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Public acceptance and cost-benefit analysis: Incinerators vs. third-party providers

Isabella Nur Adinda[1,*], Fatmah[1], Suyud Warno Utomo[1]
[1] *Department of Environmental Science, Graduate School of Sustainable Development, Universitas Indonesia, Central Jakarta, DKI Jakarta 10430, Indonesia.*
*Correspondence: isabella.ui.ac@gmail.com

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ABSTRACT

Background: The management of hazardous solid medical waste (B3) poses a challenge for hospitals in South Tangerang City, as no hospital in the area currently has its own on-site treatment facilities, meaning Hospital X still relies on third-party providers (outsourcing). **Method:** Employing a mixed-methods case study design, this research examines public acceptance of on-site incinerators through statistical association analysis (involving six key informants) and evaluates financial feasibility via a cost-benefit analysis (CBA) using three years of secondary budget data (2023–2025). Financial metrics—evaluated at a 10% discount rate across three CAPEX sensitivity scenarios, include Net Present Value (NPV) and Benefit-Cost Ratio (BCR). **Findings:** The results indicate that storage and processing aspects are significantly associated with community acceptance ($p = 0.044$, OR = 1.661; $p = 0.034$, OR = 2.538). Although the standalone incinerator generated a positive NPV over the 3-year horizon, its BCR remained below 1, whereas outsourcing resulted in cumulative savings of approximately IDR 241 million. **Conclusion:** Given low waste volumes, outsourcing is more economically rational, while public acceptance depends more on proper storage and treatment practices than technology choice. **Novelty/Originality of this article:** This study integrates social acceptance and financial feasibility within a single framework, offering practical, economically viable, and socially acceptable decision insights to guide hospital decision making in developing urban contexts, subject to a three year budget horizon limitation.

KEYWORDS: B3 medical waste; cost-benefit analysis; hospital waste; incinerator; public acceptance.

1. Introduction

There are several methods for managing solid medical waste from healthcare facilities, including incineration, autoclaving, chemical disinfection, landfill disposal, and burial (Geetha et al., 2019). Each method has its own advantages and disadvantages, making the selection of the appropriate technology a subject of research interest in its own right, particularly due to the environmental impacts involved and the significant costs (Puška et al., 2022). The selected technology is expected to meet criteria for both reliable and environmentally friendly management (Aung et al., 2019; Hinduja & Pandey, 2019). However, the planning and construction of incineration facilities often spark reactions and protests from local communities concerned about negative impacts on public health and ecosystems (Zhang et al., 2021; Keeble, 1988). Therefore, the role of the community in fostering an awareness of medical waste management issues and taking positive action to support hospitals in adopting more sustainable management practices is crucial so that this collaboration can meet the requirements of current health policies (Weraman et al., 2024).

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In terms of national capacity, as of 2020, there were only 10 licensed medical waste treatment facilities in Indonesia. Incinerators are capable of processing approximately 10 metric tons of medical waste per day and are utilized by 87 hospitals, with a combined daily capacity of about 60 metric tons; however, incinerator technology is available only at five hospitals in West Java Province that have been authorized to manage their own medical waste (Sitompul, 2021). There has been no new information regarding licensed medical waste treatment facilities since 2024. Recognizing the ongoing disparity in the number and distribution of incinerators, the Ministry of Environment plans to build 32 new incinerators between 2021 and 2024; to date, there are 110 licensed incinerators and 14 hazardous waste management service providers serving approximately 2,800 hospitals in Indonesia. This disparity is exacerbated by the uneven distribution of private waste treatment facilities, while a number of hospitals have yet to partner with third parties for advanced waste management, and many temporary storage sites do not meet the required criteria due to budget constraints for construction in accordance with regulatory standards. A study by Kurniawan (2019) supports the notion that producers, transporters, users, processors, and stockpilers of hazardous waste all have the potential to commit violations, ranging from illegal disposal, shipment to unlicensed parties, failure to use hazardous waste manifests, to illegal dumping in open areas due to the high cost of collaborating with transporters.

Cost issues also pose a distinct challenge in the management of healthcare facility waste, which is a complex problem, particularly in developing countries (Li et al., 2021). Estimates from the International Labour Organization (2014) reveal that the average costs both visible and invisibleresulting from health issues amount to approximately 4% of the world's gross domestic product annually (Jondabeh et al., 2024; McKinnon et al., 2014). At the hospital level, Hospital X collaborates with a second-party vendor for waste transportation (three times a week) and with PT X as a third party for the treatment of hazardous medical waste (B3), due to the lack of available internal treatment equipment and facilities. This collaboration with the second and third parties imposes a significant financial burden on Hospital X (Hutajulu et al., 2021). Accurate investment cost calculations for funding B3 solid medical waste treatment technology in hospitals will assist stakeholders and relevant agencies in decision-making, ensuring that the cost-benefit analysis for B3 solid medical waste management proceeds efficiently and as expected (Utami et al., 2022).

Cost-benefit analysis aims to identify the most economical solution that maximizes resource utilization while achieving the desired waste management objectives namely, an optimal balance between cost-effectiveness and waste management efficiency and helps decision-makers evaluate the effectiveness and economic viability of available waste management options (Al-Sulbi et al., 2023). In the context of Hospital X, the implementation of waste treatment using on-site incineration technology faces technical constraints in the form of thick smoke resulting from incomplete combustion due to inadequate technical standards; consequently, the hospital has not yet been able to achieve sustainable management of hazardous solid medical waste (B3) through this method. Another issue relates to Hospital X's proximity to residential areas, which prevents the unrestricted use of an incinerator to treat Category B3 solid medical waste a situation consistent with findings that incineration plans often trigger social resistance (Zhang et al., 2021).

