Economic Assessment of Medium and Large-Scale Landfill Mining Business: Case Study Thailand

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Abstract. Thailand produces over 25 million tons of waste yearly, while only a third is utilized. The waste disposed of in the landfill is rarely utilized, and research on the utilization of landfill waste in Thailand is limited. The information regarding the business model and the profitability rate of landfill mining is limited and generally was not displayed to the public. This paper examined the landfill mining business of medium and large-scale businesses in Thailand. Both sites' business operations were analyzed, and the net present value was presented. The NPV results show that landfill mining is profitable and gives more sustainable waste management. The large scale is highly profitable but requires more investment extensively, while the medium scale is easily adopted and still provides a reasonable profit. Furthermore, to understand the business operation and sensitivity of the operation, this paper uses sensitivity analysis to analyze the factors influencing business profitability. Even though the result displays that both projects are easily profitable, the large-scale operation tends to be simpler as the expense has a lower influence on the business.

Keyword. Landfill mining, Municipal solid waste, Net-present value, Refuse-derived fuel, Sensitivity analysis

1 Introduction

In recent years, the circular economy has been closely linked to the concepts of zero waste and waste utilization. The circular economy aims to create a closed-loop ecosystem where resources are effectively consumed and utilized through the principles of reduce, reuse, and recycle [1]. This paradigm challenges the traditional linear economy and emphasizes the need to minimize waste generation and maximize resource efficiency [2]. Zero waste is a key objective of the circular economy, aiming to eliminate waste by recirculating it back into production and consumption processes [3]. By adopting circular economy principles, waste can be transformed into valuable resources, contributing to the sustainable management of resources and reducing environmental impacts [4]. Waste utilization plays a crucial role in the circular economy. It involves finding innovative ways to repurpose and extract value from waste materials.

Over the past decade, municipal solid waste (MSW) management has become increasingly concerning for many countries, including Thailand. Thailand's solid waste has been increasing by an average of 10% annually. According to studies, the country generated 27.8 million tons of waste in 2018, with approximately 20.8 million tons disposed of in landfills. The overreliance on disposal in landfills has led to a shortage of landfill space [5], which has led to the government encouraging the adoption of waste-to-energy facilities to address waste challenges. As a result, Thailand has experienced growth in incineration plants and waste-to-energy facilities in recent years. Increasing solid waste has created the need to explore more efficient and sustainable management approaches, such as landfill mining (LFM). To mitigate the strain on landfill space and reduce environmental impacts, LFM has been proposed as a potential solution.

LFM is a process that involves the excavation and sorting of waste materials in landfills to recover valuable resources. The concept of LFM was initially introduced in Tel Aviv, Israel, in 1953, where it was primarily used to mine soil-like materials for fertilizer in orchards. In the 1990s, LFM gained attention as a strategy for material recovery and received a significant promotion in the United States [6,7]. However, it gained little popularity due to the challenges associated with extracting valuable materials from the mined waste. Optimizing the excavation of waste is a key consideration in LFM. Since waste in landfills consists of diverse materials, each with its characteristics, researchers are actively exploring various processes and

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technologies to enhance the profitability of LFM projects. The goal is to identify efficient methods for extracting valuable materials and maximizing their recovery. By optimizing the excavation and sorting processes, LFM has the potential to reduce the environmental impact of landfills, contribute to resource recovery, and promote a more sustainable approach to waste management. Ongoing research and development efforts are focused on improving the efficiency and effectiveness of LFM techniques to maximize this approach's economic and environmental benefits.

LFM has been defined as an environmentally friendly technology that combines material recycling and sustainable waste management [8]. The key advantage of LFM is the potential for materials recycling and the reclamation of land [9]. LFM is a concept that is gaining popularity globally due to its potential to provide resources and minimize waste in landfills. LFM involves excavating materials when the landfill is still operational or after it has been filled and capped with a protective layer. Materials that can be reused are sorted and processed, while the remainder is disposed of in a regulated landfill. This translates to a reduction in landfill waste and its associated problems.

