Comprehensive Economic Assessment of Mining Activities and Post-Mining Land Conversion for Residential Development: Leveraging Low-Cost UAV Surveys, Geotechnical Cut & Fill Planning, and Investment Analysis

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Abstract. The relationship between mining and property development offers opportunities for sustainable economic synergy. While post-mining land is often reclaimed or converted for agricultural use, strategically located former mining sites can be repurposed for residential developments, providing higher economic returns. This research evaluates the economic potential of converting a Class C soil excavation site in Parangloe District, Gowa Regency, into residential property. A cost-efficient Unmanned Aerial Vehicle (UAV) was utilized to conduct automated mapping of the area, calculate the extractable soil volume, and assess the viability of the investment. The study achieved a DEM accuracy of 18.2 cm/pixel and an RMSE of 15.22 cm. The total mineable soil volume is estimated at 32,265,263 cubic meters, while 243,794 square meters of the site are suitable for residential development, accommodating up to 1,214 housing units. The financial analysis of the residential project reveals an NPV of Rp 90,750,227,323.54, an IRR of 24.32%, a Payback Period of 4.62 years, and a Profitability Index of 8.92. The findings indicate that repurposing post-mining land for housing development is both economically viable and profitable, and supports the transition from mining to sustainable property development.

Keywords: UAV surveying, eco-friendly mining, soil stability and earthworks, housing development, financial viability analysis.

1 Introduction

Mining land is a valuable asset in regional development and plays a crucial role in meeting human demands for mineral resources. However, after the mining process is complete, the land is often left abandoned and unproductive. One solution that has

A. Arif et al. (eds.), *Proceedings of the International Conference on Multidisciplinary Studies (ICoMSi 2024)*,
Advances in Social Science, Education and Humanities Research 926,
https://doi.org/10.2991/978-2-38476-406-8_23

emerged to optimize non-productive mining land is to repurpose it through land conversion (Kodir et al., 2017). Generally, one of the objectives of land conversion is to transform it into residential areas, such as housing, to achieve greater economic returns. This is due to the significant potential that land holds in property development, especially if it is located in strategic areas with good accessibility. In fact, in the first quarter of 2023, the Gross Domestic Product (GDP) from the property sector was valued at around 120 trillion Rupiah in Indonesia (Badan Pusat Statistik, 2023). Therefore, the transformation of former mining land into residential areas can be considered to maximize profits.

There are several ways to assess the total economic potential of transforming mining land into residential areas, but one of the simplest methods is to calculate the total potential volume of extractable materials as well as the area of residential land that can be developed. In calculating this potential, Geographic Information Systems (GIS) technology based on Digital Elevation Models (DEM) in three dimensions (3D) can be used. These models provide a visual representation closer to the actual shape, producing better contour data, which will later serve as the foundation for planning the cut-and-fill of mining areas.

Various techniques are available for collecting field data, which will later form the basis of a 3D model representation of an area (Yao et al., 2018). Common methods include UAV Photogrammetry (Dawei et al., 2020), UAV LiDAR (Banerjee & Raval, 2022), Terrestrial Laser Scanners (Mabrur et al., 2023), and Synthetic Aperture Radar (SAR) (Alessi et al., 2023).

On the other hand, 3D models can represent not only mining areas but also various other applications in urban areas or residential developments. These include building analysis, road assessment, vegetation studies, water body analysis, and soil investigations. The results of 3D modeling can be used in both visual and non-visual applications (Yao et al. 2018). Examples of 3D model applications include 3D cadastre (Hajji et al. 2021), urban water needs (Bao et al. 2020), facility management (Stojanovic et al. 2018), noise analysis in an area (Konde and Saran 2017), solar radiation potential analysis (Harikesh et al. 2020), and energy demand estimation in an area (Rosser et al. 2019). Therefore, the use of 3D models is crucial in planning the conversion of former mining land into residential areas.

A primary consideration in determining the profits from converting former mining land into residential property is ensuring that the volume of soil to be mined is accurately calculated. This also impacts the land area available for property development. Consequently, this study will focus on several important aspects of mapping and the economic potential of land conversion, which will be comprehensively assessed. These aspects include calculating the volume of extractable soil using drone mapping (Vangu 2022), determining the profits from selling the soil, estimating the total land area after mining, and evaluating the potential profit from property development if housing is built on the former mining site.

Parangloe District, located in Gowa Regency, is one area with class C mining land covering approximately 69.9 hectares. This land has been mined for some time and is currently still active. However, besides its mining potential, the land holds great promise for residential development once the mining operations are complete.