The treatment of hazardous waste must be carried out by all generators of hazardous waste, as stipulated in Article 1 of Indonesian Ministry of Environment and Forestry Regulation No. 6 of 2021 and Article 24 of Indonesian Ministry of Health Regulation No. 2 of 2023. However, this obligation faces economic realities on the ground: South Tangerang City, a densely populated area with approximately 31 hospitals, still does not have a single hospital with on-site waste treatment facilities. To date, hospitals in South Tangerang City including Hospital X, which has recently begun operations still rely on external waste treatment providers located quite far away, resulting in relatively high operational costs.

Despite growing research on the financial feasibility of waste treatment technologies and the social acceptance of their implementation, few empirical studies have integrated these dimensions into a comprehensive decision-making framework, particularly in the

context of newly operational healthcare facilities. Hospital X serves as an ideal case study representing mid-sized urban facilities in rapidly developing regions like South Tangerang, where high population density, space constraints, and low daily waste generation volumes create distinct operational challenges. To address this gap, this study formulates two primary research questions: How do specific medical waste management practices (storage, sorting, containerization, processing, and transportation) associate with public acceptance in a densely populated urban setting? and how does on-site incineration compare to third-party outsourcing in terms of financial viability under realistic budget horizons and waste volume constraints? By addressing these questions, this study aims to deliver an integrated framework that provides economically rational and socially acceptable insights for hospital management.

Based on this description, this study aims to examine two interrelated issues. First, how the community perceives the choice of hazardous solid medical waste (B3) management technologies (specifically incinerators) within the environment of Hospital X and second, a cost-benefit analysis comparing the option of using an on-site incinerator versus partnering with a third party. The novelty of this study lies in the integration of social acceptance and financial feasibility within a single analytical framework, ensuring that the resulting recommendations are not only economically viable but also socially acceptable in the context of hospitals in South Tangerang City.

2. Methods

2.1 Research approach

This study employs a quantitative approach to analyze the relationship between public acceptance and the management of hazardous solid medical waste (B3), as well as a mixed-methods (qualitative-quantitative) approach to conduct a cost-benefit analysis comparing two waste management alternatives: an in-house incinerator and outsourcing to a third party. The study employs a cross-sectional design, in which observations of the public acceptance variable are conducted once at a single measurement point, while cost data are analyzed longitudinally based on secondary budget data from the past three years (2023–2025).

2.2 Population and sample/key informants

2.2.1 Community acceptance variables

The study population consists of residents of Pondok Betung Subdistrict aged 20–44 years (the productive adult age group) who reside within the planned activity area as specified in the Environmental Management Efforts and Environmental Monitoring Efforts/*Upaya Pengelolaan Lingkungan Hidup dan Upaya Pemantauan Lingkungan Hidup* (UKL-UPL) documents for Hospital X, with a total population of 13,042 people. The sample was determined using simple random sampling and the Slovin formula with a margin of error (e) of 10%:

$$n = \frac{N}{1 + N(e)^2} \quad \text{(Eq. 1)}$$

With the following definitions: n for total sample size, N for population, e^2 for error rate of 1%, 5%, 10%. To account for potential dropouts or invalid data, the sample size was increased by 10%, resulting in a final sample size of 110 respondents. Inclusion criteria included: Being between the ages of 20 and 44, and residing within the boundaries of the planned activity location as specified in Hospital X's UKL-UPL documents.

2.2.2 Cost-benefit analysis variables

For the cost-benefit analysis, the study utilized six key informants selected through purposive sampling, consisting of: the Director of Hospital X (budget authority), the Head of the Support Services Division (budget preparer), the Head of the Non-Medical Support Services Section (budget planner), the Head of the Personnel Subdivision (budget approver), as well as representatives from the South Tangerang City Environmental Agency and Health Agency serving as experts in monitoring the management of hazardous solid medical waste (B3).

2.3 Research variables

The variables in this section of the study consist of public acceptance, and cost-benefit analysis, which will be further explained in the Table 1. Primary data for the community acceptance variable was collected through questionnaires in the form of Google Forms and paper-based checklists, which were distributed with the assistance of local community organizations. Before distribution, the questionnaires were tested for validity using Pearson's product-moment correlation and for reliability. Each selected respondent who was willing to participate signed an informed consent form guaranteeing the confidentiality of their identity and personal data.

Table 1. Research variable

Variable	Operational definition	Unit of measurement	Measurement instrument
Public Acceptance	How the public understands, acts, feels, and views the management of solid B3 medical waste	Acceptable/ unacceptable	Questionnaire
Cost-Benefit	Calculating operational and investment cost planning for procuring equipment or goods for hospital needs.	IDR	Literature review and interview

Data for the cost-benefit analysis were collected through in-depth interviews with six key informants, as well as a secondary document review consisting of the Regional Revenue and Expenditure Budget/*Anggaran Pendapatan dan Belanja Daerah* (APBD) data for Hospital X for the 2023–2025 period and the contract values for collaborations with second and third parties. For the variable of public acceptance, questionnaire responses were weighted using a Likert scale. The range of rating categories was determined using the class interval formula:

$$C = \frac{Xn - Xi}{K} \quad \text{(Eq. 2)}$$

Notes: C for lass interval, K for umber of Classes, Xn for highest value Xi for lowest value. Determine the ranges for the "accepted" and "rejected" evaluation criteria. Based on calculations using the class interval formula, the following ranges of questionnaire scores related to public acceptance were obtained:

$$Grade\ range = \frac{(max.weight\ x\ number\ of\ questions) - (min.weight\ x\ number\ of\ questions)}{Total\ number\ of\ classes}$$

$$Class\ range = \frac{25 - 5}{2} = 10 \quad \text{(Eq. 3)}$$

Number of categories (2 categories: accepted and not accepted). Based on the calculations, the "Accepted" category was assigned to scores >10 and the "Not Accepted" category to scores of 1–10. For the cost-benefit analysis, budget data were classified into cost components (preparation, investment/capital, operations, maintenance) and benefit components (direct, indirect, related), following the classification by Udyanto (2021).

