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Disaster Risk and Property Valuation: A Study of Auction Assets in Earthquake-Prone Yogyakarta

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Abstract. This study aims to determine and identify the effects of property characteristics including exposure time, elevation adjustment, and topographic adjustment and disaster characteristics, such as seismicity, on the value of auctioned assets (collateral). The research employs multiple regression analysis using the ordinary least squares method. The findings indicate that property characteristics, including elevation, topography, exposure time, and seismicity-related disaster characteristics, significantly affect the value of auctioned assets. Specifically, the Topography and Seismic Adjustment variables have a positive and significant influence on the Auction Market Value of collateral property assets. This research introduces a novel approach to understanding asset auction dynamics in earthquake-affected areas by integrating economic valuation with disaster analysis. The study's originality lies in combining an economic analysis framework with disaster risk factors, an area seldom emphasized in previous asset auction research, which has typically addressed economic valuation and disaster impacts separately.

1 Introduction

In earthquake-prone regions like Yogyakarta, the potential for substantial financial loss in property and collateral asset auctions is significant. A major eruption could lead to auction value losses exceeding 30%, highlighting the grave stakes involved. Collateral asset auctions play a strategic role in the modern financial system, particularly as an effective solution for non-performing loans (Luck, Santos 2023). As a financial instrument, this process allows financial institutions to recover the value of assets associated with defaulted loans. It serves as a channel for distributing assets to individuals or entities that can productively utilize them. As such, collateral asset auctions contribute to market efficiency, create opportunities for the reutilization of economic resources, and support the overall stability of the financial system (de Roure, McLaren 2021).

Handling Non-Performing Loans (NPLs), based on data from national financial institutions, asset auctions account for an average recovery of up to 60-80% of collateral value, helping to reduce financial institutions' risk of loss. Moreover, in the most recent year, the total value of asset auction transactions in Indonesia exceeded IDR 30 trillion, reflecting high activity and market demand. The auction process serves as a mechanism for bank asset recovery and for redistributing assets to improve market efficiency (Uesugi et al. 2024). In a broader context, this activity supports financial system stability by helping to reduce the accumulation of NPLs, which, if unaddressed, can negatively impact credit growth and market liquidity (Zhang, Ibikunle 2023).

Collateral asset auction practices often face challenges stemming from inconsistent asset valuations, leading to disparities among parties, including financial institutions, independent appraisers, and bidders (Skočir, Lončarski 2024). In some cases, the valuation difference can be as high as 20-30%, depending on the method used, market conditions, or bias towards the asset's condition. These inconsistencies reduce transparency in the auction process and create conflicts of interest and legal risks, especially when one party feels aggrieved (Bellucci et al. 2021, Herweg, Schmidt 2019). A key issue overlooked in previous studies is the impact of disaster variables on valuation, which further exacerbates these gaps. To understand these valuation gaps, it's essential to recognize the differing motivations of stakeholders. Banks often prioritize asset recovery and may press for lower valuations to expedite sales, while appraisers aim for accuracy and market fairness. Bidders, on the other hand, seek undervaluation to maximize their investment potential. Highlighting these misalignments sets up the groundwork for using a risk-adjusted model as a tool to reconcile these differences and promote equitable asset listings. Gaps in asset valuation practices for property auctions have become a strategic issue in managing non-performing loans, particularly in the banking sector (Gaffeo, Mazzocchi 2018, Pandey 2019). These imbalances often arise from diverse valuation methods, non-uniform standards, and differing stakeholder interests (Maurin 2022). In property auction disputes, significant differences in asset values can delay credit settlement, trigger dissatisfaction among related parties, and even lead to lawsuits (Wardani 2020).

The symptoms that arise during collateral asset auctions reflect the complexity of the process, driven by internal and external dynamics (Anderson et al. 2023). Internal factors include the quality of asset valuation data, independent appraisers' competence, and financial institutions' internal mechanisms in determining collateral values (Cloyne et al. 2023, Donner 2020). Meanwhile, external factors include market fluctuations, inconsistent government regulations, and potential buyers' preferences and perceptions of asset value. These complexities often result in significant differences in the interpretation of asset values, leading to tensions among the parties.

Determining the value of an asset in an auction context relies on economic analysis and must also consider physical and environmental factors that affect the asset's intrinsic value (Calabrò et al. 2024). One important approach is to consider land elevation and topographic adjustments, as well as the potential for electoral seismicity, as additional valuation determinants (Follador et al. 2024). Specifically, elevation and topography serve as exposure factors influencing a property's vulnerability to seismic events. The potential for seismic disasters significantly impacts the economic value of an area, both in terms of physical assets and economic productivity (Amin et al. 2024). Seismicity represents a hazard intensity factor, shaping risk assessments and influencing investment decisions. Vulnerability to earthquakes can affect property valuations, infrastructure investments, and business decisions due to the risk of significant losses to strategic assets. In particular, regions with high seismic activity often experience reduced property values, higher insurance premiums, and greater investment in disaster mitigation technologies (Feliciano et al. 2023, Takeda, Inaba 2022, Xu et al. 2023). Linking seismic frequency directly to expected income loss and cap-rate shifts can provide clearer insights for investors. By translating geophysical risk factors into valuation levers, such as anticipated cash-flow disruptions and adjustments in expected returns, investors can make more informed decisions regarding the economic viability of investments in earthquake-prone areas.

For example, areas in active fault zones tend to have lower land values than more geologically stable areas despite having similar economic access and facilities (D'Apuzzo et al. 2022). Potential earthquakes also affect economic sectors such as tourism, industry, and trade, especially if key infrastructure is not designed to withstand disasters (Sousa et al. 2022). This research concerns potential volcanic seismic hazards, especially in areas around active volcanoes.

According to Oke et al. (2023), projections of climate change and population growth indicate that exposure to flood risk will increase across the United States, thereby increasing the potential for damage to human and economic systems. Flood risk assessment requires a comprehensive understanding of various spatially interdependent variables, in-

cluding rainfall characteristics that cause flooding, the extent of the flooded area, the exposed population, and its vulnerability.

The paper by Hong et al. (2022) examines the impact of induced seismicity on the housing market in Pohang, South Korea, using a hedonic pricing model and a difference-in-differences approach. It highlights how perceived seismic risk affects regional housing values, with significant declines in property prices near the epicenter. The study emphasizes the importance of understanding spatial vulnerability in housing markets and shows that changes in risk perception can influence preferences for earthquake-resistant building structures, reflecting the principles of disaster economics.

