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Multi-Criteria Analysis of Selection Waste Management Development Strategy for Lubuk Binjai Landfill in Lubuk Linggau City

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Keywords
Analytical Hierarchy Process; Waste Management Strategy; Landfill.

Abstract

Environmental sustainability is an urgent priority in dealing with waste management problems in Indonesian cities, one of which is Lubuk Linggau City. In the 2012-2032 Lubuk Linggau City RTRW, waste management standards have been set using the Controlled Landfill or Sanitary Landfill method, but in reality the Lubuk Binjai landfillstill adopts the Open Dumping method. This waste management not in accordance with environmentally sound waste management methods, so it is necessary to develop a waste management strategy for the Binjai Landfill. This research aims to identify priority strategies that can be applied in developing landfill waste management in Lubuk Linggau City using the Analytical Hierarchy Process (AHP) method. Data collection was carried out by conducting interviews with key informants who were managers of the Lubuk Binjai waste disposal site. Determination of criteria and sub-criteria based on previous literature studies and determination of alternative strategies based on the Lubuk Linggau City RTRW for 2021-2032. From the results of the analysis, it shows that the prioritized strategy is the Strategy for Improving Waste Management Methods & Technology, with alternatives such as recycling processing, compost, and more sophisticated waste management technology such as controlled burning or anaerobic management. This is appropriate and crucial in overcoming problems at the Lubuk Binjai waste disposal site, that the Open Dumping method is still applied. It is hoped that the implementation of this strategy can bring positive and sustainable changes in waste management in Lubuk Linggau City.

1. INTRODUCTION

The large amount of waste that cannot be handled will cause various problems to arise due to the lack of alternatives and perspectives for the community in managing and utilizing waste, both directly and indirectly. Environmental sustainability is an urgent priority in dealing with waste management problems in Indonesian cities. Waste management so far is still not in accordance with environmentally sound waste management methods, even though waste management has an influence and is the main source of environmental toxicity in soil, air, and water (Neo et al, 2021). Most of the landfill waste management in Indonesia uses the Open Dumping and Landfill method, as well as other methods such as composting, burning, sorting, and recycling, although they are not widely used (Winahyu et al, 2013). Open dumping is a disposal method that is often used for solid waste in cities throughout the world (Tun et al, 2018). According to Kardono (2007:631), waste management problems in Indonesia can be seen from several indicators, namely the high amount of waste produced, the level of waste management services is still low, the number of final disposal sites is limited, waste management institutions, and cost problems.

Lubuk Linggau City is one of the cities in South Sumatra Province. The population of Lubuk Linggau City in 2021 is 236,828 people with an area of 401.50 Km2 and is categorized as a medium city (BPS, 2022). Waste

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disposal in Lubuk Linggau City is accommodated by the Petanang waste disposal site. However, in 2015, there was an overload of waste so the Petanang landfill could no longer accommodate waste in Lubuk Linggau City.



Source: Documentation results researcher, 2021

Figure 1. Petanang Landfill is *Overload*

In response this, the city government diverted waste storage to the Lubuk Binjai landfill (Dinas Lingkungan Hidup Kota Lubuk Linggau, 2021). Lubuk Binjai Landfill has an area of 25.4 landfill with a capacity of 446.47 m^3/day. Waste Management at the Lubuk Binjai landfill is carried out using the open dumping method, which throwing away the waste on land without processing the waste. This contrasts with the government's plan stated in the Lubuk Linggau City Spatial Plans for 2012-2032. The spatial plans document states that waste management in Lubuk Linggau City must be carried out using the Controlled Landfill or Sanitary Landfill method, where waste already collected at the final disposal site is managed using the buried waste method. Waste must be compacted with heavy equipment and then covered with soil.

This study will identify strategies for developing optimal landfill waste management that the Lubuk Linggau City Government can implement. This study determines priority strategies in developing landfill waste management in Lubuk Linggau City through consideration assessment from related stakeholders by applying the principles of multi-criteria analysis using *analytical hierarchy process* (AHP) methods. This research is important to carry out because the recommended priorities can then be used to develop a waste management plan that is more environmentally friendly and can be optimal for the available landfill which will then accommodate domestic waste in Lubuk Linggau City.

