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Analysis of the Potential Cost of Damage Due to Liquefaction on Two-Story Residential Buildings in North Jakarta

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ABSTRACT

This study is motivated by the high seismic activity in Indonesia due to the interaction of three major tectonic plates, as well as the geological conditions of coastal areas such as North Jakarta, which are dominated by soft, water-saturated alluvial soils prone to liquefaction. This phenomenon can lead to severe structural damage and significant economic losses, particularly for two-story residential buildings. This research aims to analyze the liquefaction potential and estimate the economic losses caused by building damage in North Jakarta. The study employed a quantitative descriptive approach using Standard Penetration Test (N-SPT) data from 26 drilling points. Key geotechnical parameters, including Cyclic Stress Ratio (CSR), Cyclic Resistance Ratio (CRR), Magnitude Scaling Factor (MSF), and Safety Factor (SF), were calculated. Earthquake acceleration (amax) was also analyzed using Donovan, McGuire, and Matuschka methods. The results indicate that liquefaction potential increases with earthquake magnitude, with critical conditions occurring at a magnitude of 5.5 Mw, where all points experience liquefaction in shallow layers. Cilincing and Ancol are identified as the most vulnerable areas due to low N-SPT values and shallow groundwater levels. The estimated total economic loss reaches IDR 4.734 trillion, with per capita losses ranging from IDR 3.4 million to IDR 6.3 million. In conclusion, North Jakarta faces high liquefaction risk with substantial economic impacts, highlighting the need for mitigation strategies in urban planning and structural design.

INTRODUCTION

Indonesia is one of the countries with the highest seismic rate in the world because it is located at the confluence of three main tectonic plates, namely the Eurasian, Indo-Australian, and Pacific Plates. This condition causes the territory of Indonesia, including the island of Java, to have a fairly high potential for earthquakes. One of the sources of active earthquakes in western Java is the Baribis Fault, which stretches from Subang-Karawang to Bekasi and eastern Jakarta. This fault activity has been recorded through several earthquake events, including a shock with a magnitude of 4.7 SR that occurred in the Karawang area. Increasing seismotectonic understanding shows that the Baribis Fault has the potential to produce earthquakes with greater strength than ever before, so the surrounding urban areas, including North Jakarta, need to receive serious attention to the threat of earthquakes (Agustian & Ramadhan, 2021; Mokoginta & Irawan, 2022).

North Jakarta is a coastal area that geotechnically includes an area with relatively soft soil conditions, dominated by young alluvial deposits, silt, fine sand, and clay with a low-density level. Soil characteristics like this are one of the factors that cause an increase in the potential for liquefaction, which is a phenomenon of losing soil shear strength due to increased pore pressure during earthquake shocks (Hardiyatmo, 2014; Mase, 2016). When liquefaction occurs, the soil behaves like a fluid so that it can no longer withstand the weight of the buildings on it. This condition can cause various damages such as differential decrease, building slope, structural cracks, and even total collapse of the building structure (Djamaluddin & Afandi, 2016; Purba, 2020).

Demographically and socio-economically, North Jakarta is one of the areas with a fairly high population density, rapid development of residential areas, and a high number of two-storey residential buildings. The number of residential houses standing on the ground has the potential for liquefaction, making the people of this area vulnerable to material losses in the event of a major earthquake. On the other hand, most people may not be aware that soil types in coastal areas have a high risk of liquefaction, especially when the acceleration of earthquakes (*amax*) is large enough. This phenomenon has the potential to cause significant economic losses, including damage to building structures, loss of residential functions, and the need for post-disaster recovery costs.

In the context of disaster mitigation, liquefaction potential analysis is very important to determine the level of soil vulnerability and estimate its impact on residential buildings (Mulyono, 2017; Budiawan et al., 2020). The results of this analysis can be the basis for decision-making, such as regional development planning, the preparation of construction technical guidelines, the design of soil reinforcement, and the preparation of emergency handling schemes. However, studies on the relationship between the level of potential liquefaction and estimated economic losses in two-story residential buildings in North Jakarta are still limited. Some previous studies have only focused on liquefaction hazard mapping or geotechnical parameter analysis without quantitatively linking it to the value of building losses (Noor & Lestari, 2021; Sugiyanto & Kurniawan, 2020).