LFM has many benefits, which make it a viable solution to the problem of solid waste management in Thailand. LFM creates space and reduces the amount of waste in landfills, serves as a source of recycling materials, reduces greenhouse gas emissions, and can contribute to the restoration of the land. LFM enables waste to become a resource, which can be used to generate energy and minimize the need for natural resources. In addition, LFM can also create job opportunities for communities surrounding landfill sites.

However, research on LFM in Thailand is limited, and only a few studies are on the subject. One of the methods used to evaluate the feasibility of LFM projects is the net present value (NPV) analysis [10]. The NPV is the sum of the present value of cash inflows and outflows over a defined period using a predetermined discount rate. The NPV determines the feasibility and profitability of investments and can be implemented in other LFM projects [11]. The discounted cash flow technique is employed in NPV, which accounts for the time value of money. NPV is used to evaluate long-term investments in diverse industries, including LFM. The application of NPV in waste management involves forecasting future cash flows, including revenue stream, discount rate, and capital expenditure for the project. It can be useful in conducting feasibility studies and assessing the potential profitability of an LFM project [12 -14].

Several studies have utilized NPV analysis to evaluate the economic viability of landfill mining projects. For example, research conducted in Belgium examined the NPV values of different landfills, with some demonstrating economic viability while others had negative NPV values [10]. Similarly, a study in China assessed the NPV of a landfill mining project and found that it could yield positive net benefits, although the NPV was sensitive to factors such as land reuse and financial support [5]. In landfill mining research, NPV analysis is often used with other assessment methods to provide a comprehensive evaluation. For instance, a holistic assessment method was developed to evaluate landfill mining projects, incorporating both monetary factors (such as costs and proceeds) and non-monetary factors (such as environmental impact and stakeholder concerns) [15]. This integrated approach allows for a more robust evaluation of landfill mining projects' economic and environmental performance.

Sensitivity analysis is a valuable tool in assessing the financial viability and risk associated with landfill mining (LFM) businesses. It allows for the examination of how changes in key variables and assumptions impact the financial outcomes of the project. By conducting sensitivity analysis, researchers and stakeholders can gain insights into the robustness of the financial model and identify the factors that have the most significant influence on the profitability of LFM projects. In the context of LFM, sensitivity analysis can be applied to various financial aspects of the business. For example, it can explore the sensitivity of the net present value (NPV) to changes in factors such as waste composition, market prices of recovered materials, operational costs, and discount rates. By varying these parameters within a range of plausible values, sensitivity analysis can provide a comprehensive understanding of the financial risks and opportunities associated with LFM. A case study conducted on enhanced landfill mining at the Mont-Saint-Guibert landfill in Belgium highlighted the importance of valorization routes for the outputs of LFM [8]. Sensitivity analysis can be used to assess the impact of different valorization routes on the financial performance of the LFM business. It can help identify the most profitable and sustainable pathways for material and energy recovery from landfill-mined materials.

Furthermore, sensitivity analysis can also be applied to evaluate the financial feasibility of energy production from landfill-mined materials. The financial viability of energy recovery from landfill-mined materials can be assessed by conducting a sensitivity analysis on factors such as energy conversion efficiency, electricity prices, and operational costs.

This research compares the NPV of two LFM projects in Thailand: large-scale and mid-scale.

2 Materials and methods

This research collected data from two waste disposal sites that engage in landfill mining and produce refuse-derived fuel (RDF) from old waste. Site A’s first site is the Integrated Solid Waste Management Centre in Phraek Sa Mai Subdistrict, Samutprakarn province.