This study will utilize drone mapping technology to provide accurate information on the topography and volume of the mined soil (Kršák et al., 2016). This will aid in identifying the available soil resources and predicting the potential volume of mineable soil that can be sold. Additionally, the study will analyze factors influencing the sale price of soil in the area to provide a clearer picture of the profits that can be gained from selling the soil.

Furthermore, the study will examine the total area of the mined land to identify the extent to which the land can be repurposed for residential development. In this context, it is important to evaluate the physical conditions of the land, including soil stability and risk assessments related to property development on former mining land.

The potential for property profits is another important aspect to be examined in this study. Considering the strategic location and good accessibility of the former mining land, housing developments on this land are likely to attract consumer interest and increase property values. The study will analyze the factors contributing to the increased revenue from property values, including the budget for constructing residential areas and the estimated profits that can be achieved.

This study is expected to provide a better understanding of the potential for developing former mining land into residential areas. The findings can serve as a reference for property developers and local governments in planning efficient and sustainable regional development. Additionally, the study can contribute to the advancement of drone mapping technology, which is becoming increasingly sophisticated and applicable in the fields of mining and real estate.

Considering this background, the study will address several key questions: what is the volume of soil that can be mined, what are the potential profits from selling the soil, how much of the former mining land can be utilized, and what are the potential property profits if housing is developed on the former mining land ?. By gaining a deeper understanding of these aspects, effective and sustainable steps can be taken in the development of former mining land into residential areas, benefiting both the community and stakeholders involved.

2 Methods

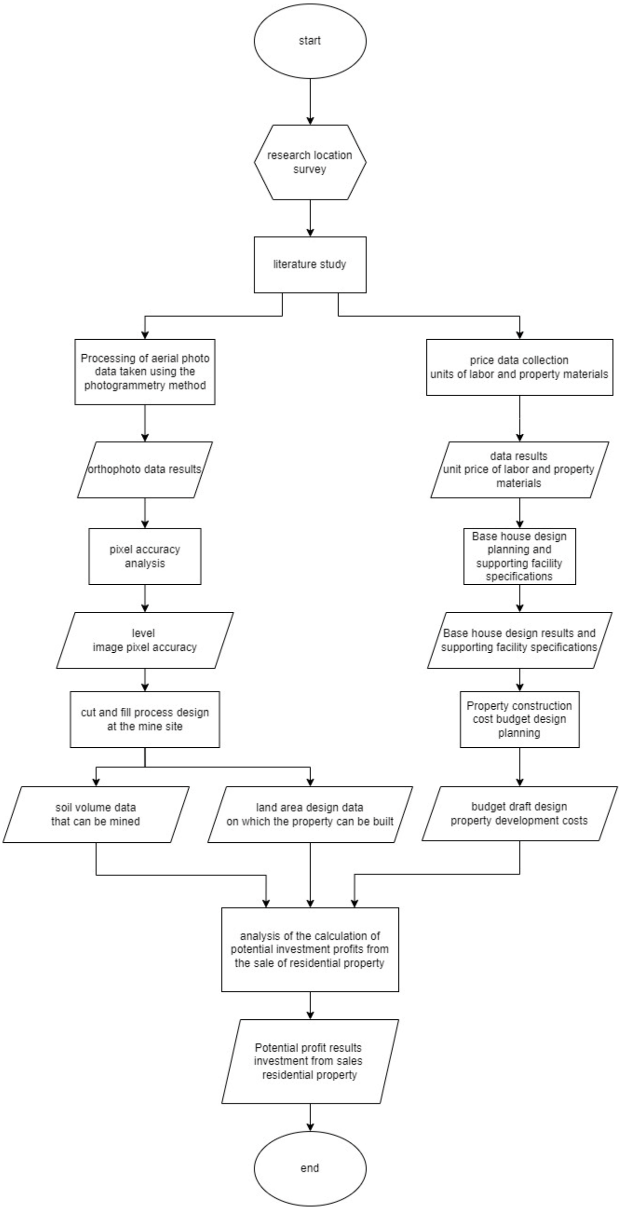

Fig. 1. Research Flow Chart

It is important to note that each stage of the data processing section from the flowchart in this research methodology has its own detailed flowchart for data processing. Specifically, this applies to the stages of DEM data modeling into contour data from drone imagery, Cut & Fill Design Modeling based on geotechnical data, Economic Profit Analysis of mining soil excavation investment and operations, and Economic Profit Analysis of Housing Construction Investment & Operations. These four stages will be elaborated in the following subsections.Shannon-Wienner breed diversity index.