Seeing the vulnerable geological conditions of North Jakarta, the high seismic activity of the Baribis Fault, and the lack of studies that link the liquefaction phenomenon with the economic impact on residential buildings, this research is important. This study analyzes the potential of liquefaction based on standard penetration test (N-SPT) data from 26 drill points spread across several important areas in North Jakarta such as Cilincing, Ancol, Pluit, and PIK. In addition, this study also analyzed earthquake acceleration (*amax*) using several empirical methods (Donovan, McGuire, Matuschka) to determine the value of earthquake acceleration that is most critical to the liquefaction potential.

The final stage of this study is to calculate the value of potential losses of two-story residential buildings based on the level of damage, the value of the building's NJOP, and the percentage of the impact of liquefaction on each soil layer. This approach provides a comprehensive overview of the level of risks faced by the community, as well as contributing to local governments, development actors, and the community in developing mitigation strategies and structuring the coastal areas of North Jakarta.

Thus, this research not only contributes in the fields of seismology and geotechnics, but also in the fields of regional planning, disaster risk management, and sustainable development policies. This study is expected to be able to improve understanding of the relationship between geotechnical conditions, seismic data, liquefaction potential, and the magnitude of the impact of economic losses on two-story residential buildings in North Jakarta.

The main problems identified in this study are related to the high vulnerability of the North Jakarta area to liquefaction due to the characteristics of young alluvial soils, low N-SPT values at shallow depths, and relatively shallow groundwater depths. The activity of the Baribis Fault as the nearest source of the earthquake adds to the potential for significant soil acceleration, while there is no comprehensive study that links the variation in earthquake acceleration, soil conditions at each drilling point, the critical magnitude of liquefaction, to its impact on two-story house buildings and estimated economic losses based on NJOP. Therefore, this study was formulated to analyze soil parameters, calculate earthquake acceleration, determine CSR, CRR, MSF, and Safety Factor values, identify critical magnitudes, classify residential housing types, and calculate the amount of damage and economic loss in each study area. The study limits were set at only 26 drill points in North Jakarta with N-SPT, GWT, and layer depth data, the earthquake source was only the Baribis Fault, the earthquake acceleration method was limited to Donovan, McGuire, and Matuschka, and the liquefaction evaluation referred to Seed & Idriss and NCEER 2001, with a focus on two-story house construction and NJOP-based loss assessment.

This research aims to produce a directed, valid, and applicable analysis in understanding the potential for liquefaction and its impact on building damage and economic losses. Theoretically, this study is expected to enrich the geotechnical literature, especially the evaluation of liquefaction based on N-SPT data and the relationship between the level of liquefaction and the economic losses of residential buildings. Practically, the results of the research are expected to be the basis for structural and geotechnical planners in determining strategies for strengthening soil and foundations, providing information to local governments regarding liquefaction vulnerability zoning, assisting in estimating damage costs as a reference for disaster mitigation, and supporting development planning and regional development in a more targeted manner.

METHOD

This research was applied quantitative research with a descriptive analytical approach that aims to examine the potential for liquefaction and its impact on two-storey residential buildings in North Jakarta. The quantitative method was chosen because the analysis was carried out through technical calculations, such as earthquake acceleration, CSR, CRR, Safety Factor, to estimation of economic losses based on NJOP. The research location focuses on the North Jakarta area which was chosen because it has coastal soil characteristics that are susceptible to liquefaction, with a total of 26 drill points spread across Cilincing, Ancol, Pluit, and Tegal Alur-PIK.

The type of data used consisted of primary data in the form of N-SPT field test results to determine soil characteristics and resistance to liquefaction, as well as secondary data in the form of earthquake parameters from BMKG, national earthquake source maps, population data from BPS, and building NJOP data. All of these data support the analysis process to be valid and representative. The research stage begins with a literature study that is the theoretical basis, then the collection of field data, followed by the analysis of earthquake parameters using the Donovan, McGuire, and Matuschka methods, as well as the determination of the maximum earthquake acceleration as the basis for calculation.

The analysis of liquefaction potential was carried out with the CSR and CRR concept approach referring to the Seed & Idriss and Idriss & Boulanger methods (Boulanger & Idriss, 2012; Mase, 2016). Calculations are carried out starting from CSR, CRR, MSF to Safety Factor to determine the liquefaction status of each soil layer. The calculation procedure is carried out manually at the sample point in each region, then recapitulated for all drill points to obtain a comprehensive picture of the vulnerability of the region. The results of this analysis are the basis for determining the level of risk at each research site (Mutmainah, 2021; Hutagaol, 2024).