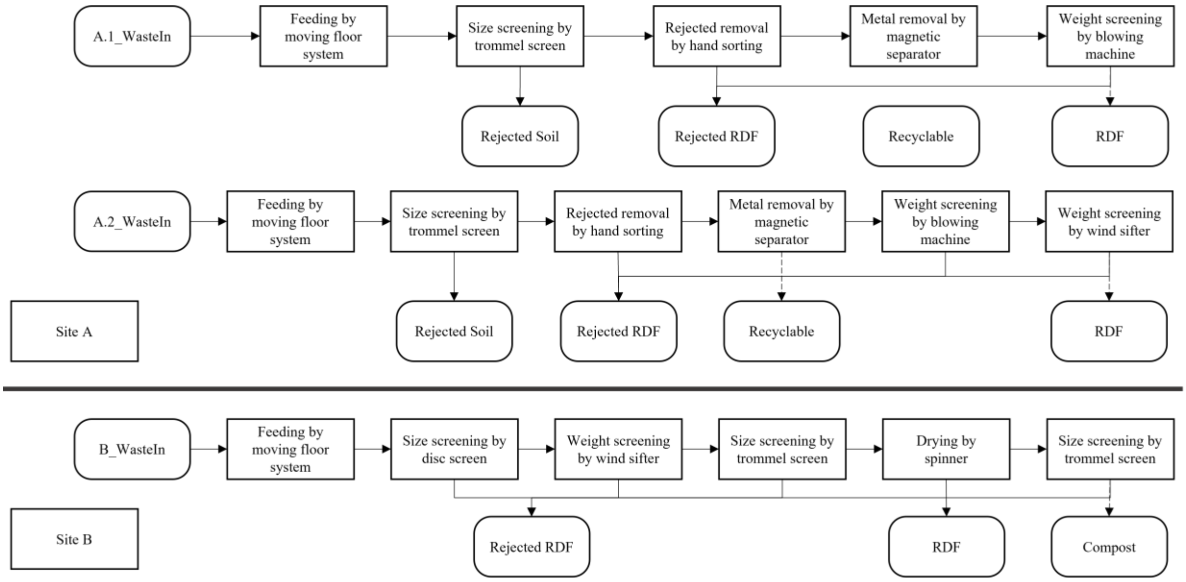

Fig. 1. The process of sorting landfill waste of study sites A (top) and B (bottom).

Operated by Eastern Energy Plus Company Limited, this site receives over 2,500 tons of municipal solid waste daily and deposits it into landfills. Old waste is excavated and used to produce RDF, which is then transported to a waste-to-energy (WtE) power plant operated by Ratchaburi Renewable Energy Company Limited. The plant generates 9.9 megawatts of electricity and sells eight megawatts to the Metropolitan Electricity Authority. This large-scale project has an investment of THB 2.3 billion (USD 66.26 million).

The second site, Site B, is the Sanitary Landfill Solid Waste Disposal Site in Chanthaburi Municipality, Chanthaburi province. This site manages 250 tons of municipal solid waste daily and disposes of it in a sanitary landfill. Old waste separation occurs at this site, producing RDF that is sold to a cement company as a substitute for coal. A private company was given the right to operate by the Chanthaburi Municipality, which manages the sanitary landfill and old waste separation process. Therefore, the municipality has invested in the landfill and part of the structure. Compared to Site A, Site B only consisted of THB 163 million (USD 4.7 million).

2.1 Process description

At both Site A and Site B, landfill mining involves using excavators to extract waste from the landfill. The excavated waste is transported to an in-house sorting facility using 10-wheel trucks. To determine the mining area, both sites rely on historical data on waste disposal, specifically targeting landfill waste over five years old. At site A, the sorting facility is equipped with a range of sorting machines, most of which are designed and fabricated in-house. The facility consists of six sorting lines divided into two sets. The first set comprises two sorting lines, while the second set comprises four sorting lines. Figure 1 illustrates the process of the first set. The process begins with the excavation machines feeding the landfill waste into the sorting lines. The waste then undergoes a screening process using a Trommel screen with a screening size of two inches. This process separates the waste into different fractions. The heavy fraction, "rejected soil," is collected and set aside. Next, the waste goes through a hand sorting process, where employees manually remove plastic bags larger than 50 cm x 50 cm and recyclable materials such as tires and wood. The removed plastic bags are considered rejected refuse-derived fuel (RDF). Metal materials are separated using a magnetic separator called the "recyclable." After the hand sorting process, the waste is passed through a blower to remove the heavy fraction mixed with the rejected RDF. The final product obtained from this process is known as refuse-derived fuel (RDF), utilized in the power plant. The process of the second set of sorting lines is like that of the first set, with one additional step. In the final step of the second set, a wind sifter is introduced to remove smaller heavy fractions from the product.