The UAV photo data processing, acquired using the photogrammetry method.. The process begins with inputting the aerial photo data into the software. The next step is the aligning process, which functions to set the basic orientation of the acquired photos. After aligning, the next stage is inputting Ground Control Point (GCP) data, which serves to bind the coordinate data to the acquired aerial photos. Once the GCP input is successful, the next step is creating the Dense Cloud. This process ensures that all the data acquired through aerial photos are identified with their ground coordinates. Upon closer inspection, the Dense Cloud can visually be considered as pre-contour data, as it consists of densely packed points with coordinates. The next step in the process is the creation of the Triangular Irregular Network (TIN), which generates DEM data from the processed Dense Cloud. This DEM data become the base data for generate contour modelling.

The Cut & Fill design modeling based on geotechnical data begins with inputting the results from the previous stage, which includes contour data of the mining permit area (IUP) obtained from aerial photo processing. This contour data is then combined with geotechnical data on soil strength provided by the company. Both datasets are are calculated, where the Cut & Fill design boundaries for the IUP area and the slope design for the mining area are planned.

Geotechnical data is generally obtained by sampling soil from the IUP area using disturbed and undisturbed soil sampling methods. Disturbed samples are taken directly after excavation at designated sampling points for testing. For undisturbed samples, the aim is to preserve the soil's natural shape and structure. This is done by digging into the surface to a certain depth and then using a wax-lined tube to penetrate the dug point, ensuring the soil sample remains intact without significant alteration.

Once all soil samples are collected, they are tested in a Geotechnical Laboratory, where variables such as shear strength, consolidation, drainage, physical properties, particle gradation, plasticity, and density are measured. This is essential to ensure that the final slope design, once implemented, will remain stable and prevent landslides.

The revised slope design obtained then applied to update the slope and Cut & Fill designs previously created. Once revised, Next, the calculation process is carried out to estimate the total volume of soil that can be excavated and the base area of the mining site that can be developed into residential housing. This data becomes crucial in assisting the economic profit analysis of both the mining excavation investment and operational project, as well as the property development project.

The analysis of the total potential economic profit from the sale of soil material begins with a literature review on the stages of investment and operational processes for mining, specifically for soil excavation and fill. Next, the results from the previous stage, namely the Cut & Fill Design modeling that incorporates geotechnical data, This allows for the full visualization of the excavation and fill boundary areas.

Once the visual model of the mining boundaries is generated, the volume difference between the original contour and the Cut & Fill design is calculated. This volume difference becomes essential data for estimating initial investment costs and operational expenses. As previously mentioned in the data subsection, investment and operational costs each have their detailed components. All these factors are calculated and summed, followed by an analysis of revenue and economic feasibility to determine the total potential profit from the mining process comprehensively.

The analysis of the total potential economic profit from residential sales begins with a literature review on the stages of investment and operational processes for housing, particularly regarding the rules and regulations related to housing development projects. Next, the results from the previous stage, specifically the Cut & Fill Design modeling that incorporates geotechnical data, become the base data for a comprehensive visualization of the excavation and fill boundary areas.

Once the visual model of the mining boundaries is obtained, the area that will emerge after the Cut & Fill process is calculated. After obtaining the area and its boundaries, the next step is to create a master plan for the residential area. The output of this master plan serves as essential data for estimating initial investment costs and operational expenses. As mentioned earlier in the data subsection, both investment and operational costs have their detailed components. All these factors are calculated and summed, followed by an analysis of revenue and economic feasibility, enabling a comprehensive calculation of the total potential profit from the housing process.

3 Results and Discussion

This modeling produced data in the form of contour data maps that serve as the database of this research. This modeling process is carried out to produce accurate and detailed contour maps, which are an important basis for planning cut & fill projects and land development in Parangloe District, Gowa Regency.