Table 2. Range of scores on the community acceptance questionnaire

Range of values	Category
> 10	Accepted
1 – 10	Not accepted

2.4 Data analysis methods

2.4.1 The relationship between public acceptance and the management of hazardous solid medical waste

Data were analyzed using the inferential chi-square statistical test with a 95% confidence level (α = 0.05) to test the relationship between aspects of hazardous solid medical waste management (sorting, containment, transportation, storage, and treatment) and the level of public acceptance. A relationship was considered significant if the p-value ≤ 0.05. The strength of the relationship between variables was assessed using the Odds Ratio (OR). The analysis was conducted using SPSS software.

2.4.2 Cost-Benefit Analysis (CBA)

An economic feasibility analysis was conducted by comparing two waste management alternatives an in-house incinerator and third-party outsourcing using three metrics: Net Present Value (NPV), to assess investment feasibility based on the present value of the difference between costs and benefits over the analysis period, using the formula:

$$NPV = \sum_{0}^{T} \frac{N_t}{(1+r)^t} - N_0 \quad \text{(Eq. 4)}$$

Notes, NPV for net present value (IDR), t for period, N_t for annual cash flow in period t, N_0 for initial investment in year 0 (IDR), R for interest rate or discount rate (%) using a discount rate (r) of 10%. Benefit-cost ratio (BCR), the BCR is a method used in the initial evaluation stage of investment planning to validate the results of evaluations conducted using other methods, such as NPV. It can also be defined as an economic measure that describes the extent to which the benefits derived from a project are commensurate with the costs incurred, after all values have been converted to present value (Rusliana et al., 2022) . The BCR serves as a comparative assessment of the benefits gained and the costs incurred in the investment (Giatman, 2011). Decision criterion: A BCR ≥ 1 is deemed feasible.

The Internal Rate of Return (IRR) is used as an alternative test of investment feasibility when there is a negative cash flow in the base year (initial investment), with the feasibility criterion being that the IRR value is equal to or greater than the benchmark interest rate. The rule for IRR-based decisions is that if the IRR value is greater than the interest rate, the project investment is feasible and can secure a loan from a bank or investor. Conversely, if the IRR value is less than the interest rate, the project investment should not be undertaken because it will result in a loss (Common & Stagl, 2005). To account for variations in the initial investment costs (CAPEX) of incinerators, which depend on capacity and technical specifications, the analysis was conducted using three price sensitivity scenarios (small-scale, medium-scale, and full-scale installations), referencing operational and investment cost data from the literature (Sharifi et al., 2024).

2.4.3 Data presentation

The results of the chi-square test are presented in a contingency table containing p-values and odds ratios (ORs) for each aspect of waste management. The results of the cost-benefit analysis are presented in a summary table of annual costs for each alternative, as well as tables showing the net present value (NPV) and benefit-cost ratio (BCR) calculations at a 10% discount rate. The study was conducted at Hospital X, Pondok Aren Subdistrict, Pondok Betung Village, South Tangerang City. Pondok Betung Village was selected as the location for community sampling because this area falls within the boundaries of the planned activity site outlined in Hospital X's UKL-UPL document; consequently, the community is directly at risk of being impacted by the hospital's medical waste management activities. This village has a population of 34,118 people comprising 11,525 households, organized into 8 Neighborhood Associations and 73 Neighborhood Groups. The study was conducted over seven months, from March to November 2025, with the community sampling phase lasting two months.