Overall, Sites A and B employ similar methods for landfill mining, utilizing excavators and in-house sorting facilities. However, there are slight variations in the sorting processes, particularly in the final steps of the second set at site A, where a wind sifter is used to refine the product further.

Figure 1 presents the sorting process at site B's landfill. In contrast to site A, the components of the sorting machine are purchased abroad and imported. While the operations at the two sites are similar, the second site's process is more concise, featuring a single sorting line that involves size screening using a disc-screening machine, removal of the heavy fraction through a wind sifter, another round of size screening using a trommel screen, a drying process utilizing a spinner, and a small trommel screen. The screening and wind-sifting processes yield rejected RDF as a by-product, while the product generated from the spinner process is RDF. Additionally, the small trommel screen produces compost. Personal communication with waste management company officials. Diagram created based on observations and site visits to the waste disposal facilities.

The major difference between sites A and B is the utilization of their products. Site A operates as a full cycle waste management having its waste-to-energy power plant, with a production capacity of 9.9 MW and export capacity of 8 MW. The RDF produced in site A is transported to their power plant facility 100 meters from the sorting plant. This helps generate more revenue streams for site A. In contrast, site B's RDFs are sold and transported to another third-party facility. Thus, making the revenue stream of site B is much less than that of site A.

2.2 Net-present value

Net Present Value (NPV) is an analytical method used to assess the financial viability of a project or investment by calculating the present value of its projected cash flows. NPV considers both the timing and magnitude of these cash flows and discounts them back to the present using an appropriate discount rate. The result is a single value, either positive or negative, that represents the net value or profitability of the project. To calculate NPV, the project's future cash flows are estimated, including income and expenses, over the project's lifespan. These cash flows are then adjusted for the time value of money by discounting them back to the present using the chosen discount rate. The discount rate represents the required rate of return or the opportunity cost of investing in the project. It considers factors such as inflation, risk, and the cost of capital. The formula for NPV is as follows:

$$\mathrm{NPV} = \frac{R_t}{(1 + i)^t} \tag{1}$$

Thus, *NPV* is net present value; *n* is the calculated duration of the project (20 years for this research); *t* is the year; R_t is the net cash flow at time *t*; and *i* is the social discount rate. The conservative discount rate of 9% was used in the model. In addition, an inflation rate of 3% per year was selected.

The NPV calculation considers all cash flows associated with the project, including initial investment costs, regular income or savings, and any additional one-time costs or benefits. By summing up the discounted cash flows and subtracting the initial investment, we obtain the NPV. If the NPV is positive, it indicates that the project is expected to generate more value than the cost of investment and may be considered financially viable. Conversely, a negative NPV suggests that the project may need to deliver more returns to justify the investment.

In this research, the operational data of both sites was collected using the 2022 data. This research classification distinguishes capital investments and operating expenses, with operating expenses further categorized into cash flows relating to investment and operational expenses. Operational expenses can be further divided into process and material flow-related cash flows. Table 1 provides an overview of the relevant economic parameters for LFM based on this classification, including an additional "liquidation" category. The table differentiates between fixed and variable parameters to indicate their dependency on the amount of material being mined.