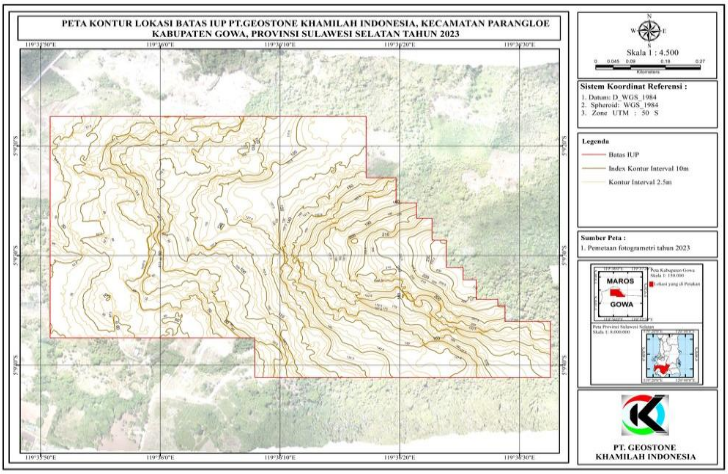

Fig. 2. Contour Data Map Modeling Results from Drone Imagery

The orthophoto data generated from UAV-photogrammetry is processed into contour maps with a contour interval of 10 meters, but the database results from drone image processing have a Digital Elevated Model accuracy of 18.2 Cm/pixel. This contour map provides a clear picture of elevation variations across the 69.9 hectare survey area.

The resulting contours show significant elevation variations in some parts of the land, with the highest elevation reaching 270 meters in the western part of the IUP, and the lowest elevation at 30 meters in the eastern part of the IUP. This visualization is critical in determining the cut & fill strategy and identifying areas that may require special handling.

Ground Control Points

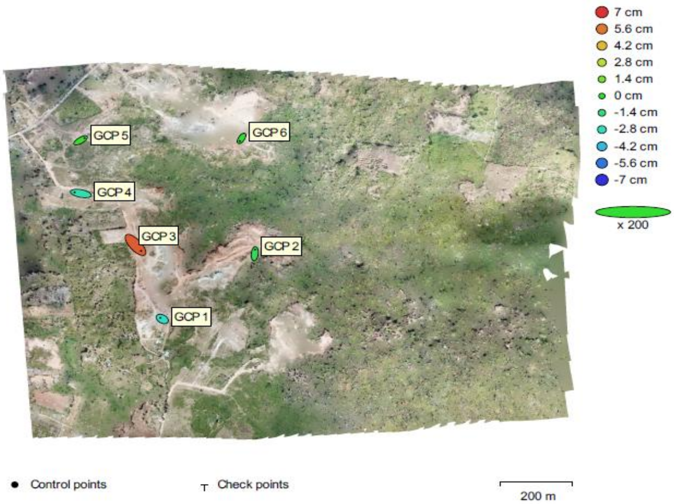

Fig. 3. GCP locations and error estimates.
Z error is represented by ellipse color. X,Y errors are represented by ellipse shape.
Estimated GCP locations are marked with a dot or crossing.

Count	X error (cm)	Y error (cm)	Z error (cm)	XY error (cm)	Total (cm)
6	10.8258	10.2785	2.98778	14.9281	15.2241

Table 3. Control points RMSE.
X - Longitude, Y - Latitude, Z - Altitude.

Fig. 3. Orthophoto Data Report Result

In the next stage, the contour data & boundaries of the IUP area are correlated with geotechnical data that has been obtained from field testing, this is necessary so that the cut & fill design made is not prone to landslides and does not cross the IUP area. IUP boundary & geotechnical data that have been taken in the field are as follows:

