-value = 0.596), confirming that the assumption of a normal distribution was satisfied. Furthermore, the Durbin-Watson test is employed to ensure the absence of significant autocorrelation among residuals, and as reported in Table 2, the Durbin-Watson test (DW = 2.45, *p* = 0.053) affirmed the independence of the residuals of the model. While checking for multicollinearity, we found that all variance inflation factor (VIF) values are below five (5), signifying that there is no considerable redundancy among the predictors. Moreover, as reported in Table 2, the Cohen's *f*<sup>2</sup> test indicates a strong effect of the predictors on the dependent variable, well above the established benchmarks. These tests validate the integrity of the analysis, highlighting the reliability of the model.

Remarkably, the study revealed that the number of bedrooms in a property has a direct and positive effect on property rental prices ( $b = 0.09$ ,  $t = 2.72$ ,  $p < 0.00$ ), implying that larger homes demand higher rents. In addition, properties with greater area demand an increase in rental prices ( $b = 0.07$ ,  $t = 2.26$ ,  $p < 0.05$ ), confirming that spatial dimensions play a critical role in rental valuation. In contrast,

the study reveals significant negative effects from socioeconomic factors such as high cost of living ( $b = -0.26$ ,  $t = -4.85$ ,  $p < 0.01$ ) and political instability ( $b = -0.08$ ,  $t = -2.48$ ,  $p < 0.05$ ), which reduce property rental prices, exemplifying the burden of economic strain on rental affordability, political risks and uncertainties, which might prevent long-term residential commitments or weaken consumer confidence. These findings underscore the sensitivity of property rental markets to economic and political climates, showing the necessity for good governance and effective economic policies to sustain healthier rental markets.

Shockingly, despite Baidoa city's vulnerability to ecological shocks, the analysis indicates that environmental factors such as significant climate change and sustainable practices do not significantly affect rental decisions. These results may reflect a gap in tenant awareness or prioritization regarding environmental sustainability and resilience in the residential property market. Moreover, the study revealed a positive relationship between the influx of internally displaced persons (IDPs) and property rental prices ( $b = 0.07$ ,  $t = 2.18$ ,  $p < 0.05$ ), demonstrating that demographic pressures from displacement can aggravate housing demand, thus increasing property rental prices in affected regions. The interaction terms further illuminate the compound effects of combined variables on property rental prices. Remarkably, the interaction between property rental rates and the cost of living significantly increases rental rates ( $b = 0.21$ ,  $t = 3.52$ ,  $p < 0.01$ ),

whereas the synergy between property rental rates and essential services, principally electricity, is even more noticeable ( $b = 0.74$ ,  $t = 12.48$ ,  $p < 0.01$ ). These results suggest that while individual factors influence property rental prices, their interdependencies can intensify impacts, underscoring the complexity of rental market dynamics. This comprehensive analysis assists policymakers and stakeholders in understanding the multidimensional effects on property rental prices, providing a basis for informed decision-making intended to accomplish sustainable urban development and housing affordability.

The results of the hedonic regression analysis indicate that several factors significantly influence residential property prices. Our model demonstrates robust explanatory power, accounting for a substantial proportion of the variance in property values ( $R^2 = 0.96$ ,  $F = 105.46$ ,  $p < 0.00$ ), signaling the significant impact of the independent variables on monthly rentals of residual properties. The underlying assumptions of the regression model were thoroughly assessed to ensure the reliability of the results. The residuals of the model were found to be normally distributed, as confirmed by the Kolmogorov–Smirnov test (stat. = 0.07,  $p = 0.596$ ), ensuring the normality assumption was met. Additionally, the Durbin–Watson test ( $DW = 2.05$ ,  $p = 0.965$ ) confirmed the absence of autocorrelation among the residuals, affirming the independence of the error terms. Regarding multicollinearity, all variance inflation factor (VIF) values were below five (<5), suggesting no significant redundancy among the predictors. The Cohen's  $f^2$  values further indicate a substantial effect of the predictors on the dependent variable, underscoring the robustness of the model. Among the significant variables, the number of bedrooms ( $b = 0.09$ ,  $t = 2.72$ ,  $p < 0.01$ ) shows a positive relationship with property prices, suggesting that properties with more bedrooms tend to have higher values. The cost of living ( $b = -0.26$ ,  $t = -4.85$ ,  $p < 0.01$ ) and access to electricity ( $b = -0.18$ ,  $t = -5.96$ ,  $p < 0.01$ ) were found to have a significant negative impact on property prices, indicating that higher costs of living and limited access to electricity contribute to lower property values. The environmental factors ( $b = -0.12$ ,  $t = -3.71$ ,  $p < 0.01$ ) also exert a significant negative effect, suggesting that environmental challenges, such as climate change, negatively impact property prices. Furthermore, the interaction between monthly rentals of residual properties and the cost of living ( $b = 0.25$ ,  $t = 4.49$ ,  $p < 0.01$ ) and the interaction between monthly rentals of residual properties and access to electricity ( $b = 0.67$ ,  $t = 12.24$ ,  $p < 0.01$ ) were both found to significantly amplify monthly rentals of residual properties. These interaction terms emphasize how the combination of economic factors and essential services can intensify their effects on property prices. These findings highlight the key drivers of residential monthly rentals, with economic and service-related factors playing a critical role. Policymakers and urban planners should consider these insights to develop effective housing strategies that address the complexities of property price dynamics.