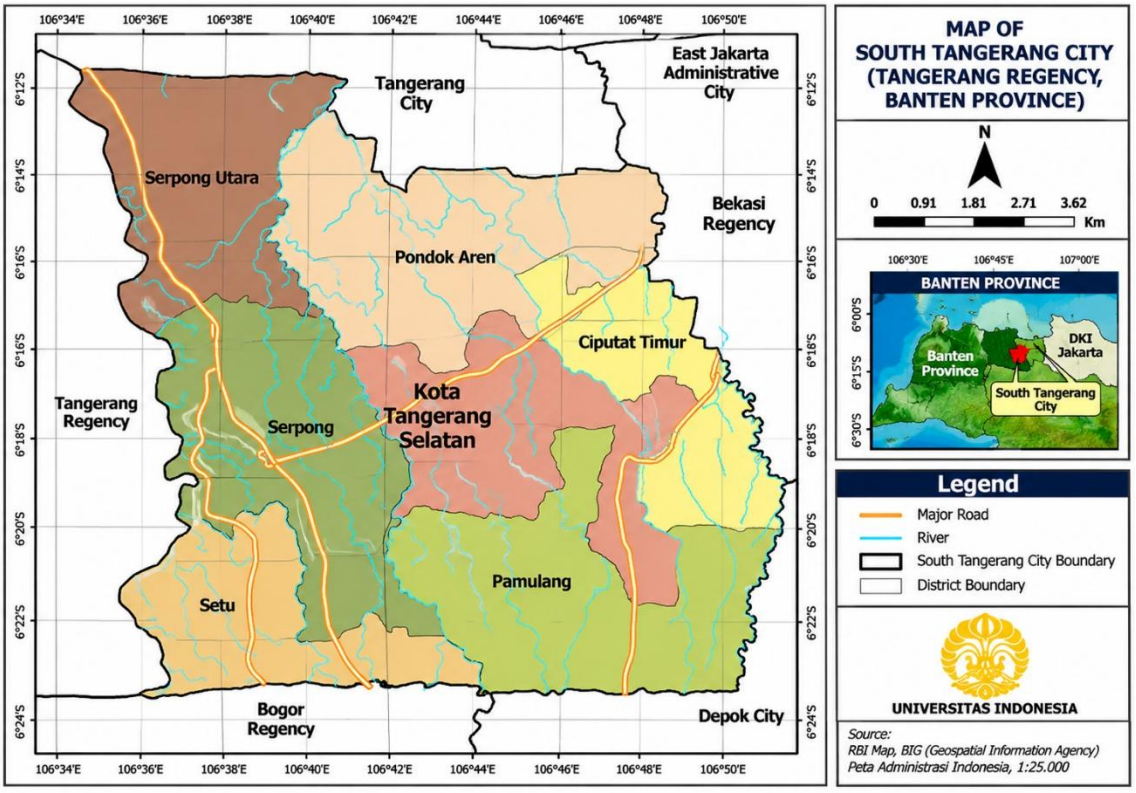


Fig. 1. Administrative map of South Tangerang City

3. Results and Discussion

3.1 Analysis of public acceptance

An analysis of the relationship between public acceptance and the management of hazardous solid medical waste (B3) is crucial because the level of public acceptance reflects social support and public participation in safeguarding public health and the environment (Bai et al., 2024). High public acceptance strengthens the effectiveness of the waste management system from sorting and containment to final treatment as the public is actively involved and does not resist the policies or practices implemented. Conversely, low public acceptance can create obstacles to implementation, such as opposition to waste treatment facilities or a lack of compliance in sorting medical and non-medical waste (Tushar et al., 2023). Therefore, this analysis aims to determine the extent to which public acceptance is related to the success of hazardous solid medical waste (B3) management,

thereby providing a basis for formulating more effective and sustainable policies and strategies. Based on the results of observations of 110 residents in the Pondok Betung urban village, who answered each question item by item, the observation results are presented in Table 3.

Based on the results of the Chi-Square test for the selection aspect, the p-value and OR (odds ratio) cannot be determined. This is because the data from the community acceptance questionnaire and the data from the selection aspect questionnaire yielded constant values, making it impossible to draw conclusions regarding the p-value and OR. This condition causes the data distribution in the contingency table to lack variation, so the statistical test is unable to detect any differences or specific patterns of association. Consequently, these variables can only be presented descriptively and cannot be used in bivariate analysis or risk calculations.

Table 3. Relationship between public acceptance and aspects of hazardous solid medical waste management

Management aspect	Accepted	Unaccepted	P-Value	OR	Remark
Sorting	110	0	-	-	Inconclusive
Containment	109	1	-	-	Inconclusive
Transportation	108	2	1	0.558	Non significant
Storage	103	7	0.044	1.661	Significant
Processing	54	56	0.034	2.538	Significant

These limitations may be attributed to several factors, including the high level of compliance with the implementation of solid B3 medical waste sorting practices, research instruments that were not sensitive enough to capture variations in field conditions, and respondents' incomplete understanding of the sorting aspects under study. Some respondents tended to provide answers based on general perceptions or everyday experiences rather than on actual technical understanding. This contributed to the uniformity of responses and limited the analysis's ability to identify more detailed relationships between variables.

Based on the results of the Chi-Square test for the containment aspect, the p-value is 1, and the OR (odds ratio) cannot be determined. This means that the analysis of the relationship between the packaging aspect and public acceptance indicates no significant relationship, as the p-value is ≥ 0.05. The odds ratio in this study cannot be optimally presented or interpreted due to the data distribution, which tends to be homogeneous. Most respondents fall into the same category, so there is insufficient comparison between groups to calculate the proportional odds of an event occurring. A limitation contributing to this situation is that respondents' understanding of the aspects under study was not entirely accurate, resulting in answers that tended to be uniform.

Based on the results of the Chi-Square test for the transportation aspect, the p-value is 1 and the OR (odds ratio) is 0.588. This means that the analysis of the relationship between the transportation aspect and public acceptance indicates no significant relationship, as the p-value is ≥ 0.05. Based on the results of the Chi-Square test for the storage aspect in Table 4.17, the p-value is 0.044 and the OR (odds ratio) is 1.661. This indicates that the analysis of the relationship between storage aspects and public acceptance reveals a significant association, as the p-value is ≤ 0.05. This OR value implies that appropriate storage aspects are 1.6 times more likely to be accepted by the public compared to inappropriate storage aspects.

Based on the results of the chi-square test for processing aspects, the p-value is 0.034 and the OR (odds ratio) is 2.538. This means that the analysis of the relationship between processing aspects and public acceptance indicates a significant association, since the p-value is ≤ 0.05. This OR value implies that proper processing practices are 2.5 times more likely to be accepted by the public than improper ones.

Based on the results of the Chi-Square test, it can be seen that two variables have significance levels less than $\alpha = 0.05$, indicating a significant relationship between the

storage and processing aspects of B3 solid medical waste and public acceptance. This indicates that the better the storage and processing practices, the higher the level of public acceptance of B3 solid medical waste management. Meanwhile, the variables of sorting, containment, and transportation have significance values greater than $\alpha = 0.05$, indicating no significant relationship with public acceptance. Based on the results of the chi-square test, which indicated a relationship among the variables, the discussion then focused on the respondents' questionnaire results regarding public acceptance. This analysis examined differences in responses between groups of respondents who accepted and those who did not, thereby explaining the trends in respondents' attitudes toward the variables under study (Wicaksono & Korom, 2023). A total of 50.9% of respondents answered reject to the questionnaire item that read, the construction of a facility (one of the devices for incinerating hazardous solid medical waste) at the hospital for waste treatment.

The community stated that they were not prepared to deal with odors and smoke reaching their homes. This finding aligns with empirical evidence indicating that Not-In-My-Backyard (NIMBY) concerns increasingly influence public acceptance of waste treatment facilities, particularly during the siting and operational phases (Li et al., 2019). A total of 49.1% of respondents answered "accept" to the questionnaire item stating, "the construction of an incinerator that prioritizes social and environmental aspects." This is consistent with the research by Nematollahi et al. (2025) which found that the main factors influencing social acceptance include perceptions of safety, environmental impacts, visual impacts, and operational noise.