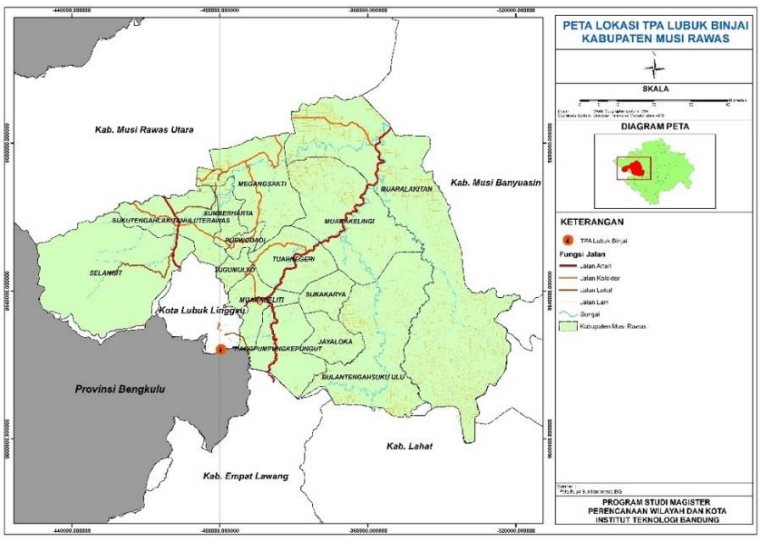


Figure 2. Lubuk Binjai landfill Location

2. LITERATURE REVIEW

2.1 *Open Dumping* Waste Management

Waste management using the open dumping method is considered less friendly because it can cause groundwater pollution. The open dumping method has a significant impact involving serious challenges to the environment and public health. In practice, discarded waste can pollute groundwater with dangerous substances, such as heavy metals, chemicals, and decomposing organic matter. Decomposing waste can produce a liquid called "leachate" which contains toxic and dangerous ingredients. This leachate can seep into the soil and pollute groundwater which is used as a source of drinking water and other groundwater (UNEP, 2015). Apart from that, this method also has the impact of causing air pollution. Garbage thrown away in open dumps can produce toxic gases such as methane (CH4) and sulfur dioxide (SO2). These gases can be released into the atmosphere and contribute to the greenhouse effect and air pollution (Bove, J., 2002). Not only does impact the environment, but open dumping waste management also poses risks to public health. Workers and local communities living around open waste dumps are at high risk of air and water pollution, as well as potential physical harm from piles of waste (WHO, 2018). Meanwhile, damage to natural habitats and local ecosystems is a direct consequence of this practice.

From the social and economic fields, people who are directly exposed can experience stigmatization and a decrease in quality of life due to odors, pollution, and other impacts. Open dumping systems tend to be unsustainable, accelerating necessary land improvements. This hampers local economic development (World Bank, 2018) and does not encourage the practice of recycling or reusing waste. By recognizing these impacts, transitioning to more sustainable and environmentally friendly waste management methods becomes imperative for future sustainability (Ongondo, Williams, & Cherrett, 2011).

2.2 *Sanitary Landfill* Waste Management

The sanitary landfill management method, although better than open dumping, also has several negative impacts on the environment. Sanitary landfills do not completely prevent groundwater pollution. Liquid waste (leachate) produced from decomposed waste can still seep through the soil layers and pollute the surrounding groundwater. This leachate contains dangerous ingredients such as heavy metals, pesticides, and other chemicals that can pollute groundwater sources. Sanitary landfills can also cause air pollution. The process of decomposing waste in landfills produces methane gas which is a strong greenhouse gas and contributes to climate change. Apart from that, there is also the release of other gases such as sulfur dioxide and ammonia which can cause air pollution (US Environmental Protection Agency, 2016).

3. METHOD

3.1 Method Data Analysis

This research was conducted using the AHP method. The existence of a hierarchical structure because of the selected criteria down to detailed sub-criteria in AHP can integrate subjectivity and objectivity in the decision-making process. AHP considers preferences hierarchically and seeks to integrate them, distinguishing them from other methods of resolving problems categorized as not too complex. This approach is based on the preferences of experienced experts in the field, particularly employees from the Environmental Service of Lubuk Linggau City. This method can also identify important factors in complex phenomena. The main tool of the Analytical Hierarchy Process (AHP) is a functional hierarchy with the main input being human perception. With hierarchy, a complex and unstructured problem is broken down into groups, and then arranged into a form of hierarchy. The hierarchy for selecting waste management strategies at the Lubuk Binjai landfill consists of alternative strategies, sub-criteria, criteria, and goals (achievements). The choice of hierarchy is based on previous research that has been synthesized.