Capital investments in LFM encompass the costs associated with establishing the landfill mining process, such as purchasing machinery, plants, or buildings. They also include one-time expenditures incurred before the project commences, such as planning facilities or the entire LFM project. Regular maintenance, repair, insurance, taxes, and administration expenses are necessary for purchased machinery or facilities, with their amounts directly linked to the corresponding capital investment. Liquidations refer to one-time cash flows at the end of an LFM project. Positive liquidation cash flows can arise from the sale of used machinery or plants and the marketing of recovered land or landfill airspace. Conversely, negative cash flows may be incurred for removing plants and infrastructure used for landfill closure and aftercare.

The variable terms in LFM are influenced by the quantity and quality of the material, as well as the intensity of the process. Positive cash flows related to material flow result from product sales, while negative cash flows arise from purchasing operating supplies and energy, residue disposal, material transport, and storage. Negative cash flows dependent on process intensity include repair and maintenance costs (linked to material throughput), wages, and aftercare for landfill segments that have not yet been excavated

Table 1. Economic Parameters for economic assessment.

Fixed parameters	Variable parameters
Capital investment - Project development	*Capital investment* - Machines, plants, buildings, etc.
Investment-related cash flows - Insurance, taxes - Administration	*Process-related cash flows* - Repair and maintenance - Salary expense - Recover space value - Diesel expense
Liquidation - Value of the capital injection - Site preparation and aftercare	*Material flow-related cash flows* - Sales of products (RDF and electricity) - Tipping fees

2.3 Sensitivity analysis

Sensitivity analysis plays a crucial role in evaluating and assessing the factors and parameters influencing landfill mining businesses' financial viability and environmental impact. By conducting sensitivity analysis, researchers and practitioners can gain insights into the key variables that significantly affect the outcomes and make informed decisions based on this information.

One study applied scenario modeling and sensitivity analysis to assess the critical factors for the climate impact of landfill mining [7]. The research identified four factors, including landfill gas management, background energy system, excavated waste composition, and waste combustion technology, that significantly influenced the net contributions to global warming. Furthermore, sensitivity analysis can also examine landfill mining projects' economic feasibility and profitability. Research conducted a cost-benefit analysis of China’s landfill mining project and found that the net present value (NPV) was sensitive to factors such as the mode of land reuse, availability of energy recovery facilities, and financial support [5].

A cost simulation model for landfill mining could be developed using a sensitivity analysis to assess the economic feasibility of recovering secondary raw materials from landfills [16]. The results indicated that the profitability of landfill mining projects depended on factors such as the amount of recoverable secondary raw materials. Sensitivity analysis can also aid in decision-making regarding landfill site selection in the context of waste management.

This research conducted a sensitivity analysis using the capital investment, salary, RDF expense, diesel consumption, income from tipping fees, the recovered space, and the RDF income to conduct the sensitivity analysis and determine the factor with the highest impact on each site.

3 Results and discussions

NPV results show that both sites are currently profitable. The large-scale operation has extensively more investment but also has a higher NPV at THB 3 billion, compared to the medium scale of THB 224 million. The major difference in their profitability is from the large-scale income from the WtE powerplant and the tipping fees of up to 3,000 tons per day. In contrast, the medium-scale site has income from only 250 tons of MSW per day and no income from the WtE powerplant.

Income from the WtE powerplant consisted of THB 243 million per year on average, while Site B can only gain an average of 31 million per year from RDF. Moreover, as Site B is further away from the capital city, their tipping fee is approximately two-thirds of Site A, and the waste is only one-tenth of Site A. The tipping fee of Site A generates an average income of THB 580.4 million per year over the course of 20 years and only THB 36.3 million per year for Site B. Furthermore, as Site A is closer to the capital city of Thailand and is within the developed area of their province, the recovered space value is higher than Site B.

Furthermore, the landfill operation expense does not increase proportionally to the waste amount or income. Figure 2 depicts the profit and expense allocation of landfill operations of Site A and B. Site A spent an average of THB 67.7 million per year on their landfill operation, which is 11.66% of their income from landfill operation. Compared to site B’s spending of THB 20.8 million per year, which is 57.26% of their income from landfill operation.