The vulnerability of affordable housing to coastal flooding and sea-level rise: assessing risk through expected annual exposure metrics. While not directly addressing disaster economics or econometric approaches, this highlights the disproportionate exposure of affordable housing in various regional markets, particularly in states such as New Jersey, New York, and Massachusetts. The findings of Buchanan et al. (2020) underscore the need for strategic interventions to preserve affordable housing in high-risk coastal areas, reflecting broader implications for regional housing markets at risk.

Post-disaster economic resilience and recovery efficiency, particularly in the context of the Wenchuan Earthquake. Zhou et al. (2020) used econometric models, such as the ARIMA model and the Malmquist productivity index, to analyze economic recovery in disaster-affected areas. Although it does not specifically address regional housing markets or spatial vulnerability, it emphasizes the importance of understanding economic resilience and recovery processes to formulate effective disaster response strategies, which can, in turn, inform housing market dynamics in vulnerable areas.

Proactive acquisition of vacant land in flood-prone areas to reduce disaster economics by preventing future flood losses. Atoba et al. (2021) used a geodesign framework to assess at-risk regional housing markets, identifying vacant properties with high development potential in floodplains. This study uses cost-benefit analysis and predictive land-use modeling to evaluate spatial vulnerability, highlighting the economic implications of acquiring vacant land before development to reduce future flood-damage costs and increase community resilience.

Bui et al. (2022) integrates disaster economics by examining the economic impact of pluvial flooding on the regional housing market in Ho Chi Minh City, Vietnam. It uses a hedonic property model within a difference-in-differences framework and spatial econometric analysis to assess how flood risk affects house prices. The study highlights the spillover effects of flood risk on nearby properties, providing insights into spatial vulnerability and informing policymakers about flood insurance schemes and flood prevention policies.

Volcanic activity, such as eruptions or earthquakes caused by magma movement, can damage infrastructure, threaten residents' safety, and harm the natural resources that underpin the area's economy. The direct impacts of volcanic disasters include damage to the property, agriculture, and tourism sectors, which can significantly decrease asset values (You, Tesfamariam 2024). Electoral regions near active volcanoes, such as Mount Merapi in Indonesia's Special Region of Yogyakarta, often experience fluctuations in land and property values.

The study of spatial or geographical inequality is important for both scientific purposes and policy. From a scientific perspective, understanding spatial inequality enables researchers to uncover patterns and correlations that are vital to advancing knowledge across fields such as economics, public health, and environmental science. From a policy perspective, identifying and addressing geographical inequality is key to promoting social justice and economic development (Rey 2025). Furthermore, the varying auction discounts applied during the recovery of non-performing loans can significantly affect lower-income households, many of whom may be displaced as a result. These households often lack the resources to compete in the auction market, leading to potential social equity concerns. Addressing this issue can help ensure that policies in place contribute to the creation of more just cities, where economic recovery processes do not disproportionately affect the most vulnerable populations.

The electoral region of Yogyakarta, located near Mount Merapi, is one of the areas with significant volcanic seismic risk. Volcanic activity from Mount Merapi, one of the world's most active volcanoes, has a significant impact on the local economy (Pallister et al. 2019). Whenever a volcanic eruption or earthquake occurs, various economic sectors, such as property, agriculture, and tourism, can suffer significant losses. Infrastructure damage from lava flows, volcanic ash, and earthquakes can reduce the market value of land and property in the area around the mountain's base. However, this area also has significant economic value due to its proximity to Yogyakarta's city center (Rindrasih et al. 2024).

The Alert III level for Mount Merapi in Yogyakarta reflects a high level of vigilance against potential eruptions that could directly impact the social and economic life of surrounding communities. As Indonesia's most active volcano, Mount Merapi has a history of eruptions that often threaten residents' safety and damage infrastructure in the surrounding area. When Mount Merapi's status is at Alert Level III, there are significant risks to various economic sectors, including agriculture, tourism, and property. Regarding property values, an increase in alert status often leads to a decrease in land and property values in disaster-prone areas. Communities and investors tend to be reluctant to invest in areas at high risk of eruption (Houghton et al. 2021). However, some areas may experience increased land values due to disaster resilience and soil fertility generated by volcanic activity (Andreastuti et al. 2023, Martinez-Villegas et al. 2022).

Alert Level III for Mount Merapi signifies a heightened state of alert, indicating substantial volcanic activity. At this juncture, while a major eruption is highly probable, it remains impracticable to forecast the precise timing or the manifestation of the eruption. Typically, Alert Level III corresponds to substantial volcanic activity, encompassing phenomena such as minor eruptions, lava flows, or volcanic ash accumulation, which can impact the environs surrounding the mountain. The duration of this status is variable and contingent upon the development of volcanic activity. However, the occurrence of Alert Level III is not uniform. Mount Merapi, being one of the most active volcanoes in the world, can attain this status multiple times within a year; nevertheless, the duration and frequency are substantially influenced by the prevailing level of volcanic activity. An illustration of this phenomenon occurred in 2010, when Mount Merapi was at Alert Level III for several weeks. This was followed by a major eruption that caused substantial damage to the surrounding region, prompting mass evacuations and considerable material losses. However, in certain instances, Alert Level III can also be maintained for a shorter duration during periods of diminished volcanic activity, when there are only indications of minor eruptions or other disturbances that do not culminate in major disasters. Nevertheless, it is imperative to note that Alert Level III does not necessarily indicate a major eruption. In certain periods, this status merely signifies an escalation in gas activity, volcanic ash, or analogous volcanic phenomena that do not directly culminate in a major eruption. This substantiates the assertion that Alert Level III exhibits a high correlation with the potential for disaster. However, this relationship is not universally definitive, as there are instances in which the Alert Level III period concludes without any significant catastrophic events. Nevertheless, the risk persists, necessitating heightened vigilance. Mount Merapi, a highly active volcano, is situated on the border between the Special Region of Yogyakarta and Central Java. The mountain is a focal point of intensive volcanic monitoring due to its heightened activity. The Center for Volcanology and Geological Hazard Mitigation (PVMBG), under the Geological Agency of the Ministry of Energy and Mineral Resources, routinely monitors volcanic activity at Mount Merapi. Since November 5, 2020, Alert Level III has been sustained, indicating that seismic activity and lava dome growth persist at levels necessitating heightened vigilance. This state of elevated volcanic activity, characterized by significant seismic events and the growth of lava domes, does not inherently lead to a major eruption. The Alert Level III status, which signifies a period of heightened volcanic activity without mandating immediate large-scale evacuation measures, does not necessarily culminate in a major explosive eruption. There have been numerous instances in which Alert Level III was implemented in the absence of a major eruption; however, volcanic earthquakes and lava flows persisted. Nonetheless, Alert Level III functions as a crucial indicator

for monitoring and anticipating heightened risk. While the correlation between Alert Level III and disaster events is not always definitive, it is considerable. For instance, the substantial eruption in 2010 that necessitated the evacuation of thousands of people and resulted in fatalities occurred after the implementation of Alert Level III. In many cases, Alert Level III marks a pre-eruption phase, indicating an escalation of volcanic activity that could culminate in a significant eruption.