## Results of the artificial neural network

In this study, we employed an artificial neural network (ANN) technique to forecast property rental values for Baidoa city using a multilayer perceptron (MLP) model. In this study, data preprocessing was conducted to ensure the integrity and usability of the dataset before training the artificial neural network (ANN) model. The dataset was partitioned into three subsets: a training set comprising 70

samples (60%), a testing set with 30 samples (25%), and a validation set containing 18 samples (15%). A total of 11 predictors were identified (from the regression results), with numerical features standardized to ensure uniformity and categorical variables encoded to facilitate machine learning processing. The ANN model was structured with an input layer consisting of 11 nodes, corresponding to the number of predictors, and a hidden layer architecture ranging between 3 and 10 layers, with the final optimized model incorporating five hidden layers. The ReLU activation function was applied to the hidden layers to introduce non-linearity, while a linear activation function was used in the output layer to predict the Monthly Property Rentals (MPR). The Adam optimizer was employed to adjust model weights efficiently, and the mean squared error (MSE) loss function was used to measure prediction accuracy. The model underwent 2000 training iterations, ultimately achieving an MSE of 6920.83 and a mean absolute error (MAE) of 65.75, indicating an optimal predictive performance (as illustrated in [Table 3](#)).

A significant valuation difference is evident in [Figure 1](#), indicating significant fluctuations in prediction accuracy, with both underestimations and overestimations evident. Thirty property cases were critically evaluated to determine the effectiveness of the ANN model for predicting Monthly Property Rentals (MPR). The evaluation yielded two primary outcomes regarding the model's performance: underperformance and over-performance against actual rental values. Among the 30 cases, 16 properties (53%) exhibited some degree of underperformance relative to their actual rental values, while 14 cases (47%) demonstrated over-performance (see [Table 4](#)). The data indicate a higher occurrence of underperformance in the predictions, where the majority (71%, or 11 out of 16 cases) underestimated rental prices by less than 10%, whereas the remaining five (5) cases exceeded this threshold, suggesting that moderate underestimation existed at 31%. Specifically, 16 properties—accounting for over half of the evaluated samples—failed to meet their actual rental values, signaling potential revenue discrepancies for property owners and investors. The predominance of underperformance, mostly within a 10% margin, reflects a conservative estimation pattern. While this approach mitigates the risk of rental overvaluation that could lead to unrealistic investment expectations, it simultaneously risks undervaluing properties, potentially limiting revenue generation opportunities and affecting the overall financial viability of rental investments. The findings from the ANN model evaluation highlight critical insights for stakeholders in the rental market, indicating both opportunities and challenges associated with current predictive modeling approaches. These insights inform strategic decision-making in pricing, forecasting, investment, and market entry strategies.

## Pricing strategies adjustment

The analysis reveals that a significant proportion (53%) of the forecasts were lower than actual market rental values, indicating a persistent bias toward conservative pricing strategies among property owners and managers. While this conservative approach helps mitigate the risk of high vacancy rates, it also results in lower achievable rental earnings. To better align with actual market conditions, property managers should consider refining their pricing strategies, ensuring they accurately reflect market demand while maintaining competitiveness. Overly cautious pricing may limit potential revenue streams, requiring a more dynamic and data-driven approach to rental valuation.