The sensitivity analysis results of sites A and B, as depicted in Figures Figure 3 and Figure 4, provide valuable insights into the profitability and risk factors associated with the respective landfill mining projects. The sensitivity of 8 factors is analyzed: capital expense (CAPEX), salary expense, diesel expense, MSW income, space recovery value gained, RDF income, RDF expense, and kHw income. Each factor is selected following the economic parameters mentioned in Table 1.

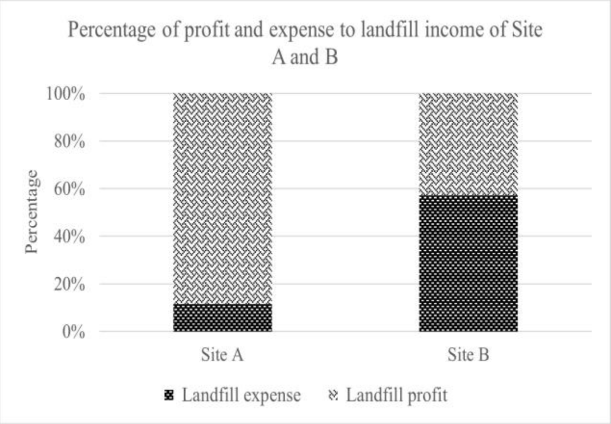

Fig. 2. Graph displaying the expense allocation to income for Site A and B landfill operation.

In the case of Site A, a large-scale landfill mining project, the income generated from municipal solid waste (MSW) tipping fees emerges as a significant driver of project profitability. This finding suggests that the project’s financial success is highly dependent on the revenue generated from waste disposal. Following MSW tipping fees, the factors influencing profitability in descending order are kWh income, capital expenditure (CAPEX), space recovery value, salary, RDF (refuse-derived fuel) expense, RDF income, and diesel consumption.

The sensitivity analysis reveals that operating a large-scale landfill mining project with a waste-to-energy (WtE) power plant is particularly sensitive to the income derived from waste disposal and the power plant’s performance. Conversely, the impact of normal operating expenses is relatively less significant. These findings highlight the importance of effectively managing waste disposal income and optimizing the power plant's performance to ensure the financial viability of the large-scale project.

In contrast, Site B, a medium-scale landfill mining project, exhibits a different sensitivity profile. Interestingly, both the income from MSW tipping fees and RDF income demonstrate similar levels of sensitivity. The project at Site B is highly sensitive to all factors considered in the analysis, with the sensitivity ranking as follows: MSW tipping fee, RDF income, space recovery value, CAPEX, diesel consumption, and salary. Given that the operator’s primary income sources are the tipping fee and the sale of RDF, the diesel consumption rate becomes a critical factor. Additionally, due to the smaller scale of the project compared to Site A, the investment demonstrates a higher rate of effectiveness in terms of project feasibility.

The results indicate that despite differences in business scaling and the amount of incoming waste, both Site A and Site B have the potential to generate positive revenue. However, due to the lower volume of incoming waste, Site B needs to focus more on managing operating expenses than Site A. Furthermore, as Site B relies on only two sources of income, namely RDF sales and tipping fees, both revenue streams are equally important and require careful consideration. In comparing both sites, if Site B adopted a WtE power plant, the income generated would be more secure, and the effective rate of diesel consumption would be significantly reduced. This highlights the potential benefits of incorporating a WtE power plant in Site B's operations, as it would enhance revenue stability and improve overall project feasibility.