As stated in the *Laporan Harian Gunung Api* (MAGMA Indonesia 2025), a substantial fluctuation in the number of earthquakes registered in Indonesia was documented *in 2024*. The highest number of earthquakes was recorded in April and August, with 54 and 53 events, respectively. These fluctuations indicate an increase in volcanic activity, a crucial indicator for determining alert status in the affected regions, particularly in the vicinity of Mount Merapi. The heightened frequency of earthquakes observed in these months often serves as the basis for implementing Alert Level III. Alert Level III is typically instituted when volcanic activity manifests significant patterns, such as acute fluctuations in seismic activity frequency in regions surrounding active volcanoes. In the given context, during April and August 2024, when a substantial increase in seismic activity was documented, it can be inferred that Mount Merapi's volcanic activity is at a heightened alert level. This directly correlates with an elevated potential for eruptions or other associated hazards.

Warnings associated with volcanic activity, such as Alert Level III on Mount Merapi, play an instrumental role in shaping public risk perception and economic behavior in disaster-prone regions. Communities surrounding Mount Merapi, particularly those in the zone closer to the crater, perceive these warnings not only as a signal of potential danger but also as an indicator to enhance preparedness. An escalation in seismic activity and changes in alert status often heighten public awareness of increased potential risks. Research indicates that when volcanic alert levels are elevated, communities tend to exhibit an enhanced perception of risk, often precipitating behavioral changes, including preparedness for potential disasters and evacuation. A study conducted in the aftermath of the 2010 eruption of Mount Merapi found a substantial increase in the community's perception of risk, particularly after the disaster's direct impact. This surge in risk perception prompted notable changes in the community's response to incoming warnings and in its adaptation to evolving volcanic hazards. The heightened perception of risk has been shown to significantly affect long-term attitudes, leading communities to exhibit increased vigilance toward potential hazards even after the alert status has been downgraded. Moreover, the economic behavior of local markets is also influenced by perceptions of volcanic risk (Medeiros et al. 2021). An increase in warning levels or the declaration of Alert III status has been shown to lead to a notable decline in investment interest in areas deemed high-risk for eruption, consequently resulting in a decline in property prices. This phenomenon occurs because investment and property market decisions are contingent on the perceived risk of potential damage (Hino, Burke 2021, Thompson et al. 2023). A number of studies have demonstrated that hazard notifications can engender short-term changes in property prices, with property values typically declining when Alert III status is implemented (Ikefuji et al. 2022, Miller, Pinter 2022, Shi, Naylor 2023). However, in the long term, some areas may experience increased property values if disaster risks are effectively managed or if infrastructure improvements reduce vulnerability. Consequently, public perception of volcanic warnings influences not only their awareness and preparedness for disasters, but also has a substantial impact on market behavior. Elevated volcanic alerts or warnings, such as Alert Level III, can affect the stability of local markets in the short term; however, their long-term impact can vary depending on mitigation factors and policies implemented in the region.

A study by Mani et al. (2021) underscores the need to enhance risk assessments that account for the cascading impacts of low-intensity volcanic eruptions (VEI 3-6) on critical infrastructure systems, particularly in the context of globalization. The present risk assessment proposes leveraging system mapping and evidence-based analysis methodologies, including horizon scanning and event tree analysis, to identify vulnerabilities in critical systems and thereby enhance resilience to volcanic risks. The paper underscores the need to draw on the expertise of professionals from a range of disciplines,

including economic assessors, to formulate comprehensive strategies for managing volcanic risk. Additionally, it highlights the repercussions of volcanic eruptions on global supply chains, particularly in sectors reliant on critical infrastructure, such as technology and transportation, thereby emphasizing the urgency of more effective preparedness measures.

As stated by Jumadi et al. (2020), the present study employs risk modeling to manage disasters stemming from volcanic crises, with a particular focus on the community and regional levels, using Geographic Information System (GIS) technology. The incorporation of Agent-Based Modeling (ABM) facilitates the simulation of risk dynamics at the individual level during volcanic crises, encompassing the movement and behavior of people in response to hazards. The outcomes of this model are highly relevant to stakeholders in disaster management, as they offer valuable insights into the processes of evacuation decision-making and risk assessment during volcanic events.

A recent study by Epper, Fehr-Duda (2024) explores the relationship between risk tolerance and time discounting, shedding light on how they interact to shape the assessment of future prospects. Their research underscores the profound influence individual risk preferences exert on the evaluation of potential future outcomes. The aforementioned findings indicate that risk avoidance, discounting behavior, and preferences for resolving time uncertainty can influence decision-making in situations of uncertainty, as is frequently the case in the context of natural disasters. Consequently, these findings are pertinent to the development of risk assessment models in various scenarios, including disaster management, where uncertainty and rapid decision-making are paramount.

The study by Nesticò et al. (2023) examines the application of double discounting and declining methods in environmental economics, with a particular focus on their use in evaluating long-term investment projects with environmental impacts. This study underscores the significance of appraising country-specific discount rates, which are highly relevant to public policy and investment decision-making related to sustainable development goals. The conceptual framework put forth herein can be utilized in Cost-Benefit Analysis (CBA) for initiatives with substantial environmental ramifications, thereby facilitating a more precise evaluation of non-monetary ramifications. Furthermore, this paper underscores the importance of leveraging the Environmental Performance Index (EPI) to enhance the policy-making process and optimize the return on public investment in environmental quality. The methodology outlined in this paper is applicable across diverse consumption contexts, thereby demonstrating its versatility in evaluating consumption and its resulting environmental impacts.