The next stage is the estimation of the value of losses calculated based on the level of building damage attributed to the NJOP value as well as the number of houses and residents. The calculation includes losses per house, per region, and per person so that the areas with the greatest potential economic losses can be known. The entire research process is then summarized in conclusions and mitigation recommendations, and is equipped with a research flow diagram as a systematic guide to the research flow from beginning to end.

RESULT AND DISCUSSION

A. Liquefaction Potential Analysis

The analysis of liquefaction potential in this study was carried out based on 26 drill points spread across six sub-regions of North Jakarta, namely North Ancol, East Ancol, West Ancol, Pluit, Tegal Alur-PIK, and Cilincing. The evaluation was carried out using earthquake acceleration parameters calculated by the Donovan, McGuire, and Matuschka methods for the magnitude range of 4.7 to 5.5. This calculation results in a variation in the value of a different peak ground acceleration (*amax*) at each point, influenced by the distance of each location to the position of the epicenter of the Karawang Regency earthquake.

In the analysis process, a two-stage approach is used, namely:

1. Analyze manual calculations for one sample point in each region. The sample point was selected based on the most critical conditions, namely the point with the largest earthquake acceleration value and/or the smallest Safety Factor (SF) value at magnitude 5.5 conditions.
2. A comprehensive analysis of all points was carried out through a recapitulation table containing the CSR, CRR, MSF, SF, and liquefaction values for the three soil layers at each point. The recap table is not narrative elaborated, but is presented in full at the end of this subchapter.

The analysis methodology refers to the standard procedures of geotechnical planning, namely:

a. Total and effective voltage calculation,
b. Convert the value of N-SPT to $(N_1)_{60}$,
c. Correction of the sand grains to $(N_1)_{60}$cs,
d. Calculation of cyclic equivalent voltage (CSR),
e. Liquefaction resilience capacity (CRR) assessment,
f. Magnitude correction using MSF,
g. As well as the calculation of safety factors (SF).

B. Liquefaction Analysis Recapitulation of All Locations

This subchapter presents a comprehensive summary of the results of the evaluation of liquefaction potential at all 26 drill points spread across the North Jakarta area, including North Ancol, East Ancol, West Ancol, Pluit, Tegal Alur-PIK, and Cilincing. This recapitulation contains the values of CSR, CRR, MSF, Safety Factor (SF) and liquefaction status for each soil layer at each point, based on variations in earthquake scenarios ranging from a magnitude of 4.7 Mw to a critical magnitude of 5.5 Mw.

The purpose of this recapitulation is to provide a comprehensive overview of the spatial distribution and depth of layers that have the potential to undergo liquefaction in each location, so that soil vulnerability patterns in North Jakarta can be analyzed in a more structured manner. This approach also allows the identification of differences in soil response characteristics between regions, which are influenced by factors such as N-SPT values, groundwater level conditions, effective pressure, and the distance of each point to the source of the Karawang earthquake.

The recapitulation data shows a gradual change in the status of liquefaction as the magnitude of the earthquake increases. At low magnitudes (4.7–4.8 Mw), all points are still in a safe condition, although some show SF values that are close to the critical limit. Entering the magnitude of 4.9 Mw, liquefaction begins to appear in shallow layers at certain points with small N values and very shallow groundwater levels. In the magnitude range of 5.0–5.4 Mw, the liquefaction zone is expanding, especially in layers 1 and 2 in almost all regions. The peak occurred at a magnitude of 5.5 Mw, where all drill points showed liquefaction at a depth of 2 meters, so this condition was set as a critical magnitude in this study.

This recapitulation is an important basis for further analysis, especially in linking the level of vulnerability of each location with the potential for building damage, the value of NJOP, and the estimated economic loss in the next chapter. Thus, the results of the recapitulation of these 26 drill points not only describe the condition of the soil technically, but also provide a basis for a comprehensive risk assessment for the North Jakarta area. Analysis of the Relationship of Causative Factors of Liquefaction

Analysis of the relationship between the factor’s causing liquefaction is needed to understand the dynamics of interaction between soil parameters and earthquake parameters in determining the level of vulnerability of an area. Liquefaction is not only determined by one factor, but is the result of a combination of soil conditions (N-SPT value, effective pressure, groundwater level), earthquake intensity (*amax*), and characteristics of the sediment layer in the study area. This subchapter discusses the influence of each parameter separately and then interprets its relationship to the liquefaction yield pattern at 26 drill points in North Jakarta.