Thus, it can be concluded that storage and processing are the most decisive factors in building public acceptance, while other aspects have not shown a significant correlation. This can be explained by the fact that these processes primarily occur within healthcare facilities and are not directly experienced or observed by the public, and therefore do not significantly influence their level of acceptance. This aligns with the findings of Absori & Latif (2020), who noted that the technical stages of medical waste management are often internal in nature and require specialized knowledge, making them less of a focus for the general public. Nevertheless, even though the public does not pay much attention to these aspects, healthcare facilities must still comply with technical standards to ensure the safety and security of hazardous solid medical waste (B3) management.

This analysis underscores the importance of strengthening proper storage and processing practices as the first step in managing hazardous solid medical waste (B3) (Arumdani et al., 2025; Kollu et al., 2022), as these aspects are more easily observed by the public and directly impact their perceptions of environmental cleanliness and health. Public acceptance of a policy or program is greatly influenced by its visibility and public involvement in the implementation process. Additionally, research findings consistent with those of Zhang et al. (2021) indicate that public trust is a critical factor to prioritize, as lower levels of trust correlate with lower levels of public acceptance. The community must be involved; open communication must be established; and the selection of the incinerator construction site must also be determined through community discussions to build trust (Zhang et al., 2021).

3.2 Cost-benefit analysis of hazardous solid medical waste (B3) management

A cost-benefit analysis is an approach used to assess the feasibility of a program or technology by comparing the costs incurred and the benefits obtained (Brent, 2023). In the context of hazardous solid medical waste management, this analysis is crucial when considering two distinct alternatives: treatment via incineration and conventional methods currently in use (such as sorting, packaging, transportation, storage, and final treatment by third parties). The incineration alternative offers advantages in terms of waste volume reduction and processing efficiency, but requires high investment and operational costs (Hasan et al., 2025). Meanwhile, conventional methods tend to involve lower initial costs but pose challenges regarding sustainability, environmental risks, and public acceptance.

Table 4. Budget for the management of class B3 solid medical waste at Hospital X

Activities	Year	Total	Handling fees	Contract value
Management of Hazardous Solid Medical Waste (B3)	2023	500 Kg	IDR 13,910,000	IDR 3,000,000
Management of Hazardous Solid Medical Waste (B3)	2024	2800 Kg	IDR 42,000,000	IDR 16,800,000
Management of Hazardous Solid Medical Waste (B3)	2025	4000 Kg	IDR 60,000,000	IDR 24,000,000

Thus, this cost-benefit analysis is expected to provide a comprehensive overview of the most optimal option from both economic and environmental perspectives. Based on primary data obtained from direct interviews, Hospital X's budget comes from the regional budget, known as the APBD. Hospital X has another budget source, namely the BLUD, but it has not yet used BLUD funds for the management of this hazardous solid medical waste (B3). Hospital X's APBD budget for 2023–2025 is presented in Table 4 as follows. The temporal assessment of costs and benefits was adapted from previous studies emphasizing the importance of defining the timing and duration of benefit realization in CBA. In this study, a three-year analysis period (2023–2025) was established based on financial data availability. The assessment of benefits was therefore restricted to the observation period, with the timing of benefit realization determined according to the actual implementation of waste management activities (Chelli et al., 2025). Referring to Table 4, the secondary data obtained was derived from the Regional Budget (APBD) and budget data as specified in the contract. This data was then calculated using the formula for annual in-house costs.

$$Annual\ in-house\ cost = management\ budget + operating\ costs + maintenance\ costs \quad \text{(Eq. 5)}$$

Given that the cost of transporting medical waste is IDR 6,000 per kg, the frequency of medical waste transport is 3 times per week, and the volume of medical waste per transport is 100 kg per day, the operational and maintenance costs for Hospital X to manage its own hazardous solid medical waste (B3) or "in-house" management can be calculated as follows:

Operating costs = total waste (kg) × cost per kg × collection frequency

Operating costs = Per day: 100 × 6,000 = IDR 600,000
Per week: 3 × 600,000 = IDR 1,800,000
Per month: 4 × 1,800,000 = IDR 7,200,000
Per year: 12 × 7,200,000 = IDR 86,400,000

Maintenance costs: 7% of operating costs = 7% × monthly operating costs

Maintenance costs = 7% × 7,200,000 = IDR 504,000 per month
Per year: 504,000 × 12 = IDR 6,048,000

An in-house incinerator means bearing all three components: the waste management budget, operational costs, and maintenance costs; whereas the contract (outsourcing) option involves the specified contract amount (which is the annual contract cost), and operational and maintenance costs are not borne by Hospital X (since they are handled by the second and third parties). A breakdown of costs starting with the APBD budget, operational and maintenance calculations for an in-house incinerator, and a comparison with the contract value involving second and third parties as well as the calculation of cost savings, is explained in Table 5.

Referring to Table 5, it can be seen that operating and maintenance costs remain the same, but the annual waste management budget increases in line with waste volume. Table 4.18 summarizes the alternative costs under a scenario where Hospital X operates an in-

house incinerator in 2023, which could reach IDR 106,358,000; the highest costs stem from operations and maintenance. Hospital X has been using an outsourcing service with a contract of IDR 3,000,000 per year. This results in a significant cost savings difference of IDR 95,448,000.

Table 5. Summary of alternative costs

Year	Response budget	Operations and maintenance	Total In-house insinerator	Contract (outsourching)	Savings
2023	13,910,000	92,448,000	106,358,000	3,000,000	95,448,000
2024	42,000,000	92,448,000	134,448,000	16.800,000	109,248,000
2025	60,000,000	92,448,000	152,448,000	24,000,000	116,448,000

By 2024, an increase in the waste management budget caused the total in-house cost to rise to IDR 134,448,000, with operational and maintenance costs remaining constant, while the outsourcing contract value remained lower at IDR 16,800,000. This difference results in savings of IDR 109,248,000. In 2025, this trend continues; in-house costs rise again in line with the increasing volume of B3 solid medical waste, while contract costs remain lower. Consequently, the resulting cost savings increase to IDR 116,448,000.