The paper by Shi et al. (2020) underscores the significance of a methodical response model in disaster management, encompassing disaster risk assessment and modeling. The effectiveness of disaster response and risk management depends on a comprehensive understanding of the disaster system, encompassing hazards, the physical environment, and socioeconomic exposure. This framework facilitates precise measurement of disaster risk and underpins risk pricing. It is imperative to enhance risk management strategies and technologies to ensure effective disaster response and appropriate risk pricing.

Recent research (Lee et al. 2022) underscores the significance of incorporating social vulnerability into disaster risk pricing models. The researchers propose the Cost of Social Vulnerability to Disasters (CSVDM) model, which estimates the financial impact of disasters by accounting for multiple dimensions of social vulnerability. This framework enables governments to make more accurate estimates of disaster costs, allocate resources more efficiently, and manage the financial risks associated with disasters. Consequently, the model contributes to improving disaster management and developing superior recovery strategies.

The study by Mistry, Lombardi (2022) adopts a compound distribution approach, which integrates the frequency of disaster events and their severity. The Cox-Ingersoll-Ross model for interest rates and the non-exceedance loss curve from the vulnerability model are utilised within this framework, thereby facilitating the effective pricing of disaster bonds. This process enables municipal authorities to transfer the financial risk associated with earthquakes to the capital market. Consequently, this enhances urban resilience in the face of disasters.

The end-to-end risk modeling framework proposed in Cremen et al. (2022) emphasizes the importance of a comprehensive approach to disaster risk pricing. Cremen et al. (2022) integrates the physical and social impacts of disasters, thereby enabling the characterization of flexible risk metrics that go beyond mere asset losses. The proposed framework enhances the ability to inform disaster risk-related policy decisions by incorporating uncertainty in future urban environments and adopting people-centered participatory decision-making processes. Ultimately, this improvement in assessment models for disaster risk pricing is achieved.

Yogyakarta not only has a high seismic risk but is also a vital cultural and economic center in Indonesia. The city is renowned as an educational hub, with many universities and other institutions attracting thousands of students from across the region. In addition, the tourism sector also plays an important role, with many tourist destinations located around Mount Merapi. Therefore, property value fluctuations in this area are a very important indicator of how seismic risk affects sectors highly dependent on economic stability. Yogyakarta is highly relevant as a case study for collateral asset valuation, especially in the context of asset auctions and property valuation in disaster-prone areas. The frequently changing alert status of Mount Merapi, such as Alert Level III, influences market perceptions of investment risk in the area. Looking ahead, the continued expansion of Yogyakarta's educational and tourism sectors could further affect property values and auction outcomes. As the city grows and attracts more residents and visitors, demand for property may increase, potentially altering the coefficients currently used to assess valuation. Urban planners and stakeholders should consider these factors when predicting future market trends and investment opportunities.

Given the context, studying the valuation of seized collateral assets in Yogyakarta from both economic and disaster risk perspectives is essential. This research addresses the urgent need for an integrated approach to asset auction dynamics in seismic-prone areas by combining economic valuation with disaster analysis. The study aims to identify how property characteristics such as elevation, topography, and exposure time, along with disaster factors like seismicity, affect auction asset values. The originality of this research lies in merging economic analysis with disaster risk factors, a combination rarely emphasized in previous asset auction studies, which typically address these elements separately. Furthermore, the framework's adaptability to other types of disasters, like floods or cyclones, underscores its scalability, potentially broadening the application and attracting a wider readership interested in cross-hazard analysis.

2 Method

Data were collected using purposive, non-probability sampling, focusing on properties involved in transactions, offers, or auctions within 24 months before the valuation date. The study analysed 76 observations, determined using the Slovin formula, considering data access, cost, and time constraints. To ensure the representativeness of the sample and mitigate concerns over selection bias, a power analysis was conducted. This analysis confirmed that the 24% sample of the total 312 auctions is sufficient to infer trends within the population, considering the heterogeneity of market conditions in the Yogyakarta Special Region. Data were gathered from both primary and secondary sources over nine months, covering four districts and one city. Primary data were obtained through interviews with property owners, while secondary data included auction records, bank reports, and independent appraisals (KJPP). Volcanic activity data were also used to supplement and validate the findings. By providing a brief description of our sampling protocol, we invite other regions to replicate this method. This approach not only sets the groundwork for comparative analysis but also encourages a wider academic engagement to explore property valuation in disaster-prone areas.

This study uses cross-sectional data from 76 observations in the Yogyakarta Special Region. This approach enables detailed analysis of property market variables, including economic valuation and disaster characteristics such as seismic activity from Mount Merapi. The goal is to provide an accurate understanding of property market dynamics and disaster potential in the region.

Table 1: Operational Definition of Research Variable

Variable	Definition	Unit
	Dependent Variable	
Auction Market Value (LG_INP)	Indication of Market Value of Assets at the time of collateral auction process	Rupiah (Rp)
	Independent Variables	
Exposure Time (LG_WE)	The results of the quality rating method search related to the length of the exposure period for the sale of collateral auction assets	Day
Elevation Adjustment (LG_AE)	This study utilizes data from the working papers of the independent appraisal report of the public appraisal service office to examine asset value adjustments relative to the average level of elevation, equality, and depression.	Rupiah (Rp/cm)
Topography Adjusment (LG_T)	Indication of Asset Value Adjustment to the condition of flat/hilly/downhill/wavy level	Rupiah (Rp)
Seismicity (LG_K)	Potential number of seismic hazards of Mount Merapi in the form of volcanic/hybrid/volcanic clusters	Number of Occurrences

The present study employs multiple regression analysis with the Ordinary Least Squares (OLS) approach to examine the effect of independent variables on dependent variables. Statistical modelling and data analysis using the OLS approach were selected for their ability to generate efficient and consistent parameter estimates and to facilitate hypothesis testing to assess the significance of the variables' effects within the scope of this study. To justify the use of OLS assumptions and assure readers regarding the validity of the coefficient estimates, diagnostic tests such as the Breusch-Pagan test for heteroskedasticity and Moran's I test for spatial autocorrelation were conducted. These tests confirmed that our error terms behave well and that neighboring properties do not unduly bias estimates. The results of these tests, which passed, reinforce the reliability and robustness of the model used in the analysis.

This study uses statistical tests to evaluate the model's accuracy, including the F-test for overall significance, the t-test for the individual effect of independent variables, and the Coefficient of Determination (R^2) to explain the variation in the dependent variable. Classical Assumption tests, including normality, linearity, multicollinearity, autocorrelation, and heteroscedasticity, are also applied to ensure the model meets statistical criteria and produces reliable estimates.