1. The Effect of N-SPT Variation on CSR and CRR

The N-SPT value is an indicator of relative density and soil strength which plays a direct role in soil resistance to cyclic loads (Adiansyah, 2018; Diana et al., 2024). The variation of N-SPT in each layer greatly affects two important parameters in the liquefaction analysis, namely:

a. Cyclic Resistance Ratio (CRR) as soil resistance capacity.

b. Cyclic Stress Ratio (CSR) as the cyclic load received by the soil.

1) Influence on CRR

The CRR value increases proportionally with the increase $(N_1)_{60}$, so that layers with high N-SPT have a greater capacity to withstand earthquake loads. In this study, layers with low N-SPT (2–8 strokes) showed much smaller CRR values than layers with moderate or high N-SPT. This is evident at points in Cilincing and Ancol, where the first and second layers have a low CRR so that it is faster to enter SF < 1 conditions when the magnitude increases.

2) Influence on CSR

Theoretically, CSR is a function of earthquake acceleration, total pressure, and effective pressure. The N-SPT variation does not directly change the CSR value, but affects the effective pressure ($\sigma'v$) through the correlation of density and soil content weight. Soil with low N-SPT tends to be looser, has less effective pressure, and as a result the CSR/CRR value will be larger so that it is easier to liquefaction.

3) The relationship between the two

Soil layers with low N-SPT values show a combination:

a. Small CRR,
b. CSR is relatively greater than CRR,
c. so that SF drops below 1 faster.

The results of the analysis showed that the points with low N-SPT at a depth of 2–4 meters were almost always the first layers to liquefy at magnitude 4.9–5.0 SR

2. The Effect of GWT Depth on Safety Factors

The depth of the groundwater table (GWT) is a very significant factor in triggering liquefaction. The shallower the GWT, the greater the potential for the formation of excess pore water pressure during an earthquake (Tohari & Kurniawan, 2018; Ambarwati et al., 2020).

a. Effect on effective pressure

When the GWT is very close to the surface, the effective pressure value (σ'v) on the shallow layer becomes small. Low effective pressure lowers the CRR and increases the soil's susceptibility to liquefaction. At many points in North Jakarta, the GWT is at 0–2 meters, so the shallow layer is very vulnerable to liquidation.

b. Impact on Safety Factor (SF)

Safety Factor is the ratio between CRR and CSR. Because shallow soils receive the greatest dynamic loads and simultaneously have the least effective pressure, shallow soils exhibit the lowest SF values compared to deeper soils. This explains why all points at magnitude 5.5 SR undergo liquefaction at a depth of 2 meters.

c. Patterns in the research area

1) Cilincing and Ancol have the shallowest GWT, so SF drops faster.
2) Pluit and PIK have a slightly deeper GWT, so the SF is relatively more stable to greater magnitudes.

Overall, the analysis shows that shallow GWT is one of the most dominant factors in accelerating the decline of SF in the coastal area of North Jakarta.

3. The Effect of Earthquake Acceleration Value on Liquefaction Potential

Peak ground acceleration (amax) is the main triggering factor that determines the amount of cyclic load received by the ground (Cragin, 2020; Ansori & Artati, 2020). In this study, the amax value was calculated using the Donovan, McGuire, and Matuschka methods, then combined with the distance of each drill point to the source of the Baribis Fault earthquake (Amien & Hanif, 2020).

a. The relationship between earthquake acceleration and CSR

CSR is directly proportional to the value of amax. The greater the acceleration of an earthquake, the greater the CSR value, so the more stressed the soil is to withstand cyclic loads. The calculation pattern shows that the Cilincing area received the highest acceleration in all magnitude scenarios because it is located closest to the source of the earthquake, while Tegal Alur-PIK received the smallest acceleration.

b. Effects of increasing magnitude

As the magnitude increases from 4.7 SR to 5.5 SR:

1) The *amax* value increased significantly,

2) CSR increases,
3) CRR is fixed (because it comes from the nature of the soil),
4) So that SF dropped drastically.

This value is especially noticeable at points that are initially stable but begin to liquefy at magnitudes above 5.0 SR.

c. Region-wide patterns

1) At magnitude < 5.0 SR: only points near the source (Cilincing, Ancol) begin to show liquefaction.
2) At magnitude 5.1–5.3 SR: the liquefaction potential extends to Pluit and PIK.
3) At 5.5 SR: the entire site loses resistance and liquefaction occurs at all points.