This comparison clearly shows that the cost of processing Class B3 solid medical waste through outsourcing is significantly lower than the cost under a scenario where Hospital X manages Class B3 solid medical waste using an in-house incinerator. Table 4.18 outlines the comparative analysis to assess cost savings (benefits); furthermore, the calculation of the Net Present Value (NPV) aims to demonstrate the extent of a project's impact on social welfare by considering the costs and benefits derived from the project (Ananda & Nugroho, 2022). The NPV and BCR calculations are presented in Table 4.19 as follows:

3.2.1 NPV & BCR calculations (r = 10%)

Cash flows occur at the end of each year; therefore, the discount factor for year t is , where t=1 for 2023, t=2 for 2024, and t=3 for 2025. Per year (discounted value, r = 10%). This NPV calculation excludes the initial investment and can only be calculated for 3 years because the secondary data available extends only through 2025. The net cash flow calculation has been replaced with the present value (PV) of the savings. The NPV calculation is detailed in Table 6 as follows.

Table 6. NPV calculation

Year	PV (In-house)	PV (Contract)	PV (Savings)
2023 (t=1)	IDR 96,689,091	IDR 2,727,273	IDR 85,506,364
2024 (t=2)	IDR 111,114,050	IDR 13,884,298	IDR 82,998,347
2025 (t=3)	IDR 114,536,439	IDR 18,031,555	IDR 72,567,994
Total PV (t=1..3)	IDR 322,339,579	IDR 34,643,125	IDR 241,072,705

Table 6 presents a summary of the present value (PV) for the three main components: in-house costs, contract costs, and the savings resulting from the difference between the two. In 2023, the PV of in-house costs was recorded at approximately IDR 96,689,091, while contract costs were only about IDR 2,727,273. This difference resulted in savings of approximately IDR 85,506,364. The following year, in 2024, the present value of in-house costs increased slightly to approximately IDR 111,114,050, while the present value of contract costs rose to approximately IDR 13,884,298. Although contract costs increased, the difference between the two remained significant, resulting in savings for this year of approximately IDR 82,998,347. A similar trend is observed in 2025, with the in-house PV in the range of IDR 114,536,439, while the contract cost reaches IDR 18,031,555. The savings achieved this year remain relatively large, at approximately IDR 72,567,994.

When the figures for these three years are totaled, the total in-house PV amounts to IDR 322,339,579, while the total contract PV is only about IDR 34,643,125. The cumulative difference results in total savings of approximately IDR 241,072,705 million over the three-

year period. This figure indicates that, although in-house costs are higher than contract costs, the benefits in the form of savings remain highly significant when viewed from the perspective of the time value of money. The conclusion that the NPV > 0 for the incinerator alternative provides greater advantages in terms of cost and economics.b. Benefit-Cost Ratio (BCR)

This means that a BCR value less than 1 indicates that, economically speaking, the total benefits obtained are not yet sufficient to cover all the costs incurred. This suggests that, from an economic perspective, the management alternatives analyzed do not yet provide direct financial benefits. However, these results still need to be considered alongside non-financial aspects such as environmental benefits, regulatory compliance, and reduced pollution risks. Costs Based on the data provided and the scenario described for using a standalone incinerator, the pure outsourcing (contract) cost is significantly lower than the in-house option (Godfrey, 2021). Based on the calculations, a BCR value of 0.75 indicates that, in terms of the benefit-to-cost ratio, the in-house alternative is not yet fully efficient. However, the NPV analysis yields a positive value, indicating long-term cost savings compared to the contract system; thus, the in-house alternative is still considered relatively more advantageous. The IRR is not relevant here because there is no initial investment or negative cash flow; if there were one-time switching or transition costs, the IRR could be calculated.

$$\text{BCR} = \frac{PV\ (Benefit)}{PV\ (Cost)} = \frac{241{,}072{,}705}{322{,}339{,}579} \approx 0.75 \qquad \text{(Eq. 6)}$$

This study applies the Modified Benefit-Cost Ratio (Modified BCR) method to evaluate the economic feasibility and budget efficiency of the standalone incinerator project (Pacheco & Alves, 2025). In this public sector context, the analysis evaluates the project relative to existing operational baselines. Therefore, the denominator of the ratio uses the total internal operational costs of the baseline option (PV In-house, amounting to IDR 322,339,579), while the numerator consists of the cumulative cash savings generated by adopting the alternative option (PV Savings, amounting to IDR 241,072,705). Under this framework, the resulting Modified BCR value of 0.75 does not indicate an economic failure or financial loss. Instead, it demonstrates high cost-efficiency, confirming that the new management alternative successfully intercepts and recaptures 75% of the total expenditures required by the baseline system.

This efficiency is firmly validated by the Net Present Value (NPV) analysis, which yields a highly positive value (+IDR 287,696,454). The positive NPV mathematically confirms substantial long-term net savings, proving that transitioning away from the baseline system is highly advantageous. Furthermore, the Internal Rate of Return (IRR) is mathematically omitted from this analysis because the project cash flow does not involve a conventional negative initial investment or upfront capital transition costs. Ultimately, while the financial indicators both the positive NPV and the 75% efficiency ratio strongly support the economic viability of the project, the final management decision must be weighted alongside non-financial advantages. These include long-term regulatory compliance, environmental sustainability, and the mitigation of secondary pollution risks associated with medical waste management.