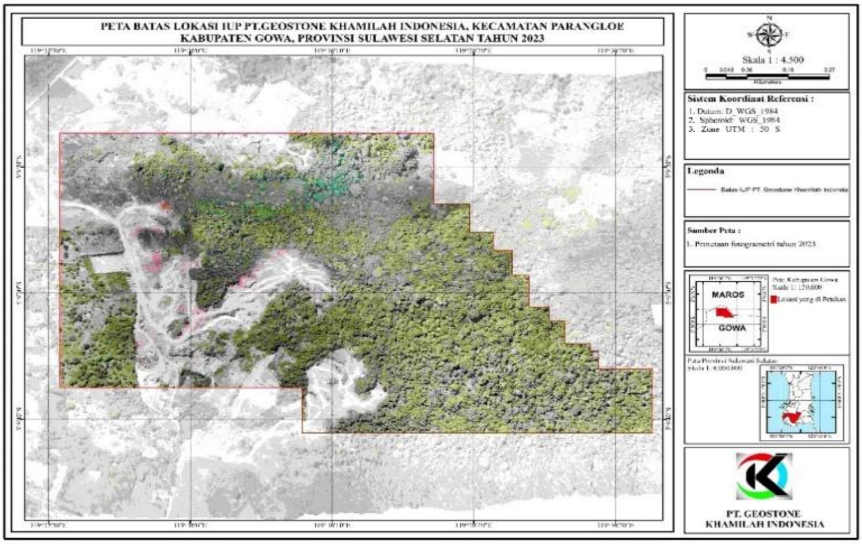

Fig. 4. IUP Boundary Map of PT.Geostone Khamilah Indonesia

Table 1. Geotechnical Testing Results of Soil Sample

Parameter	Sampel 1	Sampel 2	Sampel 3
Weight Density (kN/m3)	13.827 kN/m3	12.062kN/m3	12.062kN/m3
Cohesion Value (kPa)	28.38 kPa	32.39 kPa	119.72 kPa
Internal friction angle of Direct Shear (Φ)	83.41°	82.92°	81.62°

This correlation allows the identification of areas with potential geotechnical problems, such as landslide-prone soils or areas with low bearing capacity. Thus, contour maps serve not only as a topographic visualization tool, but also as an analytical tool that assists in planning safer and more effective mitigation measures and land development strategies, in the form of mine slope design to be applied for cut & fill planning.

For the design of the cut & fill mine area, it is necessary to design the basic dimensions of a slope that is stable and not prone to landslides. In the process of making the design dimensions of this slope requires some data, including the highest elevation data of the soil in the IUP location, and geotechnical data of soil samples in the research location. From this data, the design of the slope section applied in this research is made, and its stability is corrected through the Rocscience Slide application.

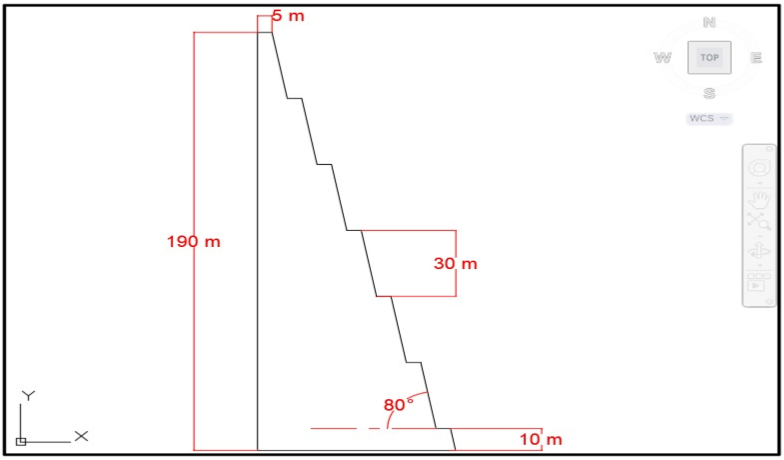

Fig. 5. Design and Dimensions of Slope Cuttings

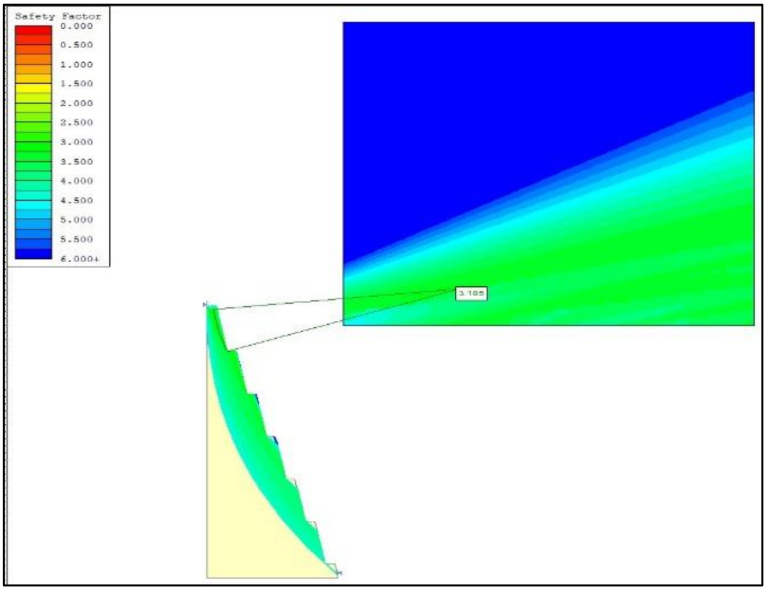

Fig. 6. Results of Slope Design Stability Values

When the design of the slope design form and its stability value have been obtained, the slope design form planning is then applied to the IUP area boundary using the Surpac application so that the overall shape of the mining area and the volume of mineable soil can be seen as a whole along with the volume of mineable area.