This confirms that the value of earthquake acceleration is a factor that greatly determines the magnitude of the impact of liquefaction in all regions.

4. Differences in Results Between Locations

The difference in liquefaction results in the six study areas was greatly influenced by the heterogeneity of soil conditions, distance to earthquake sources, and groundwater depth. The analysis per region shows a consistent and logical pattern based on geotechnical principles.

a. Cilincing

It is the region with the highest level of vulnerability. This is due to:

1) The closest distance from the epicenter,
2) Highest earthquake acceleration,
3) N-SPT is low on many layers,
4) GWT is very shallow.

Cilincing has always been the first region to experience SF < 1 at low magnitude.

b. Ancol (North, East and West)

The three Ancol regions showed very similar behavior.

1) Low to moderate N-SPT,
2) GWT shallow,
3) Medium distance from the source of the earthquake.

Ancol began to show liquefaction at magnitude 4.9–5.0 SR and experienced a steady decline in SF to critical magnitude.

c. Pluit

Areas that have saturated soil conditions but with a distance from the source of the earthquake.

1) It began to experience liquefaction at a magnitude above 5.1 SR.
2) SF fell slower than Cilincing and Ancol.

The difference in earthquake acceleration is the dominant factor.

d. Tegal Alur–PIK

It is the region that is the slowest to show liquefaction.

1) The farthest distance from the source of the earthquake,
2) the lowest *amax*,
3) Some layers have better N-SPT than others.

Even so, it still underwent full liquefaction at magnitude 5.5 SR.

e. Conclusions between regions:

The difference in liquefaction potential is mainly influenced by:

1) Distance from the source of the earthquake → affect the amax
2) Soil density (N-SPT)
3) GWT Depth
4) Effective pressure variation between layers

With the combination of all these factors, Cilincing is the most vulnerable location, while PIK is the location that is the slowest to experience liquefaction, but the entire region is ultimately unable to withstand cyclic loads at a critical magnitude of 5.5 SR.

C. Analysis of the Value of Losses in Residential Houses Due to Liquefaction

The analysis of the value of losses in residential houses due to liquefaction is an important part of this study because it serves to quantify the economic impact of geotechnical phenomena that have been analyzed in the previous sub-chapter. Liquefaction not only has an impact on technical aspects in the form of a decrease in soil carrying capacity and damage to building structures, but also has significant economic consequences, especially in densely populated areas in the coastal area of North Jakarta (Budiawan et al., 2020; Tarigan, A., 2022).

The research areas analyzed in this sub-chapter refer directly to the results of the evaluation of liquefaction potential at 26 drill points, spread across four main areas, namely Ancol, Pluit, Tegal Alur-Pantai Indah Kapuk (PIK), and Cilincing. The division of this area is carried out based on the similarity of geotechnical characteristics and the distribution of drill points, so that the results of the estimated losses obtained reflect the actual conditions of the areas affected by liquefaction.

Loss analysis is carried out through several main stages, namely:

a. The determination of the percentage of damage to residential houses is based on the severity of liquefaction.
b. The determination of the economic value of residential buildings uses the Selling Value of Tax Objects (NJOP).
c. Calculation of the estimated total loss of residential buildings per region.
d. Analysis of economic losses per person to describe the impact on society.

1. Residential Damage Percentage Value

The level of damage to residential buildings due to liquefaction is greatly influenced by the condition of the subsoil, the depth of the water-saturated sand layer, and the intensity and duration of earthquake shocks (Kusumawardani et al., 2023; Adinugroho, 2015). Based on the results of the Liquefaction Safety Factor (SF) analysis in each study area, the level of building damage was classified into several categories of damage (Tarigan, H., 2022; Hidayat et al., 2019).

Areas that show a predominance of SF values < 1 in most soil layers are categorized as severely damaged, while areas with a combination of SF values close to or slightly above 1 are categorized as experiencing moderate to severe damage. The determination of the percentage of damage refers to the approach commonly used in the study of losses due to earthquake and liquefaction disasters.

The percentage of damage to residential buildings used in this study is presented in Table 4.20 as follows.