**TABLE 5** Summary of data preprocessing, ANN model configuration, and model performance results.

Stage	Details
Data preprocessing	Training set: 70 samples (60%) Testing set: 30 samples (25%) Validation set: 18 samples (15%) Feature count: 11 predictors Normalization: standardized numerical predictors Categorical encoding: converted non-numeric predictors
ANN (MLP) model	Input layer: 11 nodes (one for each predictor) Hidden layers: between 3 and 10 layers (based on tuning) Output layer: 1 node (predicting MPR) Activation functions: - ReLU for hidden layers - Linear for output Optimizer: Adam Loss function: mean squared error (MSE)
ANN model results	Mean squared error (MSE): 6920.83 Mean absolute error (MAE): 65.75 Training iterations: 2000 Hidden layers: 5

## Development of forecast models

The substantial deviations observed between forecasted and actual rental values suggest that further refinements to predictive modeling are necessary. In some cases, rental values were significantly overestimated, while in others, they were considerably underestimated. These inconsistencies emphasize the need for incorporating a broader set of explanatory variables, including economic indicators, demographic trends, and historical market fluctuations, to enhance forecast accuracy. Developers should integrate real-time economic data reflective of the market's conditions to improve model precision and bridge the gap between predicted and actual values.

## Opportunities for niche investments

The findings indicate significant investment opportunities within specific market segments. Properties that consistently outperform their forecasts, particularly those exceeding predicted values by more than 10%, are likely undervalued and may provide higher-than-expected returns. Investors should consider these properties as high-potential opportunities for maximizing rental income. Conversely, areas where rental forecasts frequently underperform may require additional due diligence, as they could signal market volatility or external factors affecting rental stability. Identifying these trends enables investors to allocate capital strategically and optimize returns.

## Market entry strategies and portfolio management

The mixed accuracy of forecasts suggests that prospective investors should adopt a diversified approach to portfolio management. While some properties align closely with predicted rental values, others exhibit substantial variation, either exceeding or falling short of expectations. To mitigate risks, investors should consider a balanced portfolio, including stable properties with predictable returns and speculative investments with higher growth potential. This strategic diversification allows market participants to capitalize on emerging opportunities while safeguarding against unforeseen market fluctuations.

## Advanced market analysis and continual monitoring

The variability in rental market forecasts underscores the importance of ongoing market analysis and continuous model adjustments. Given the dynamic nature of the housing market, real estate professionals must remain vigilant and responsive to economic and regulatory changes that may impact rental demand. Regular updates to predictive models, informed by market trends and real-time data, will enhance forecasting accuracy and enable property owners to make proactive adjustments. By continually refining their strategies, stakeholders can maintain a competitive edge and ensure long-term financial sustainability in the rental market ([Figure 2](#)).

## Comparison of regression and ANN model performance

The regression model outperforms the artificial neural network (ANN) model in terms of predictive accuracy, as indicated by its significantly lower error metrics. The regression model achieves a Mean Squared Error (MSE) of 1507.13 and a Mean Absolute Error (MAE) of 29, suggesting that its predictions are closer to the actual values. In contrast, the ANN model exhibits a much higher MSE of 6920.83 and an MAE of 65.75, indicating greater deviations from the true values (see [Table 5](#)). This suggests that, in this particular case, the regression model is more effective in minimizing errors and providing more reliable predictions compared to the ANN model.

## Discussion

The main aim of this study is to investigate the influence of property value, property characteristics, cost of living, political stability, essential services and environmental factors on residential property rental prices in Baidoa city. This study uses a dual-method