3.2.2 Advantages of an in-house incinerator compared to outsourcing

Since the incinerator does not generate revenue, the benefit is equivalent to the cost savings. Based on Table 4.19, the total present value (PV) of the savings is IDR 241,072,705. It is concluded that over a 3-year period, an in-house system can provide economic benefits of IDR 241,072,705 compared to a contracted system. The benefits of the contracted system cannot be calculated because there is no revenue, no savings only costs. The conclusion is that the contracted system does not provide financial benefits; it only incurs routine operating costs. Another study assumes a total installed CAPEX of USD 50,000 or IDR

821,000,000 (including installation, permits, and site preparation) and operating costs of ≈ USD 0.30 per kg or IDR 4,926 (operating costs, fuel, and labor per kg (Sharifi et al., 2024). The analysis horizon spans 2023–2025 (same as before). Annual waste volume: 2023 = 500 kg, 2024 = 2,800 kg, 2025 = 4,000 kg. Cost data already used (Table 4.17). In-house (total) per year (budget + operations + maintenance): 2023 IDR 96,689,091; 2024 IDR 111,114,050; 2025 IDR 114,536,439.

Contract (outsourcing) per year (contracted): 2023 = IDR 3,000,000; 2024 = IDR 16,800,000; 2025 = =IDR 24,000,000 (Table 4.17). Discount rate (r) = 10%. Incinerator operating costs (variable cited from a study): USD 0.30 per kg (including fuel, electricity, labor, and consumables this figure comes from a series of studies/estimates on healthcare waste management costs) (Sharifi et al., 2024). Exchange rate: 1 USD = IDR 16,420. Incinerator CAPEX (total installed cost) this value varies significantly depending on capacity, country, facility, or permits. Three scenarios were used to assess sensitivity:

Scenario A (low-cost): USD 5,000 or IDR 82,100,000 (small unit, hardware only) based on a low-end supplier's catalog (Accio, 2025).

Scenario B (medium): USD 20,000 or IDR 328,400,000 (hardware + partial installation or taxes).

Scenario C (conservative or realistic for a complete installation): USD 50,000 or IDR 821,000,000 (hardware + shipping + installation + site preparation + permits).

Annual operating costs (operational fuel, labor, or consumables) = 0.30 USD/kg × kg × 16,420 IDR/USD.

2023 (500 kg): 0.30 × 500 × 16,420 ≈ IDR 32,463,000
2024 (2,800 kg): 0.30 × 2,800 × 16,420 ≈ IDR 43,792,800
2025 (4,000 kg): 0.30 × 4,000 × 16,420 ≈ IDR 49,704,000

Annual maintenance costs for a small unit (e.g., spare parts, servicing): IDR 30,000,000/year. This is a conservative estimate (lower than the known in-house maintenance cost of IDR 100 million/year, since small-scale incinerators typically require periodic servicing). Therefore, total annual operating and maintenance costs = (operating cost per kg) + (assumed annual maintenance cost of IDR 30,000,000). Annual operating and maintenance costs (IDR):

2023 = IDR 62,463,000 (including maintenance)
2024 = IDR 73,792,800
2025 = IDR 79,704,000

The summary calculation also shows a scenario without additional maintenance to allow for a clear comparison; in the calculation table, I've included O&M figures both with and without maintenance). CAPEX two approaches to incorporating it into the analysis, namely: Method (A), CAPEX paid at t = 0 shows the initial funding requirement and total PV. Method (B), annualized CAPEX uses a capital recovery factor (CRF) to allocate CAPEX as an annual cost for easy comparison with other annual costs. Parameters used (example for CAPEX of USD 50,000) as follows.

CAPEX (USD 50,000) → CAPEX_IDR = 50,000 × 16,420 = IDR 821,000,000. Conservative lifespan: 10 years.

Discount rate 10% → CRF ≈ 0.1627.

Therefore, annualized CAPEX ≈ IDR 821,000,000 × 0.1627 ≈ IDR 133,614,000/year. (For CAPEX of USD 5,000 and 20,000, the same method is applied)

Calculate PV (r = 10%) brief comparison (key figures). The table shows three key comparisons (all PVs are calculated for the 2023–2025 horizon with r = 10%): Total PV of in-house costs (as in the previous calculation): IDR 322,339,579. PV of contract (outsourcing) costs (from the previous calculation): IDR 34,643,125. (This is very small compared to the in-house cost.) PV of incinerator costs two methods as follows. First, if CAPEX is USD 50,000 (IDR 821,000,000) and we annualize the CAPEX (over 10 years): Total PV (annualized CAPEX + operations and maintenance) over 3 years ≈ IDR 435,325,731. Comparison to in-house (PV):

NPV (savings) = PV(in-house) − PV(incinerator_annualized) ≈ IDR 30,137,154 (slightly positive).
BCR = PV(benefit) / PV(cost) = PV(in-house) / PV(incinerator) ≈ 1.07 → meaning the incinerator is only slightly better, given that high CAPEX and the assumptions regarding operations and maintenance hold true.

Second, if CAPEX is USD 20,000 → PV(incinerator annualized) decreases, resulting in: BCR ≈ 1.97 (the incinerator becomes more attractive). Third, if CAPEX is USD 5,000 → PV(incinerator annualized) is very small and BCR ≈ 3.42 (the incinerator is much cheaper than the in-house option). Brief numerical conclusion: The contract (outsourcing) remains the cheapest in terms of PV (IDR ~34.6 million). The incinerator can outperform outsourcing if the required CAPEX is relatively small. However, for high installed CAPEX (IDR 821,000,000 / USD 50,000), the incinerator's advantage over in-house operations is very slim (low NPV), and it is significantly more expensive than the contract. If the primary goal is short-term cost savings (3 years) and minimal initial investment, opting for the contract (outsourcing) aligns with the calculated research data.