Table 1. Percentage of Residential Damage Based on Analysis Area

Yes	Region	Characteristics of Liquefaction	Damage Percentage (%)
1	Ancol	Dominant liquefaction in saturated sand layers	80
2	Pluit	Moderate–heavy liquefaction, significant soil subsidence	70
3	Tegal Alur – PIK	Moderate liquefaction	60
4	Cilincing	Heavy and even liquefaction	80

(Source: Results of Liquefaction Safety Factor analysis at 26 research drill points)

The Ancol and Cilincing areas showed the highest level of damage because they have a layer of loose sand saturated with water with a considerable thickness and a very shallow groundwater level. This condition causes a significant loss of soil shear strength during an earthquake, so that it has a direct impact on the stability of residential buildings.

Meanwhile, the Pluit and Tegal Alur-PIK areas showed a relatively lower level of damage than Ancol and Cilincing, but were still in the moderate to severe category. This is due to variations in soil conditions and uneven liquefaction-prone layer thickness at all drill points.

This percentage of damage is then used as a multiplier factor in calculating the value of economic losses of residential buildings in the next sub-chapter.

2. NJOP Houses for Residence in North Jakarta

The economic value of residential buildings in this study is calculated based on the Selling Value of Tax Objects (NJOP) determined by the DKI Jakarta Provincial Government through the Regional Revenue Agency (Bapenda). NJOP is used as a property value approach because it has a clear legal basis, is updated regularly, and reflects variations in economic value between regions. The following is the average NJOP value of residential houses in the research area described in Table 2 as follows.

Table 2. NJOP Average Two-Story Residential Houses in the Research Area

Yes	Region	NJOP Average Residential Houses (Rp/unit)
1	Ancol	75.000.000
2	Pluit	65.000.000
3	Tegal Alur – PIK	55.000.000
4	Cilincing	50.000.000

(Source: Jakarta Provincial Regional Revenue Agency, NJOP Zoning Map 2024–2025)

The difference in NJOP values between regions shows that there is a variation in the characteristics of residential areas in North Jakarta. The Ancol area has the highest NJOP value because it is a strategic area with tourism functions and settlements with high economic value. The Pluit area also has a relatively high NJOP value because it is a dense residential area with good infrastructure access.

On the other hand, the Tegal Alur-PIK and Cilincing areas have lower NJOP values, which are influenced by the character of the area dominated by dense settlements, industrial activities, and more diverse socio-economic levels of the community. Although the NJOP value is lower, the potential loss in this region remains significant due to the sizable number of affected houses

3. Analysis of Losses in the North Jakarta Region

Analysis of regional losses is an important stage to integrate the results of the liquefaction evaluation with the economic impact on the community. In the context of this study, losses are calculated based on:

a. The percentage of residential damage obtained from the classification of the level of liquefaction (Subchapter 4.5.1);
b. Selling Value of Tax Objects (NJOP) of two-storey house buildings (Subchapter 4.5.2);
c. Population distribution based on BPS data;
d. Assumption of the average number of inhabitants per dwelling house, which is used to calculate the estimated number of houses;
e. Calculation of total losses per region and losses per person.

This analysis aims to provide a comprehensive picture of the economic burden that may be borne by the community if the liquefaction scenario actually occurs, especially in critical conditions of magnitude 5.5 SR where almost all points experience liquefaction at shallow depths. The following are the results of the analysis of residential building losses due to liquefaction per region described in Table 3 as follows.

Table 3. Estimated Losses of Residential Buildings Due to Liquefaction

No	Region	Number of Affected Houses	Damage Percentage (%)	NJOP (Rp/unit)	Estimated Loss (Rp)
1	Ancol	28.000	80	75.000.000	1.680.000.000.000
2	Pluit	16.000	70	65.000.000	728.000.000.000
3	Tegal Alur – PIK	22.000	60	55.000.000	726.000.000.000
4	Cilincing	40.000	80	50.000.000	1.600.000.000.000
	Total	**106.000**			**4.734.000.000.000**

(Source: DKI Jakarta Bapenda; BPS DKI Jakarta; results of research analysis)

The results of the calculation show that the Cilincing and Ancol areas suffered the greatest economic losses. This condition is caused by a combination of the high number of affected houses and the level of damage to buildings that are in the severe category. This is consistent with the results of the liquefaction analysis which shows the lowest Safety Factor values in both regions (Tandaju, 2019; Tohari & Kurniawan, 2018).

The Pluit and Tegal Alur-PIK areas showed lower losses than Ancol and Cilincing, but still made a significant contribution to the total losses of the research area. This difference shows that the level of damage due to liquefaction is not only influenced by the economic value of the property, but also by the distribution and density of settlements.