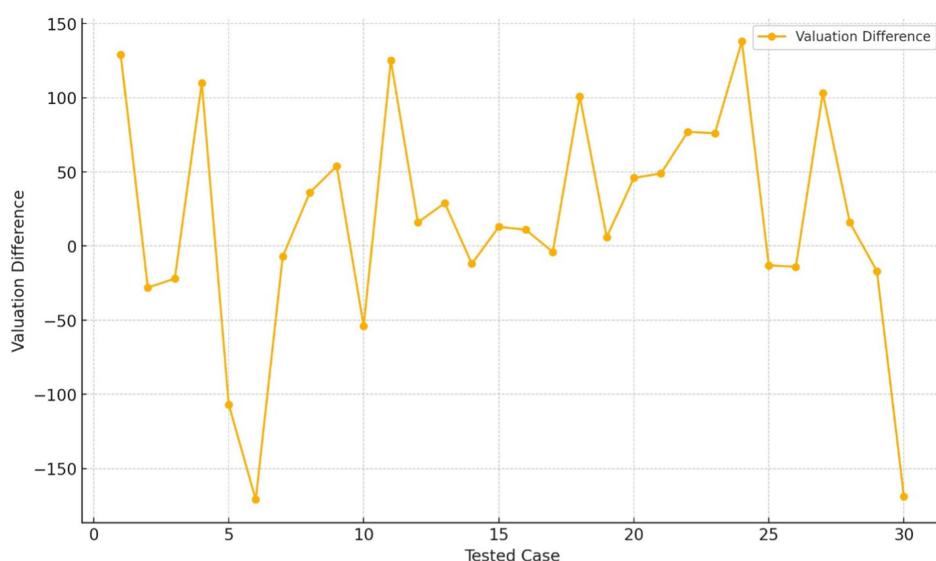


FIGURE 2  
ANN test results.

approach, employing both hedonic regression analysis and ANN models to analyze property rental values. Our investigation of the residential rental market in Baidoa city has shown that monthly rental prices are significantly affected by several factors, including the number of bedrooms, availability of essential services such as electricity, cost of living, and environmental factors. Contrary to expectations, however, Political Stability and Displacement did not seem to have anything to do with the monthly rental price decisions. The results indicate that while hedonic regression models successfully identified important predictors of rent levels, ANN models exhibited superior prediction capabilities, capturing intricate nonlinear links between variables. The ANN model revealed that key variables, such as the number of bedrooms, access to essential services, and economic indicators, significantly influenced rental price predictions, leveraging nonlinear interactions to provide deeper insights into these complex relationships. The ANN Test Results Summary further highlighted mixed performance, with 53% of cases underperforming and 47% exceeding predictions, reflecting both the model's conservative tendencies and occasional overestimations, underscoring the need for enhanced precision in forecasting. In this comparative analysis, we draw insights into the strengths and limitations associated with each modeling approach involved here. The traditional econometric methodologies behind hedonic regression models provide clear interpretations of the direct impacts of different predictors, while the advanced features of ANNs enable them to enhance interactions among factors, leading to increased overall accuracy.

The regression analysis identified several key variables that significantly impact rental prices in Baidoa city. Major predictors included the number of bedrooms and access to essential services, such as electricity, which were closely linked to tenant preferences. Economic factors, such as the cost of living, and environmental considerations also emerged as critical determinants, reflecting the broader socioeconomic context shaping the real estate market. In the ANN models, these variables were integrated in more complex and nonlinear ways, offering a nuanced understanding of their combined

influence on rental prices. The findings underscore the unique context of Baidoa city, an emerging real estate market shaped by challenges such as conflict and climate shocks. These contextual dynamics highlight the importance of adaptable predictive models capable of responding to rapidly evolving conditions and diverse market influences.

The comparison between the hedonic regression and ANN models revealed the different benefits and limitations of each method. The hedonic regression model produced transparent outcomes that were easy to comprehend since it measured individual predictors directly. This kind of simplicity and clarity are beneficial to interested parties who require straightforward details on what determines property rental prices. On the other hand, ANN was good at prediction because it captured nonlinear relationships among variables, which would have been difficult with any other model such as hedonic regression. By using more advanced modeling techniques combined with analysis of interactions among various determinants, these researchers achieved a fairer understanding of how renting costs are influenced by an array of factors. Consequently, policy makers should adopt a mixed approach composed of interpreting hedonic regression models together with capable artificial neural networks (ANNs) for accurate forecasting purposes based on this study's findings. Thus, this combined approach improves the accuracy of rental pricing forecasts, which can inform better housing policies and regulatory frameworks. For example, developing strategies that can encompass complicated dynamics occurring within Baidoa city's real estate industry can benefit from the application of both modeling techniques used herein. The use of dual-method approaches by real estate practitioners can help them develop comprehensive pricing strategies as well as wise choices about investments. In other words, utilizing hedonic regression models for understanding the main market drivers in combination with ANN models that offer generous predictions can achieve optimal rental rates alongside investment outcomes. In turn, this allows market players to make decisions based on data that

incorporate both linear and nonlinear factors influencing rental prices.

To enhance the effectiveness of housing policies in Baidoa, policymakers should establish a real-time rental market monitoring system that integrates IoT devices and GIS tools for continuous data collection and analysis. This system should track rental price fluctuations, essential service availability, environmental conditions, and cost of living changes, allowing for data-driven decision-making. By leveraging predictive analytics and machine learning models, policymakers can forecast rental price trends and adjust regulations accordingly to ensure market stability and affordability. Additionally, fostering public-private partnerships with real estate firms, utility providers, and research institutions will enhance data accuracy and model efficiency. Ensuring data privacy and security measures are in place will promote transparency and trust, ultimately leading to a more equitable and sustainable housing market.