The research approach shows that auction asset valuation cannot rely solely on economic market value but requires a multidimensional analysis that includes physical aspects of the environment and disaster potential, integrating elevation and topography adjustments, as well as disaster risk from Mount Merapi's seismic activity, into the valuation method. This research applies the Analytical Survey method to analyze the influence of the variables under study. The operational definitions of variables are formulated in detail to clarify the terms used and to set operational limits for implementing the following research concepts.

Table 1 presents a comprehensive overview of the research variables and their respective operational definitions. The Auction Market Value (LG_INP), measured in Rupiah (Rp), underwent a logarithmic transformation to normalize its distribution, given the extremely wide range in the original data. This transformation allows for the expression of variables in percentage terms, providing percentage elasticities valuable for investors conducting sensitivity analyses. This method was employed to minimize extreme fluctuations in market value and to clarify the relationship between auction market value and other factors. (For practitioners, this means they can interpret a 1% change in a variable as indicative of a corresponding shift in auction market value.) Exposure Time (LG_WE), which denotes the number of days required to sell or auction a property, is logarithmically transformed. This is done to mitigate the impact of uneven distribution and provide a more precise representation of the relationship between exposure time duration and property market value. Elevation Adjustment (LG_AE), which measures the

Table 2: Descriptive Statistic

Variable	Mean	Min	Max
Auction Market Value (LG_INP)	Rp994.913.255	Rp234.000.000	Rp4.252.125.000
Exposure Time (LG_WE)	237	180	360
Elevation Adjustment (LG_AE)	Rp91.882	Rp117	Rp504.000
Topography Adjusment (LG_T)	Rp146.826	Rp9.010	Rp590.635
Seismicity (LG_K)	36	9	54

impact of elevation changes on property value, is quantified in Rupiah per centimeter (Rp/cm). A logarithmic transformation is employed to achieve a uniform distribution of the data and streamline the analysis of the effect of elevation on auction-market value, as variations in elevation have been observed to influence a property's attractiveness. The concept of topography (LG_T) pertains to the influence of topographical conditions, including plains, hills, and valleys, on property value. This variable is measured in Rupiah. The incorporation of logarithms in this variable ensures the analysis of significantly varying topographical values in a more controlled manner, thereby clarifying the impact of geographical conditions on property market value. Seismicity (LG_K), which gauges the frequency of earthquakes or seismic activity over a given time period, is quantified as the number of events. By applying a logarithmic transformation, the impact of extreme fluctuations in earthquake frequency can be mitigated, thereby facilitating a more consistent analysis of the influence of seismic risk on property market value.

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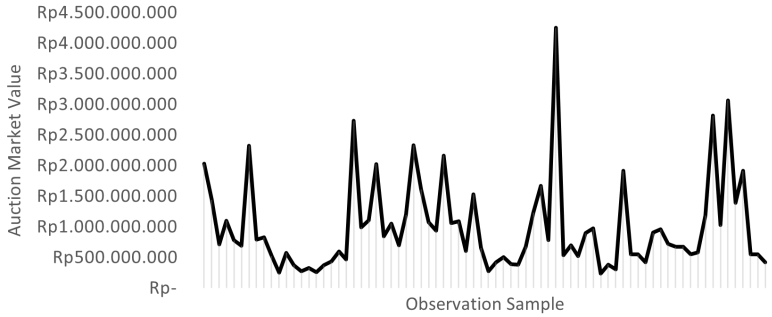
3 Result

This study collected 76 observations of property offers and transactions in the Yogyakarta Special Region, focusing on data within 24 months of the valuation date. Data collection followed the research schedule and relied on verified, reliable sources, including direct communication and documentation.

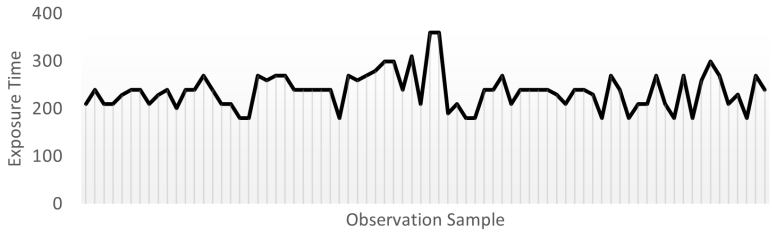
Descriptive statistics in Table 2 summarize the study data, including the mean, median, maximum, and minimum values for both independent and dependent variables.

Based on BNPB data on Mount Merapi's eruption history from the 17th to the 20th century, the number of fatalities from eruptions, both from hot clouds and lava, has exceeded 5,200. In the 2010 eruption, 198 people died directly from hot clouds, while 188 people died indirectly. In addition, the number of displaced people reached 400,000. The



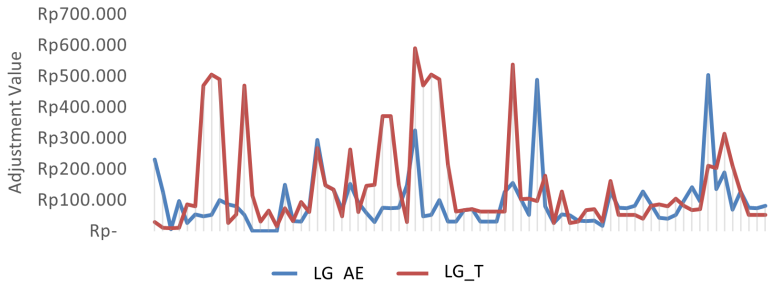
Notes: Collateral property auction values in the Yogyakarta Special Region range from Rp234,000,000 to Rp4,252,125,000, with an average of Rp994,913,255. The data indicate significant value disparities between districts and cities.

Figure 1: Trend chart of Auction Market Value



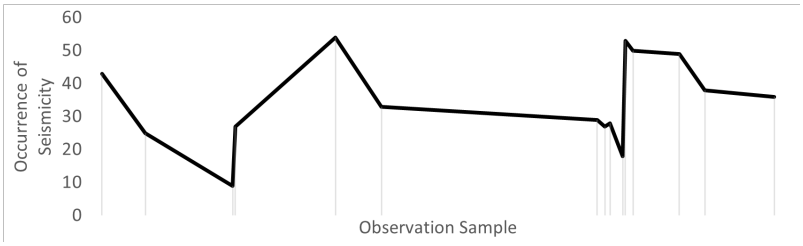
Notes: Exposure time for collateral auction asset sales ranges from 180 to 360 days, with an average of 237 days. Longer exposure periods are influenced by location, market conditions, property prices, and demand. Typically, more competitive markets require shorter exposure times.