Table 1. Previous Research to determine the Hierarchy

No	Researcher and Year	Title Study	Criteria	Sub Criteria
1	Dino Rimantho and Marlina Tamba (2021)	Proposed Solid Waste Management Strategy at the Burangkeng Bekasi landfill using the SWOT and AHP Approach	Human	Number of human resources
				HR expertise
			Technology	Innovation Management
				Mastery Technology Waste
			Finance	Capital
				Technology Prices In accordance
			Source Power	Raw material
				Facilities and infrastructure
				Materials and tools
			Institutions and Government	Support Management
				Requests and Cooperation
				Policy Government
				Suitability with RTRW
2	Alref BA and Tri Padmi (2015)	Multi Criteria Analysis of the Selection of Waste Management Concepts (Case Study: Village Areas in the Lake Sentani Region)	Technical Aspects	Initial waste handling patterns
				Management effectiveness
				Ease of operation
				Total processing time
			Social Aspect	Community desires in waste management
				Local community wisdom in waste management
				HR readiness in applying technology
				Employment
				Community participation
			Environment Aspect	Spread of disease vectors
				Potential air pollution
				Water and soil pollution due to leachate produced
				Aesthetic aspect/environmental beauty
			Institutional Aspect	Availability of institutions
				Availability of regulations
				Collaboration between stakeholders
			Economic Aspects	Low investment value
				Low operational and maintenance costs
				Increasing direct benefits to society
3	Mochammad Chaerul, Elprida Agustina, and I Made Wahyu Widyarsana (2019)	Multicriteria Analysis in Selection of Waste Processing Systems in Klungkung Regency, Bali Province	Environment	Prevent environmental pollution
				Aesthetics
				Disease vector
			Financial	Investment costs

In data management, Expert Choice software is used, which is an application based on the AHP method to determine criteria weights (Erdogan et al., 2017). Expert Choice can produce a level of inconsistency in respondents' answers. A CR value < 0.1 indicates that the respondent was consistent in providing assessments. The hierarchical structure of decision-making can be seen in the following figure.

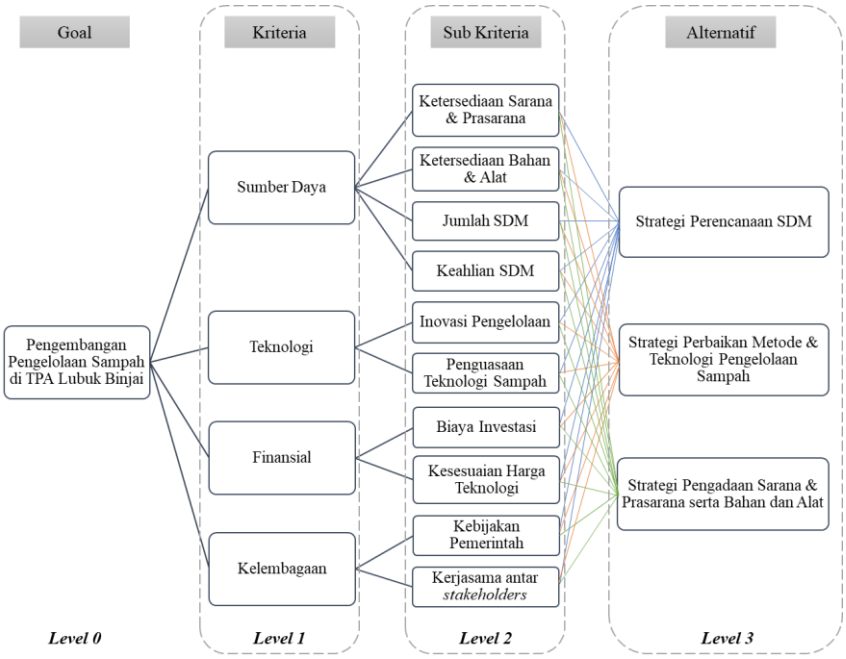


Figure 3. Hierarchy of Selection of Waste Management Development Strategies Lubuk Binjai Landfill

3.2 Method Data collection

Data collection was carried out by structured interviews using the questionnaire/questionnaire method. The questionnaire was structured based on a predetermined hierarchy and was discussed in advance with two respondents (Kepala Bagian Tata Usaha dan Kepala Bidang Pengelolaan Sampah dan RTH DLH Kota Lubuk Linggau) to adapt it to the case study at Lubuk Binjai Landfill.