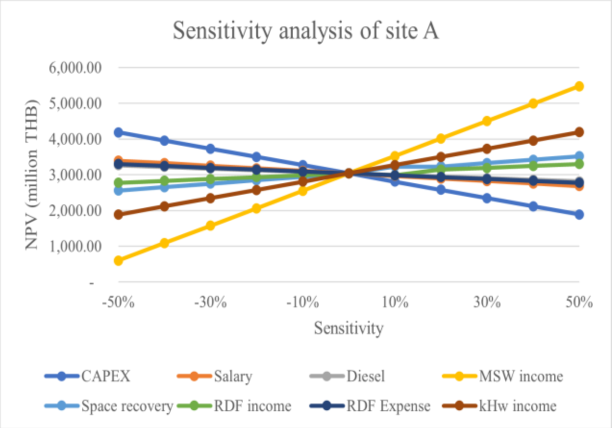

Fig. 3. Sensitivity analysis of Site A, including the WtE power plant on site.

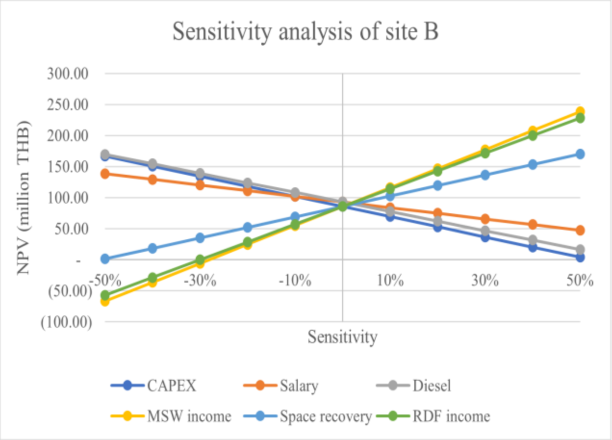

Fig. 4. Sensitivity analysis of Site B, having no WtE power plant, RDF is sold to a cement plant.

It is important to note that these findings are based on the sensitivity analysis conducted, and actual results may vary. However, the analysis provides valuable insights into the key factors influencing the profitability and risk of the landfill mining projects at both sites, aiding decision-making and strategic planning for the successful implementation of such ventures.

4 Conclusion

This study utilized the Net Present Value (NPV) and sensitivity analysis to examine the profitability of two landfill mining projects, one of medium scale and the other of large scale. The objective was to identify the key factors that influence the financial viability of these projects and assess their vulnerability to operational factors. The findings of the study indicate that both medium-scale and large-scale landfill mining projects are profitable. However, the large-scale project is more likely to be profitable and less susceptible to operational factors. This suggests that scaling up the project size can enhance its profitability and reduce the risks associated with operational challenges. The sensitivity analysis conducted in this study shed light on the specific factors that significantly impact the profitability of each project. For Site A, waste disposal income emerged as a highly influential factor. This implies that any changes in the income generated from waste disposal activities can substantially affect the project's profitability.

However, due to the operation of their own waste-to-energy (WtE) power plant, Site A is unlikely to incur losses. The presence of the WtE power plant provides an additional revenue stream and mitigates the financial risks associated with waste disposal income fluctuations. On the other hand, as a smaller-scale project, Site B is also highly affected by waste disposal income. However, the sensitivity analysis revealed that all factors examined in the study significantly influence the project's profitability. This suggests that, due to its smaller scale, Site B is more sensitive to changes in various operational factors, including waste disposal income, operating expenses, and other project-related costs.

In summary, the results of this study indicate that landfill mining projects, whether medium or large-scale, have a high probability of being profitable. However, the profitability of a large-scale project with a WtE power plant is expected to be higher than a medium-scale project. The presence of a WtE power plant provides a stable revenue source and reduces the project's vulnerability to operational factors. These findings highlight the potential financial benefits of landfill mining projects and emphasize the importance of considering project scale and additional revenue streams, such as WtE power generation, to enhance profitability and mitigate risks.

It is worth noting that the profitability and sensitivity analysis results presented in this study are specific to the examined medium and large-scale landfill mining projects. The findings may vary for different projects depending on their unique characteristics, waste composition, market conditions, and other relevant factors. Further research and analysis are necessary to validate these findings and provide a more comprehensive understanding of the financial aspects of landfill mining projects.

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