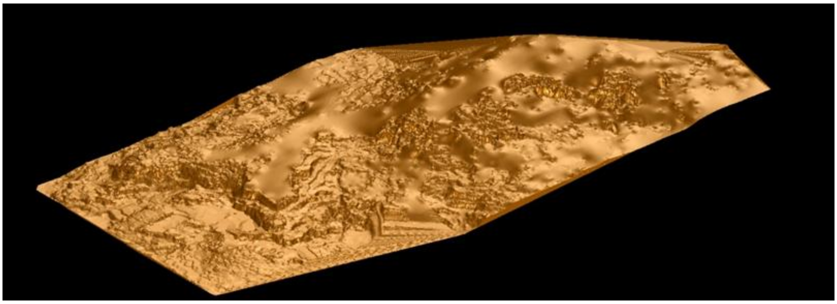

Fig. 7. IUP Area Before Slope Design is Implemented

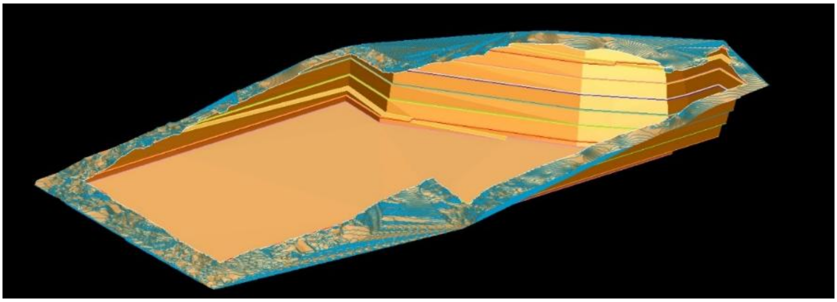

Fig. 8. IUP Area After Slope Design is Implemented

From the calculation of the difference between the initial contour and the final contour of the mining plan, the planned volume of mine excavation is 32,265,263 m3.

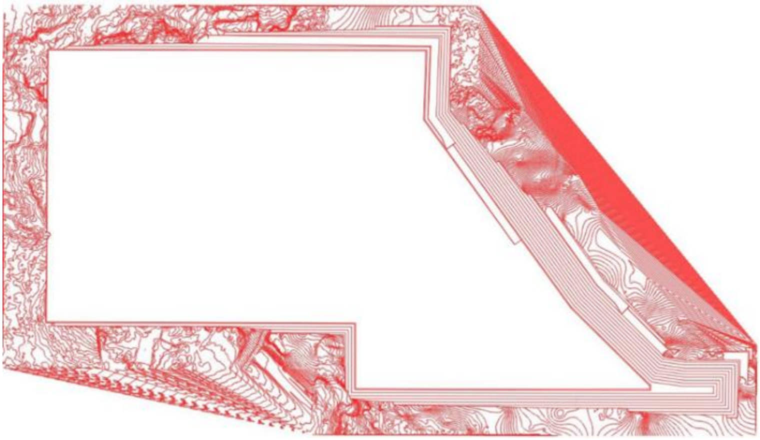

Fig. 9. Contour Line of Mining Area

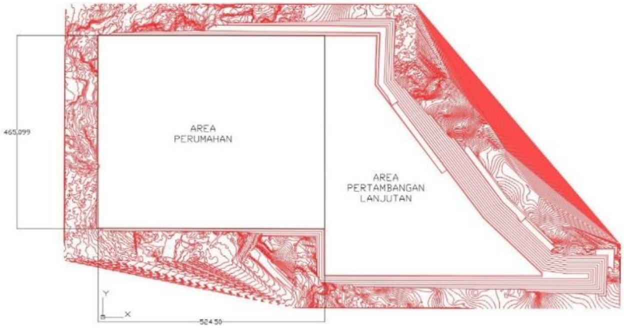

Fig. 10. Residential Area Planning Boundary Line

It can be seen from the picture, the planned housing area has a length of 524.90 m and a width of 465.09 m, so the area to be built housing is 243,794 m2.