4. Analysis of the Loss of Research Areas Per Person

The analysis of losses per person was carried out to illustrate the magnitude of the economic burden borne on average by each resident in the study area due to the liquefaction event. Losses per person are calculated by dividing the total loss of residential buildings in each area by the number of inhabitants of the area. The following is an analysis of the losses of the research area per person described in Table 4 as follows.

Table 4. Analysis of Research Area Losses Per Person

No	Region	Total Population (souls)	Total Loss (Rp)	Loss per Person (Rp/Person)
1	Ancol	265.000	1.680.000.000.000	6.340.000
2	Pluit	145.000	728.000.000.000	5.021.000
3	Tegal Alur – PIK	210.000	726.000.000.000	3.457.000
4	Cilincing	430.000	1.600.000.000.000	3.721.000

(Source: BPS DKI Jakarta Province; results of research analysis)

The results of the analysis show that the Ancol area has a relatively high value of losses per person, which is influenced by the high NJOP value of residential houses and the large level of building damage. The Pluit area also showed a significant loss per person even though the number of houses affected was smaller.

Meanwhile, the Tegal Alur-PIK and Cilincing areas have a relatively lower value of losses per person. This is due to the large population, so the total loss value is divided by a larger population. However, the value of these losses still shows the potential for significant socio-economic impacts on the community.

Based on the results of the analysis of the value of residential building losses due to liquefaction, it can be concluded that the liquefaction phenomenon has the potential to cause a very significant economic impact in the coastal area of North Jakarta. The difference in the value of losses between regions is influenced by a combination of geotechnical conditions, the level of building damage, the economic value of property, and population density.

This analysis confirms that areas with high liquefaction potential and large settlement densities require special attention in disaster mitigation planning and regional development. The results of this research are expected to be the basis for the preparation of liquefaction risk mitigation strategies and development policy making oriented towards disaster risk reduction in North Jakarta.

CONCLUSION

Based on a series of analyses ranging from the collection of earthquake parameter data, evaluation of earthquake acceleration with three empirical methods, calculation of liquefaction potential at 26 drilling points in North Jakarta, analysis of causative factors, to estimation of economic losses, it was concluded that the research area has significant liquefaction potential, especially in water-saturated sand layers with low N-SPT values and shallow groundwater levels. with Ancol and Cilincing showing the highest vulnerability. The increase in earthquake magnitude is shown to be directly proportional to the depth and severity of liquefaction, where the 4.7–5.5 Mw earthquake scenario is able to trigger liquefaction in vulnerable soil layers, and at a critical magnitude of 5.5 SR almost all points at shallow depths undergo liquefaction. The Safety Factor value shows a consistent decrease as the magnitude increases, with a shallow layer of 0–3 meters as the most vulnerable zone, while N-SPT variation, groundwater level depth, and earthquake acceleration are the dominant factors forming liquefaction potential. The analysis of economic losses shows that the burden of losses per person varies between regions, ranging from around Rp3,457,000 to Rp6,340,000 per person with the highest value in Ancol due to the high NJOP and the level of building damage, while other areas such as Tegal Alur-

PIK and Cilincing continue to show significant impacts due to the large number of affected populations. Overall, the results of the study confirm that North Jakarta is an area with a high level of liquefaction vulnerability, so this risk is not only a geotechnical problem, but also has a social and economic impact that requires serious attention in development planning and disaster mitigation.

REFERENCES

Adiansyah, R. (2018). Pemodelan Risiko Likuifaksi Menggunakan Data N-SPT di Wilayah Cilegon. Jurnal Teknik Sipil Universitas Sultan Ageng Tirtayasa, 9(2), 87–95.

Adinugroho, R. (2015). Evaluasi Potensi Likuifaksi di Kawasan Reklamasi Pantai Utara Jakarta. Jurnal Teknik ITS, 4(2), D157–D162.

Agustian, R., & Ramadhan, A. (2021). Studi Risiko Bencana Gempa dan Likuifaksi di Kota Padang. Jurnal Geofisika Indonesia, 4(1), 33–42.

Ambarwati, I. W., Feranie, S., & Tohari, A. (2020). Analisis potensi likuifaksi di wilayah Cekungan Bandung dengan menggunakan metode uji penetrasi konus. Risalah Geoteknik dan Tambang, 30(1), 21–37.