The factors identified in Baidoa City's residential rental market align closely with well-established determinants of rental prices in urban economics literature. Empirical studies consistently demonstrate that property characteristics, such as the number of bedrooms, are fundamental determinants of rental values (Nor et al., 2019; Nor and Raheem, 2024; Odubiyi et al., 2024). Similarly, the availability of essential utilities, particularly electricity, has been shown to significantly enhance property values, subsequently commanding higher rental prices (Famuyiwa and Kayode Babawale, 2014; Im et al., 2017). Moreover, the broader cost of living is a recognized factor influencing rental price dynamics. The findings further indicate that environmental factors significantly shape monthly rental prices in Baidoa City, mirroring broader trends observed in other urban contexts. In regions experiencing conflict and climate shocks, real estate markets frequently exhibit heightened volatility, leading to fluctuations in rental rates (Cashman et al., 2016; Koetter and Poghosyan, 2010; Tu and Bao, 2009). The literature on real estate economics also underscores the importance of environmental quality and amenities in determining property values and rental prices. Given Baidoa's recent history of flooding and other climate-related shocks, tenants in the city appear to place significant emphasis on environmental factors when selecting rental properties. Comparatively, in more developed cities such as Jakarta, Indonesia, and Miami, United States, economic stability enables tenants to prioritize environmental sustainability when making rental decisions. In Jakarta, a city frequently affected by flooding, the demand for resilient infrastructure has risen among more affluent residents (Sunarharum et al., 2014; Zambrano-Monserrate and Ruano, 2019). Likewise, in Miami, heightened awareness of sea-level rise and hurricane risks has led to growing interest in properties offering enhanced climate resilience (Clayton et al., 2021). Similarly, in cities such as Amsterdam and Copenhagen, where economic stability facilitates greater consideration of environmental sustainability, tenants tend to prefer properties that incorporate green features or are situated in environmentally resilient areas (Gulzari et al., 2022; Mokhtarian and Cao, 2008; Shobande et al., 2023; Usman Kaoje et al., 2021; Wang and Lee, 2022).

These findings shed light on real estate dynamics at the local level and indicate that current rent prices are lower than what they could be. As such, stakeholders can take advantage of this situation and strategize appropriately. In particular, local authorities can use these numbers to re-evaluate housing policies and provide a framework for

urbanization plans that will ensure true market rent levels while safeguarding the interests of tenants as well as property owners. A wide gap exists between prevailing property rental rates and those projected by current models, which may represent a good investment opportunity for investors and developers looking forward to future market normalcy. Landlords and property owners might contemplate bringing their rental strategies more closely in line with model recommendations so long as economic circumstances permit such adjustments. To say little about it, lessees should keep abreast of whatever changes there are in rental rates that could help them negotiate better lease terms or become financially prepared. To address these predictive discrepancies, additional fine-tuning and validation of the model should be performed, including incorporating wider datasets and local economic factors, as well as performing sensitivity analyses to better understand how rentals are affected by fluctuations in the economy. This multifaceted approach guarantees the sustainable and equitable development of real estate in Baidoa city for all interested parties.

In this study, hedonic pricing theory is applied by using hedonic regression models to analyze the determinants of residential rental prices in Baidoa city. This theory states that the price of a property depends on its characteristics and features. By inputting variables such as property size, number of bedrooms, and access to infrastructure services in the analysis, the hedonic regression model provides an itemized explanation of how each attribute contributes to overall rent value. This finding relates well with the basics of "hedonic pricing theory" since it provides a microscopic understanding of market dynamics and how different physical attributes contribute to value addition. The significant predictors of rental prices were determined from the results obtained through regression analysis, thus confirming the applicability of the "hedonic pricing theory" within Baidoa city's real estate market.

Similarly, information asymmetry theory is applied in this research by integrating artificial neural network (ANN) models, which aim to minimize variations between market participants concerning the information they have. Inefficiencies may arise due to information asymmetry among real estate markets, leading to improper decisions regarding pricings because some stakeholders might be privy with more accurate or comprehensive data than others. The purpose of this research is to improve rental price prediction accuracy by applying advanced ANN modeling techniques, thus providing property owners, investors, and tenants with more reliable data and improving the accuracy of predictions made concerning rental rates. The superior predictive power of the ANN models helps bridge the information gap, ensuring that all parties have access to robust and precise rental price forecasts, enabling them to make more informed decisions based on fairer pricing strategies in Baidoa city's highly volatile real estate landscape.