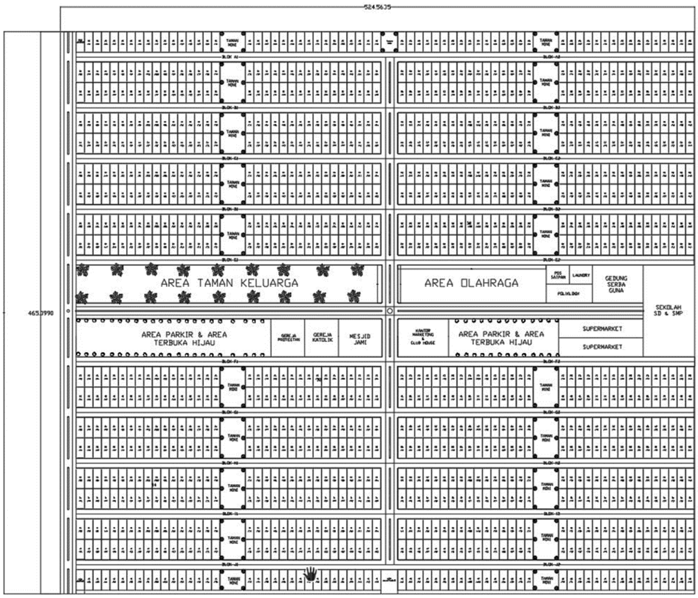

Fig. 11. Residential Siteplan Plan Result

Analysis of investment and operational costs of housing construction is the first step in assessing the feasibility of this project. Investment costs include basic land administration costs. Table.3 presents details of investment costs that have been estimated based on the 2024 Analysis of Unit Price of Work (AHSP) guidelines, the project is assumed to be implemented starting in 2023 until completion in 2034 with an inflation factor of 3.5% and a Discount Rate (BI Rate) value of 6%.

Table 2. Details of Basic Cost of Residential Construction Investment

Year	Investment Permits and Land Administration
2023	Rp 10,178,063,286

Table 3. Breakdown of Annual Operating Costs of Residential Construction

Year	Building Construction	Public Facilities construction	Corporate Social Responsibility	Office Workers & Utilities	Promotion Costs	Total
2024	Rp 34,460,744,049	Rp 9,441,426,928	Rp 208,600,000	Rp 183,000,000	Rp 1,685,544,481	Rp 45,979,315,458
2025	Rp 35,666,870,090	Rp 9,771,876,870	Rp 215,901,000	Rp 189,405,000	Rp 1,744,538,538	Rp 47,588,591,499
2026	Rp 36,915,210,544	Rp 10,113,892,561	Rp 223,457,535	Rp 196,034,175	Rp 1,805,597,387	Rp 49,254,192,201
2027	Rp 38,207,242,913	Rp 10,467,878,800	Rp 231,278,549	Rp 202,895,371	Rp 1,868,793,295	Rp 50,978,088,928
2028	Rp 39,544,496,415	Rp 10,834,254,558	Rp 239,373,298	Rp 209,996,709	Rp 1,934,201,061	Rp 52,762,322,041
2029	Rp 40,928,553,789	Rp 11,213,453,468	Rp 247,751,363	Rp 217,346,594	Rp 2,001,898,098	Rp 54,609,003,312
2030	Rp 42,361,053,172	Rp 11,605,924,339	Rp 256,422,661	Rp 224,953,725	Rp 2,071,964,531	Rp 56,520,318,428
2031	Rp 43,843,690,033	Rp 12,012,131,691	Rp 265,397,454	Rp 232,827,105	Rp 2,144,483,290	Rp 58,498,529,573
2032	Rp 45,378,219,184	Rp 12,432,556,300	Rp 274,686,365	Rp 240,976,054	Rp 2,219,540,205	Rp 60,545,978,108
2033	Rp 46,966,456,855	Rp 12,867,695,771	Rp 284,300,388	Rp 249,410,216	Rp 2,297,224,112	Rp 62,665,087,342
2034	0	0	Rp 294,250,901	Rp 258,139,573	Rp 2,377,626,956	Rp 2,930,017,431