Figure 2: Exposure Time Trend chart



Notes: Elevation and topography adjustments reflect changes in auction asset values based on elevation relative to the road and terrain type. Elevation adjustments range from Rp117 to Rp504,000, with an average of Rp91,882. These factors influence property attractiveness, accessibility, and potential use. Topography adjustments range from a minimum of Rp9,010 to a maximum of Rp590,635, with a mean value of Rp146,826. These adjustments account for various terrain conditions—such as flat, hilly, downhill, or undulating—and their subsequent impact on property functionality, accessibility, and development potential.

Figure 3: Trend graph of Elevation Adjusment (LG_AE) and Topography Adjusment (LG_T)



Notes: Seismicity data show a range of 9 to 54 seismic events, with an average of 36. The frequency of seismic events from Mount Merapi—including impact, hybrid, and volcanic types—can significantly affect auction asset values, especially for properties in disaster-prone areas. Seismic impact analysis is supported by risk maps, historical volcanic activity data, and assessments of property disaster resilience.

Figure 4: Seismic Trend graph

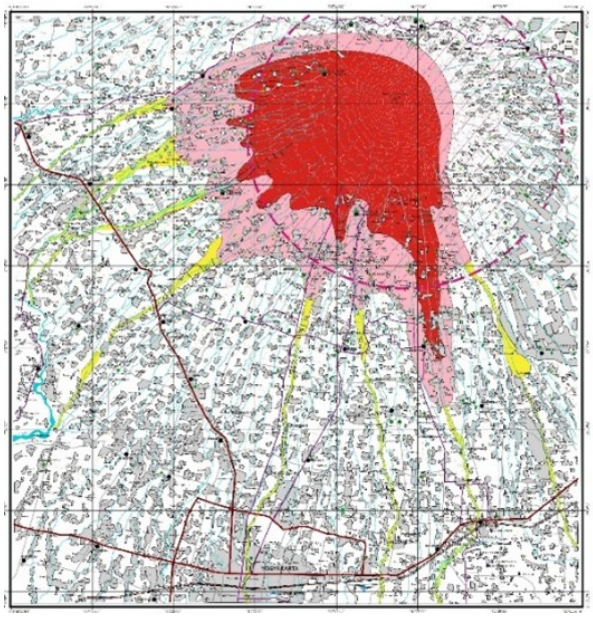


Figure 5: Volcanic hazard map of the study area (Sayudi et al. 2010), issued by the Center for Volcanology and Geological Hazard Mitigation (CVGHM)

hot clouds generated by the eruption damaged several villages, including Umbulharjo, Kepuharjo, Glagaharjo, Argomulyo, and Wukirsari in Cangkringan Sub-district, Sleman Regency, as well as Balerante in Kemalang Sub-district, Klaten Regency. The map of Mount Merapi Disaster-Prone Areas serves as a reference for local governments in designing regional spatial planning to reduce risk in disaster-prone areas. In addition, the surrounding community can use it as a guide for self-rescue efforts in the event of an eruption or lava flood. This map is also a reference in regional spatial planning related to the development and commercialization of property assets.

Table 3 presents the regression results, confirming the appropriateness of the log-transformed model based on the statistical criterion tests. The model yields an R-squared (R^2) value of 0.585, indicating that approximately 58.5% of the variability in auction market values is explained by the independent variables, namely exposure time, elevation adjustment, topography adjustment, and seismicity. Notably, the F-statistic of 7.792 is significantly greater than the F-table critical value of 2.20 ($F > 2.20$). This confirms that the independent variables collectively have a significant impact on the dependent variable. These findings suggest that the model effectively reduces pricing uncertainty, providing a more reliable framework for asset valuation and risk management in decision-making processes.

Table 3: Regression Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	8.444198	1.018419	8.291478	0.0000
LG_WE	-0.707430	0.454560	-1.556297	0.1241
LG_AE	0.013190	0.021493	0.613693	0.5414
LG_T	0.231408	0.069668	3.321577	0.0014
LG_K	0.610295	0.162773	3.749375	0.0004

R-squared	0.585089	Mean dependent var	8.894.737
Adjusted R-squared	0.265939	S.D. dependent var	0.289779
S.E. of regression	0.248275	Akaike info criterion	0.114967
Sum squared resid	4.376.476	Schwarz criterion	0.268304
Log likelihood	0.631272	Hannan-Quinn criter.	0.176248
F-statistic	7.792.841	Durbin-Watson stat	1.627.367
Prob(F-statistic)	0.000029		

Table 4: Descriptive Ordinary Least Squares

Multiple Regression Analysis	Test Statistics	Description
	T-test	
Exposure time	T-Stat value of -1.56 < T-tab 1.667 and prob value 0.1241 > 0.05	Not significant
Elevation adjustment	T-Stat value of 0.61 < T-tab 1.667 and prob value of 0.5414 > 0.05	Not significant
Topography adjustment	T-Stat value of 3.32 > T-tab 1.667 and prob value 0.0014 < 0.05	Significant
Seismicity	T-Stat value of 3.75 >T-tab 1.667 and prob value 0.0004 <0.05	Significant
	F-test	
Full model	F-stat 7.792841 > F-table 2.20	Significant
	Classical assumption tests	
Normality test	probability value 0.1873 > 0.05 and Jarue-Bera 3.3505	No indication of non-normality
Multicollinearity test	value R-square 0.5851 < 0.8	No indication of multicollinearity
Heteroscedasticity test	Probability value passed test 0.0662 > 0.05	No evidence of heteroscedasticity

Table 4 summarizes the statistical results of the hypothesis testing and classical assumption diagnostics. The t-test results indicate that topography adjustment and seismicity are the significant determinants of the dependent variable, while exposure time and elevation adjustment do not show statistical significance. Furthermore, the F-statistic of 7.792 confirms the overall significance of the model. Diagnostic tests demonstrate that the model adheres to the required classical assumptions. Specifically, the Jarque-Bera test yields a probability value of 3.3505 and ($0.1873 > 0.05$), indicating no violation of the normality assumption. Additionally, the multicollinearity test shows an R-square value of 0.5851, which is well below the 0.8 threshold, confirming no serious multicollinearity among the independent variables. No evidence of heteroscedasticity was found, ensuring the reliability of the OLS estimates.