Amien, M. F., & Hanif, M. (2020). Perbandingan Metode CSR dan DMT dalam Analisis Likuifaksi. Jurnal Teknik Sipil Universitas Negeri Semarang, 9(1), 22–31.

Ansori, M., & Artati, S. (2020). Pemodelan Terjadinya Likuifaksi di Tanah Berpasir Menggunakan Metode CRR. Jurnal Teknik Sipil Terapan, 5(2), 123–130.

Boulanger, R. W., & Idriss, I. M. (2012). Probabilistic Standard Penetration Test–Based Liquefaction-Triggering Procedure. Journal of Geotechnical and Geoenvironmental Engineering, 138(10), 1185–1195.

Budiawan, D., et al. (2020). Evaluasi Kerusakan Bangunan Akibat Likuifaksi Menggunakan Metode HAZUS-MH. Jurnal Penanggulangan Bencana, 11(2), 117–128.

Cragin, M. (2020). Liquefaction Process Modeling for Urban Earthquake Engineering. Earthquake Engineering Research Institute.

Diana, N. A., et al. (2024). Evaluasi Risiko Likuifaksi Berdasarkan Karakteristik Ukuran Butir Tanah dan Hasil N-SPT. Proteksi, 6(1), 51–58.

Djamaluddin, R., & Afandi, M. (2016). Kajian Kerusakan Infrastruktur Akibat Likuifaksi pada Tanah Pasiran. Jurnal Teknik Sipil Untan, 14(2), 79–86.

Hardiyatmo, H. C. (2014). Mekanika Tanah 2. Yogyakarta: Gadjah Mada University Press.

Hidayat, M., Putra, R., & Sari, D. (2019). Studi Perbandingan Metode Stabilisasi Tanah. Jurnal Teknik Tanah dan Fondasi, 7(3), 33–42.

Hutagaol, S. P. (2024). Potensi Likuifaksi Pada Proyek Pengembangan Infrastruktur Jalan Di Bandara Kualanamu Berdasarkan SNI 1726:2019. Tesis, Universitas Medan Area.

Kusumawardani, R., et al. (2023). Evaluasi Likuifaksi Pasir Silika Rembang Melalui Uji Triaxial. Jurnal Teknik Sipil, 147–152.

Mase, L. Z. (2016). Evaluasi potensi likuifaksi berdasarkan data SPT dan CPT. Jurnal Teknik Sipil dan Lingkungan, 4(1), 1–12.

Mokoginta, M., & Irawan, R. (2022). Pengaruh Gempa Terhadap Struktur Tanah dan Fenomena Likuifaksi. Jurnal Geoteknik Terapan, 9(2), 89–96.

Mulyono, A. T. (2017). Metodologi Penilaian Risiko Bencana Gempa dan Likuifaksi terhadap Infrastruktur Jalan. Jurnal Infrastruktur Sipil, 5(1), 1–12.

Mutmainah, S. (2021). Analisis potensi likuifaksi menggunakan data N-SPT. Jurnal Teknik Geoteknik, 8(2), 99–110.

Noor, F. M., & Lestari, A. (2021). Pemetaan Likuifaksi Berbasis GIS di Wilayah Perkotaan Bekasi. Jurnal Geografi, 19(1), 44–53.

Purba, R. A. (2020). Mekanika tanah dan aplikasi geoteknik. Penerbit Andi, Yogyakarta.

Sugiyanto, H., & Kurniawan, Y. (2020). Penerapan Sistem Zonasi Likuifaksi pada Peta Tata Ruang Kota. Jurnal Teknik Lingkungan, 26(3), 131–139.

Tandaju, R. (2019). Evaluasi Potensi Likuifaksi Tanah di Wilayah Pesisir Indonesia Timur. Jurnal Rekayasa Sipil, 8(1), 23–35.

Tarigan, A. (2022). Perencanaan pondasi pada tanah berpotensi likuifaksi. Jurnal Teknik Sipil, 14(2), 112–124.

Tarigan, H. (2022). Kajian Efektivitas Perkuatan Tanah terhadap Likuifaksi di Kawasan Reklamasi. Jurnal Geoteknik Indonesia, 3(2), 55–61.

Tohari, A., & Kurniawan, W. (2018). Studi Kerentanan Likuifaksi di Jakarta Utara Berdasarkan Data Penetrasi Standar (SPT). Jurnal Geoteknik Indonesia, 7(2), 121–130.