Table 4. Projected Revenue from Sales of Residential Units

Net Profit						
Year	Expenditure	Income	Net income	Tax Cuts	Net Income After Tax	Accumulated Net Income
2023	Rp 10,178,063,286.25	Rp -	-Rp 10,178,063,286.25	Rp -	-Rp 10,178,063,286.25	-Rp 10,178,063,286.25
2024	Rp 45,979,315,457.73	Rp -	-Rp 45,979,315,457.73	Rp -	-Rp 45,979,315,457.73	-Rp 56,157,378,743.98
2025	Rp 47,588,591,498.75	Rp 68,976,812,049	Rp 21,388,220,549.81	Rp 6,266,466,164.94	Rp 15,121,754,384.87	-Rp 41,035,624,359.11
2026	Rp 49,254,192,201.20	Rp 71,391,000,470	Rp 22,136,808,269.05	Rp 6,491,042,480.72	Rp 15,645,765,788.34	-Rp 25,389,858,570.78
2027	Rp 50,978,088,928.24	Rp 73,889,685,487	Rp 22,911,596,558.47	Rp 6,723,478,967.54	Rp 16,188,117,590.93	-Rp 9,201,740,979.85
2028	Rp 52,762,322,040.73	Rp 76,475,824,479	Rp 23,713,502,438.01	Rp 6,964,050,731.40	Rp 16,749,451,706.61	Rp 7,547,710,726.76
2029	Rp 54,609,003,312.16	Rp 79,152,478,336	Rp 24,543,475,023.34	Rp 7,213,042,507.00	Rp 17,330,432,516.34	Rp 24,878,143,243.10
2030	Rp 56,520,318,428.08	Rp 81,922,815,077	Rp 25,402,496,649.16	Rp 7,470,748,994.75	Rp 17,931,747,654.41	Rp 42,809,890,897.51
2031	Rp 58,498,529,573.07	Rp 84,790,113,605	Rp 26,291,584,031.88	Rp 7,737,475,209.56	Rp 18,554,108,822.32	Rp 61,363,999,719.83
2032	Rp 60,545,978,108.12	Rp 87,757,767,581	Rp 27,211,789,473.00	Rp 8,013,536,841.90	Rp 19,198,252,631.10	Rp 80,562,252,350.93
2033	Rp 62,665,087,341.91	Rp 90,829,289,446	Rp 28,164,202,104.55	Rp 8,299,260,631.37	Rp 19,864,941,473.19	Rp 100,427,193,824.12
2034	Rp 2,930,017,430.84	Rp 104,975,951,278	Rp 102,045,933,846.91	Rp 30,463,780,154.07	Rp 71,582,153,692.84	Rp 172,009,347,516.95
Total Net Income						Rp 182,187,410,803.21

To determine the economic feasibility of this housing construction project, several key financial indicators are used: Net Present Value (NPV), Internal Rate of Return (IRR), Payback Period, and Profitability Index (PI).

1. Net Present Value (NPV): NPV is calculated by discounting all cash inflows (revenues from unit sales) and cash outflows (investment and operational costs) to the present value using a relevant discount rate. If the NPV is positive, the project is considered financially viable. In this case, a discount rate of 6% was used, and an NPV of Rp90,750,227,323.54 was obtained, indicating that the project is financially feasible.
2. Internal Rate of Return (IRR): IRR is the rate of return generated by the project. If the IRR exceeds the discount rate used, the project is considered profitable. Based on the calculations, an IRR of 24.32% was obtained, indicating that the project is more profitable than the discount rate applied.
3. Payback Period: The Payback Period shows the time required to recover the initial investment from the cash flows generated. In this case, the Payback Period is calculated to be 4.62 years, indicating that the project can recover the capital in a relatively short period.
4. Profitability Index (PI): PI is the ratio of the present value of cash inflows to the initial investment. If PI is greater than 1, the project is considered viable. In this

calculation, a PI of 8.92 indicates that every Rp1 invested generates a return of Rp8.92, further confirming the economic feasibility of the project.

Table 5. Summary of Evaluation of Economic Feasibility of Housing Projects

Investment Feasibility Indicators	Value	Conclusion
NPV	Rp 90,750,227,323.54	Eligible
IRR	24.32%	Eligible
Payback Period	4.62	Eligible
Profitability Index	8.92	Eligible

4 Conclusion

Based on the research findings, the orthophoto data processing produced a DEM accuracy of 18.2 cm/pixel, with an RMSE value of 15.22 cm, ensuring reliable topographic data for further analysis. The slope stability evaluation, supported by geotechnical testing, yielded a safety factor of 3.185, indicating that the site is safe for development. Additionally, the Cut & Fill modeling revealed a total excavatable soil volume of 32,265,263 m^3, while the site plan indicated a construction-ready area of 243,974 m^2, sufficient for 1,214 housing units.

The investment feasibility analysis confirmed the financial viability of the project, yielding an NPV of IDR 90.75 billion, an IRR of 24.32%, a Payback Period of 4.62 years, and a Profitability Index of 8.92. These results demonstrate that transitioning from mining operations to residential property development is both technically feasible and economically profitable.

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