4 Discussion

Based on the t-test results, the variables Topographic Adjustment (3.321577) and Seismicity (3.749375) have a positive and significant influence on the Auction Market Value of collateralized property assets. To assist property assessors in recognizing potential risks, specific thresholds can be highlighted. For example, it's observed that an exposure to more than 40 seismic events annually could lead to a reduction in property values by approximately 5%. Similarly, topographical changes that result in slope inclines exceeding 15% could act as red flags, suggesting potential depreciation in the asset's market

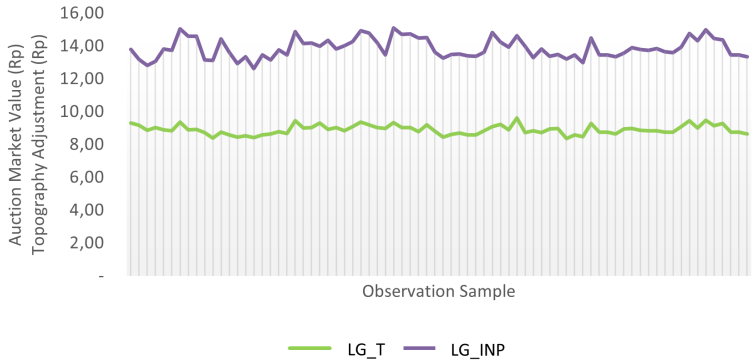


Figure 6: Trend chart of Auction Market Value (LG_INP) and Topography Adjusment (LG_T)

value. By translating these coefficients into simple rules of thumb, property assessors can more effectively gauge risk factors and make informed valuations.

Figure 6 illustrates the trend relationship between Auction Market Value (LG_INP) and Topographic Adjustment (LG_T). The regression analysis demonstrates that auction market value is significantly influenced by topographic adjustment, with a coefficient of 0.231408. This indicates that each Rp1 increase in topographic adjustment raises the Auction Market Value of collateral property assets by 0.2314%. This result supports the hypothesis that topography adjustment has a positive and significant effect on auction market value. Incorporating topographic characteristics into asset valuation is essential, as land topography—whether flat, hilly, downhill, or undulating—substantially affects a property's market value by influencing functionality, visual appeal, accessibility, and development costs. Flat land is generally considered ideal due to its facilitation of development and optimal accessibility, resulting in higher market values.

In contrast, while hilly land may offer aesthetic advantages, such as attractive views, it may entail additional engineering costs, such as soil stabilization, which may reduce its market value if there is no specific demand. Downhill and undulating conditions often require a greater investment in infrastructure, such as drainage or land leveling, which can affect asset value assessment. Properties with downhill topography also face risks such as waterlogging or inconvenient access, which can reduce their attractiveness in the auction market. Auction asset valuations that consider topography are conducted through a comparative market analysis, in which properties with similar characteristics are compared to assess the impact of topography on price. In addition, an analysis of remediation costs and land development potential was used to estimate the economic impact of less-than-ideal topographic conditions. The results of this adjustment show that topography that favors development and accessibility will significantly increase property values. In contrast, topography that creates obstacles can reduce market values unless other factors, such as a premium location or a unique landscape, compensate. As such, topography is an important variable that significantly affects the auction market value of property assets and should be thoroughly analyzed in the valuation process.

In the hedonic pricing literature, property valuation is conducted by identifying and measuring physical and environmental attributes that influence consumer perceptions of property value (Shi et al. 2022, Zheng, Wang 2024). Topography, as one factor in this model, affects property prices through various dimensions, including accessibility, land use, and aesthetics. This exposition elucidates the fundamental theory posited by Rosen (1974), which holds that real estate prices are determined by a suite of attributes that influence consumer preferences. Topography is thus considered an integral component of these attributes (Boto-García, Leoni 2022, Kovacs et al. 2022, Rosen 1974).

The hedonic pricing model serves as the foundation for property price assessment, assuming that property values are influenced by various attributes, including topography, which encompasses land conditions such as flat, hilly, sloped, or undulating. Topog-

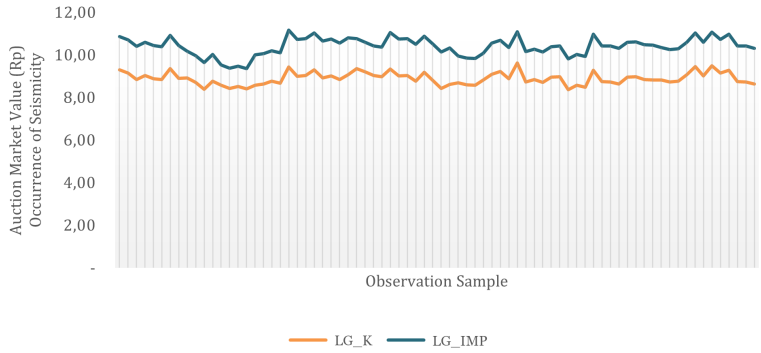


Figure 7: Trend graph of Auction Market Value (LG_INP) and Seismic Adjustment (LG_K)

raphy plays a significant role in determining property prices by affecting accessibility, construction costs, and aesthetics. However, when using the hedonic pricing model, it is imperative to acknowledge that topography must be examined alongside other salient factors, such as location and socio-economic characteristics, which collectively influence market prices. Hilly land is often appraised at a lower value due to the additional costs associated with soil stabilization and other infrastructure. However, its natural beauty can enhance its appeal to buyers who prioritize quality of life. Conversely, sloping or undulating land increases development costs, such as drainage or land leveling, which can diminish the property's market value. Nevertheless, consumer preferences and local demand can often mitigate the negative impact of poor topography. Furthermore, premium locations or unique landscapes have been demonstrated to offset physical obstacles arising from topographical conditions. Additionally, changes in government policy and infrastructure developments, such as road improvements or stormwater management, have been found to enhance property values, even when topography is suboptimal.