Determining the number of respondents at this stage uses the purposive sampling method, namely a random sampling methodology. The researcher determines special criteria according to the research objectives. The criteria of respondents were carried out based on the consideration that the person or group selected acted as a decision maker, faced or was directly involved in determining waste management strategies at the Lubuk Binjai landfill.

Table 2. List of Respondent

No	Name	Position	Department
1	Erik Estrada	Head of the Administration Section of the Lubuk Linggau City Environmental Service	Office
2.	Rully Wijaya	Head of the Waste Management and Green Open Space Division of the Lubuk Linggau City Environmental Service	Office
3.	Anis Asril	Head of the Waste Management Section of the Lubuk Linggau City Environmental Service	Office
4.	Hartono	Lubuk Binjai landfill Coordinator Supervisor	Office/landfill

4. RESULT AND DISCUSSION

4.1 Analysis Criteria Development Management Lubuk landfill waste Binjai

The analysis in this section determines the criteria that respondents consider most important in selecting priority strategies for developing waste management at landfills (Dan & Ngo, 2018). The results of this analysis are a calculation of the combined weights of all respondents. Based on the results of data management with Expert Choice software, it can be seen that the respondents' assessment of the importance of the criteria prioritized in selecting a development strategy for landfill waste management is the technology criteria (aspect) with a priority weight of 38.1%, then the resource criteria 36.2%, financial criteria 14.7%, and institutional criteria 11%. In this analysis, the inconsistency level is 0.04, which is less than 0.1, meaning it is acceptable. Technology Criteria is a priority criterion because technology is considered to be something that must be improved in the waste management aspect at Lubuk Linggau landfill. This section discusses the results of the analysis which can be displayed in the form of diagrams, pictures, tables, or other forms of illustration that are easy to understand and communicate.

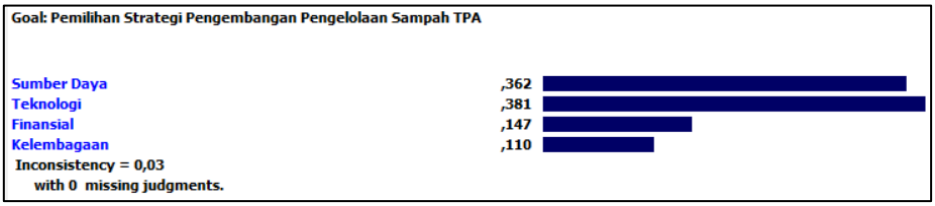


Figure 4. Expert Choice Results Priority Criteria for Lubuk Linggau Landfill Waste Management Development Criteria

In waste management, the technological aspect is important, because great technology can influence the efficiency, sustainability, and environmental impact of the waste processing process. Technology that is sophisticated and appropriate to local conditions can help reduce negative environmental impacts, increase efficiency in processing, and produce more valuable products from waste in Lubuk Linggau City. However, the technology operation certainly requires qualified resources, adequate financing for technology maintenance, and supporting institutions (World Bank, 2005).

4.2 Sub-Criteria Analysis and Alternative Development Strategies Management Lubuk Binjai Landfill

The analysis in this section is to find which sub-criteria are considered more important by respondents in each criterion in selecting priority strategies for developing waste management at landfills. The results of this analysis are a calculation of the combined weights of all respondents.

A. Resource Power

The priority sub-criteria for selecting strategies for developing waste management at landfills in the Resource criteria is HR Skills at 39.3% with an inconsistency of 0.03 < 0.1. HR expertise is prioritized compared to other criteria because Human Resources (HR) expertise shows the ability/skills in management needed to develop waste management at Final Processing Sites (Landfill).