If Hospital X seeks long-term technical independence (e.g., >10 years), wishes to reduce dependence, or has specific needs (location, regulations), an incinerator may be considered but take into account the installed CAPEX and environmental or permitting risks. Perform calculations covering 10+ years and include sensitivity analyses for fuel prices or interest rates. A practical suggestion is to request detailed price quotes (full installed cost) from 2–3 vendors (including shipping, installation, permitting, training, and emissions control costs) since economic decisions are sensitive to CAPEX).

Evaluate other technological alternatives such as non-incineration methods (autoclaves, microwaves, sterilization), which in some cases are more environmentally friendly and cost-competitive; UNEP and scientific reviews discuss these alternatives (Attrah et al., 2022). When conducting a cost-benefit analysis of solid medical waste management between two alternatives outsourcing (external contracts) and the use of in-house incinerators there are significant differences in the cost and benefit structures of each. The incinerator alternative requires a fairly high capital investment (CAPEX); for on-site incinerators with a capacity ranging from 5 to 3,500 kg per hour, the reported capital cost ranges from US$900,000 to US$4,000,000 per unit. Meanwhile, for smaller scales (10–50 kg/hour), there are examples of incinerators offered at prices ranging from US$5,000 to US$30,000.

From an operational perspective, the operating costs of an incinerator range from US$ 0.27 to US$ 1.66 per kg of waste, or an average of approximately US$ 0.30 per kg according to a study on hazardous waste management costs (Sharifi et al., 2024). Given the low waste volume as low as a few thousand kilograms per year, as in this context operating an incinerator is relatively expensive compared to outsourcing, which, based on the data, costs only tens of millions of rupiah per year. Therefore, although incinerators offer benefits such as waste volume reduction and the potential for processing autonomy, the total cost (capital + O&M) over the short-term horizon (3 years) tends to be higher in present value (PV) terms, resulting in a net present value (NPV) of benefits that is only slightly positive (if CAPEX is

low) or even negative if CAPEX is high and is at least less economical than the outsourcing option, which has proven to be far cheaper with an NPV of benefits ranging from tens to hundreds of millions of rupiah and a very high benefit-cost ratio (BCR).

The incinerator option only makes sense if the unit has low CAPEX (e.g., under US$20,000–30,000), the waste volume is sufficiently large, or a long-term horizon is factored into the calculations, so that annualized CAPEX and operating costs are distributed more efficiently. All of this supports the recommendation that outsourcing remains more cost-effective in the short term for small-scale waste volumes, while a new incinerator is economical only if the initial investment is manageable and viewed from a long-term perspective.

4. Conclusions

The aspects of storage and treatment of hazardous solid medical waste (B3) demonstrated a statistically significant association with public acceptance ($p = 0.044$,OR $= 1.661$ and $p = 0.034$,OR $= 2.538$, respectively), whereas sorting, containment, and internal transportation showed no significant effect ($p > 0.05$). Interpretation of these results indicates that the local community tends to accept B3 waste management when storage and treatment adhere strictly to standard operating procedures, as these stages directly shape perceptions of health, odor, and environmental risks. This finding aligns with previous empirical studies emphasizing that visual containment and controlled emission processing are primary determinants of public trust in waste infrastructure. Regarding the financial evaluation, operating an on-site standalone incinerator requires balancing substantial capital expenditure (CAPEX) against cumulative operational variances. This study applies the Modified Benefit-Cost Ratio (Modified BCR) method to evaluate budget efficiency relative to the existing institutional baseline. In this context, the denominator used is the total internal operational costs (PV In-house, amounting to IDR 322 million), while the numerator consists of the cumulative cash savings generated over the three-year horizon (PV Savings, amounting to IDR 241 million).

Based on the calculations, the resulting Modified BCR value of 0.75 does not indicate financial failure. Instead, it reflects an excellent cost-reduction performance, confirming that the management alternative successfully recovers 75% of the total expenditures required by the baseline system. This efficiency is firmly validated by the Net Present Value (NPV) analysis, which yields a positive value (NPV > 0, estimated at IDR 287 million). The positive NPV mathematically confirms long-term net savings, proving that transitioning away from the baseline system is highly advantageous under current operational conditions. Consequently, while on-site incineration under a standalone system demonstrates high efficiency through a positive NPV and a 75% budget recovery ratio, the final decision must be weighted alongside non-financial advantages. These include long-term regulatory compliance, environmental sustainability, and the mitigation of secondary pollution risks associated with medical waste management.

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Author Contribution

Conceptualized the study and methodology, I.N.A., F., & S.W.U.; Collected data and conducted analysis; I.N.A.; Interpreted findings, supervised research, and contributed to manuscript writing and final approval, I.N.A., F., & S.W.U.

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Declaration of Generative AI Use
During the preparation of this work, the authors used [tool name] to assist in [specific function]. After using this tool, the author reviewed and edited the content as needed and took full responsibility for the content of the publication.

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Biographies of Authors

Isabella Nur Adinda, Department of Environmental Science, Graduate School of Sustainable Development, Universitas Indonesia, Central Jakarta, DKI Jakarta 10430, Indonesia.

- Email: isabella.ui.ac@gmail.com
- ORCID: N/A
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: N/A

Fatmah, Department of Environmental Science, Graduate School of Sustainable Development, Universitas Indonesia, Central Jakarta, DKI Jakarta 10430, Indonesia.

- Email: ffatmah@yahoo.com
- ORCID: 0000-0002-2763-0219
- Web of Science ResearcherID: N/A
- Scopus Author ID: 57217831885
- Homepage: https://scholar.ui.ac.id/en/persons/20021982-fatmah/
-

Suyud Warno Utomo, Department of Environmental Science, Graduate School of Sustainable Development, Universitas Indonesia, Central Jakarta, DKI Jakarta 10430, Indonesia.

- Email: suyud.si@ui.ac.id
- ORCID: 0009-0000-1424-0433
- Web of Science ResearcherID: N/A
- Scopus Author ID: 57201691938
- Homepage: https://scholar.ui.ac.id/en/persons/suyud-warno-utomo/