Secondly, the regression results demonstrate that the auction market value is significantly influenced by seismic adjustments, with a coefficient of 0.610295. Figure 7 illustrates the trend relationship between seismic activity (LG_K) and auction market value (LG_INP), visually confirming this positive correlation. This indicates that each additional seismic adjustment of 1 seismic event will increase the auction market value of collateral property assets by 0.6103%. This finding supports the hypothesis that seismic adjustments have a positive and significant effect on auction market value. However, this counter-intuitive result warrants further exploration to ensure robustness. One plausible alternative hypothesis is that the areas affected by seismic activity may attract a specific segment of buyers who are drawn to disaster-driven amenities, such as fertile land for agriculture, scenic landscapes, or enhanced infrastructure developed in response to frequent natural events. These factors can increase demand, possibly offsetting the risk perception typically associated with seismic zones. To further explore this hypothesis, examining whether demand, rather than risk, might drive the positive coefficient observed is a potential avenue for investigation. As a robustness check, instrumenting seismicity with exogenous eruption alerts could clarify the underlying factors contributing to this result. By exploring potential endogeneity, we aim to strengthen confidence in the observed effects. Seismic activity, including landslide, hybrid, and volcanic earthquakes, has been shown to exert a significant influence on market perception, investment feasibility, and property attractiveness, even when the property is situated in a high-risk zone. Geological phenomena, such as earthquakes and volcanic activity, have been shown to significantly influence real estate valuation. In areas deemed high risk, a decline in property prices has been observed, attributable to uncertainty and the potential for damage to infrastructure or buildings from disasters. This factor, compounded by the fear and heightened risk perception among prospective buyers, as well as the possibility of long-term management of these risks, results in lower property prices in vulnerable zones relative to safer zones. This issue is also related to higher insurance costs and the need

for additional investment in building or infrastructure resilience in earthquake-prone areas. However, despite the potential for damage, some areas with high volcanic or seismic activity, such as around Mount Merapi, still have fairly high market demand. The reasons for this phenomenon require further investigation and understanding (Farquharson, Amelung 2022, Hardiansyah et al. 2020, Terry et al. 2022).

High demand persists in the area surrounding Merapi due to its highly supportive environment. For instance, the northern portion of Yogyakarta, closer to Merapi, offers fresh, clean air and natural beauty, appealing to individuals seeking a healthier, more comfortable living environment. In recent years, property buyers, particularly those from highly polluted metropolitan areas, have placed significant emphasis on air quality and environmental factors. Moreover, numerous regions have been outfitted with sufficient social and public facilities, including educational institutions, medical centers, and commercial hubs (Das et al. 2022, Jennings et al. 2021, Zhang et al. 2022). The presence of such amenities enhances the desirability of these locales, particularly for families seeking an improved quality of life. With access to quality educational facilities and healthcare services, many prospective buyers prioritize the quality of life they can attain in relatively tranquil areas, despite the potential for natural disasters. Despite the evident hazard of potential disasters, many contend that the risk of harm can be substantially reduced through the implementation of effective disaster mitigation systems and advanced technologies designed to fortify critical infrastructure. Consequently, the market value of properties situated in regions such as northern Yogyakarta, which lies in close proximity to Mount Merapi, can remain high or even continue to rise. This phenomenon can be attributed to a shift in the perceived risk associated with these areas. Recent studies indicate an increasing awareness among both communities and investors that disasters are unpredictable and cannot be precisely predicted. Moreover, when effective risk mitigation policies are in place—such policies include early warning systems, building reinforcement, and sustainable urban planning—a greater sense of security is engendered, leading to increased investment in these areas (Kurnio et al. 2021, Thamarapani, Rockmore 2022, Thompson et al. 2023). Additionally, the appeal of a healthy lifestyle in these areas has been shown to influence property market demand (Chen et al. 2022). The phenomenon of individuals and families choosing to reside in areas more closely associated with natural environments, even when these areas are near regions susceptible to natural disasters, has been widely documented (Taylor, Aalbers 2022). This phenomenon has been variously referred to as 'disaster gentrification', a term that denotes the increase in property prices in such areas despite heightened risk (Thompson et al. 2023).

In addition to environmental factors, the affordability of property in the northern part of Yogyakarta also contributes to rising property prices. The phenomenon of rapid urbanization in major cities has driven a growing demand for affordable, well-connected housing. Despite its designation as a disaster-prone area, the region surrounding Merapi often offers property prices lower than those in the densely populated, costly city center. The decision to invest in real estate in this region is often driven by the desire to acquire a residence at a comparatively lower cost while maintaining access to superior amenities and an enhanced quality of life. Moreover, improvements in infrastructure in high-risk areas significantly influence property value maintenance or appreciation. Local and national governments frequently allocate substantial financial resources to infrastructure development and disaster mitigation (Fischer et al. 2022, Saputra et al. 2021). Such initiatives include the construction of more robust roads, efficient drainage systems, and structures more resistant to seismic activity. These policies serve to indirectly reassure prospective buyers that the potential for damage from disasters can be effectively managed. It should be noted that even within risk zones, locations with strategic value or significant economic potential may still retain market appeal. Seismicity is a primary risk factor that affects property auction market values, particularly in regions susceptible to natural disasters. Accurate assessments must consider this risk through data-driven methodologies, geographic risk analysis, and an evaluation of available mitigation measures. Consequently, property market values can reflect the equilibrium between potential returns and seismic risk, thereby ensuring equitable transparency for all parties involved in the auction process.

5 Conclusion

Simultaneously, the independent variables collectively influence auction market value, but only topography adjustment (LG_T) and seismicity (LG_K) have a significant individual effect in Yogyakarta Province for 2023-2024. This research is limited to exposure time, elevation adjustment, topography, and seismicity. To enhance the predictive power of our model, incorporating insurance premium data could be particularly beneficial. This addition would provide a more comprehensive view of the financial risks associated with properties in disaster-prone areas, potentially improving the model's accuracy. Further studies should consider additional determinants and broader geographic coverage, as this study was constrained by time, cost, and location. A specific limitation imposed by the 24-month data window is its restriction on capturing longer-term price adjustments. This limitation may prevent a comprehensive understanding of the prolonged effects that seismic activity and other variables can have on property values. Acknowledging this trade-off openly enhances the study's credibility and sets the stage for future longitudinal research that can explore these impacts over a more extended period.

Based on an understanding of the creation of auction market value, an appropriate assessment education program is needed that is not only influenced by economic factors but also has significant seismic potential. The government must develop policies and programs that support disaster risk mitigation in vulnerable areas, including spatial planning, infrastructure strengthening, and property protection through insurance.

To enhance policy relevance, the findings suggest two actionable recommendations: first, integrate hazard maps into loan-to-value limits to better assess the risks associated with collateral in disaster-prone areas; second, implement mandatory risk assessments for properties located in high-seismic zones to ensure comprehensive valuation practices. Clear policies for disaster risk assessment can help maintain the stability of collateral market value, thereby providing a sense of security for collateral owners, financial institutions, and investors. As Yogyakarta continues to face seismic risks, robust policies in these areas can mitigate potential economic impacts and foster safer development practices

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