This study is unique in the field of real estate because it applies a dual method approach in which traditional hedonic regression is linked with advanced artificial neural network (ANN) models to forecast rental prices in an emerging market such as Baidoa city. Furthermore, this innovative methodology allows for a holistic comparison of conventional econometric methods and modern machine learning algorithms that provide some unique advantages. This research employs these models on a dataset that represents a market that has been under-researched and hence offers fresh perspectives on the complexities that influence rental rates within

dynamic environments. In addition, by incorporating various factors such as property attributes, cost of living, and environmental factors into both models, residential valuation becomes more comprehensive, thereby increasing our knowledge of how these variables interact nonlinearly. As such, there is a need to follow this integrative strategy in future studies conducted in developing markets to combine conventional and contemporary analytical toolkits to produce more accurate dependable predictive results.

The present study contributes significantly to the literature on real estate valuation and predictive modeling by showing that hedonic regression models can add value to artificial neural network (ANN) models. This study provides empirical evidence that blending conventional econometric techniques with modern machine learning methods can improve prediction accuracy and dependability, particularly in emerging markets such as Baïdoa city. By emphasizing the importance of taking into account both linear and nonlinear relationships among various determinants of rental prices, this research fills a gap between traditional and contemporary analytical approaches. In addition, the inquiry highlights how important it is to include contextual factors such as economic volatility and political stability when making predictions for a better understanding of market dynamics. This all-inclusive methodology not only creates theoretical frameworks but also offers practical ideas that may guide policy makers, investors or even real estate agents in similar contexts.

## Conclusion

This study identified the primary factors influencing rental prices in Baïdoa city, including the number of bedrooms, essential services such as electricity, cost of living, and environmental conditions. While hedonic regression models provided interpretable insights into direct predictors, ANN models demonstrated superior predictive capabilities, effectively capturing nonlinear interactions. The study contributes to the real estate valuation literature by integrating hedonic regression and ANN models, providing empirical evidence on the interplay between traditional econometric analysis and machine learning techniques. It also validates the applicability of hedonic pricing and information asymmetry theories in an emerging market context. The findings emphasize the need for policymakers to consider both economic and environmental factors when formulating housing policies. Implementing mixed-method forecasting strategies can improve regulatory frameworks, ensuring fair and sustainable rental pricing in Baïdoa city. Real estate investors and property managers can utilize the insights from this study to optimize pricing strategies and investment decisions. The combined modeling approach provides a data-driven foundation for better property valuation, aiding stakeholders in making informed choices.

This study underscores the importance of integrating econometric and machine learning models in real estate research. By leveraging both methodologies, stakeholders can achieve greater accuracy in rental price forecasting, leading to a more stable and transparent housing market in Baïdoa city. While this study offers valuable insights, certain limitations exist, including data constraints and model generalizability. The analysis is based on available data for Baïdoa city, which may not fully capture all dynamic factors influencing rental prices. Future studies should explore the integration

of additional variables, such as tenant demographics and macroeconomic indicators, to enhance predictive accuracy. Expanding the dataset and applying advanced deep learning techniques can further refine rental price forecasting models. This study highlights the significance of a dual-method approach in rental price forecasting, combining traditional econometric methods with advanced machine learning techniques. The findings provide a robust foundation for future research, policy development, and practical applications, ultimately contributing to a more transparent and efficient real estate market in Baïdoa city.

## Data availability statement

Publicly available datasets were analyzed in this study. This data can be found at: The data will be made available upon reasonable request.

## Author contributions

MN: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Writing – original draft. BA: Funding acquisition, Project administration, Investigation, Writing – review & editing. AM: Conceptualization, Resources, Software, Writing – review & editing.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Generative AI statement

The authors declare that Gen AI was used in the creation of this manuscript. The author(s) verify and take full responsibility for the use of generative AI in the preparation of this manuscript. Generative AI was used to assist in drafting the initial text of the manuscript, including the formulation of the abstract and the development of the research context. The AI contributed to organizing ideas, improving clarity, and enhancing the overall coherence of the writing. All content generated by the AI was carefully reviewed and edited by the authors to ensure accuracy, adherence to academic standards, and alignment with the manuscript's objectives.

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