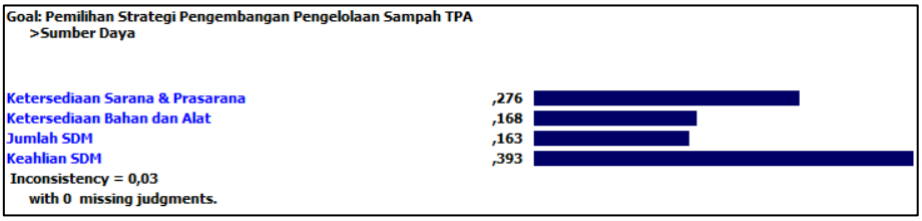


Figure 5. Expert Choice Results Priority Criteria for Resources for Lubuk Linggau Landfill Waste Management Development

In the resource aspect, human resource expertise has a high priority because the quality and effectiveness of the processing are very dependent on the knowledge, skills, and competence of the workers involved in the operation. Although facilities and infrastructure, availability of tools and materials, and quantity of human resources are also important, human resource expertise is a very determining factor in achieving optimal and sustainable waste processing results (World Bank, 2012). A skilled workforce can contribute to technological development and innovation in waste processing. Good HR skills can also increase efficiency in waste processing operations. In addition, trained human resources can help ensure that waste processing is carried out by applicable regulations and standards, avoiding negative impacts on the environment and health.

1. Availability of Facilities and Infrastructure Sub-Criteria

The alternative priority for selecting a waste management development strategy at the landfill in the Availability of Facilities & Infrastructure sub-criteria is the Procurement Strategy for Facilities & Infrastructure and Materials & Tools at 37.6% with an inconsistency of 0.00008 < 0.1 which is acceptable.

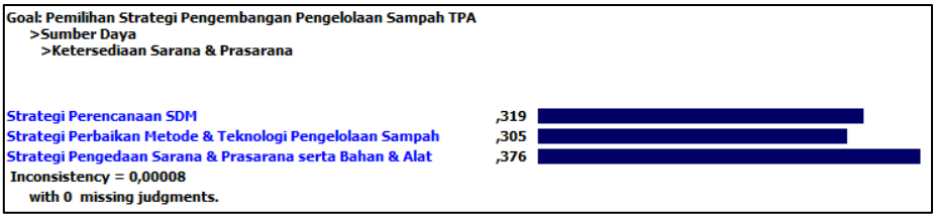


Figure 6. Results of Expert Choice Priority Sub-Criteria Infrastructure for Development of Lubuk Linggau Landfill Waste Management

2. Availability of Materials and Tools Sub Criteria

The alternative priority for selecting a waste management development strategy at the Landfill in the Availability of Materials & Tools sub-criteria is the Strategy for Procurement of Facilities & Infrastructure and Materials & Tools at 42% with an inconsistency of 0.00084 < 0.1 which is acceptable.

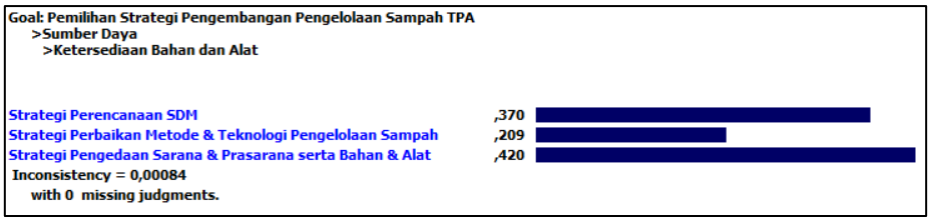


Figure 7. Results of Expert Choice Priority Sub Criteria for Tools and Materials for Development of Lubuk Linggau Landfill Waste Management

3. Human Resources Sub-Criteria

The alternative priority for selecting a waste management development strategy at the landfill in the sub-criteria for Number of Human Resources is HR Planning Strategy at 62.6% with an inconsistency of 0.02 < 0.1 which is acceptable.

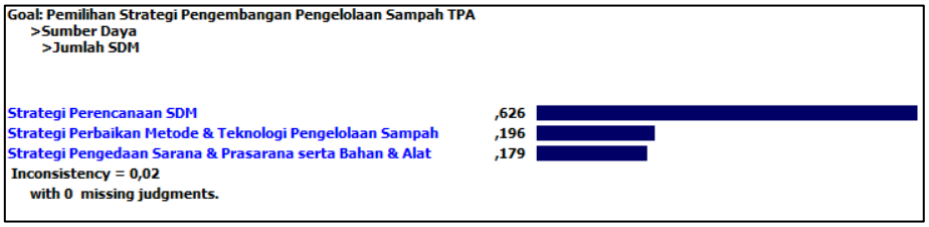


Figure 8. Expert Choice Results Priority Sub Criteria Number of Human Resources for Lubuk Linggau Landfill Waste Management Development

4. Human Resources Expertise Sub Criteria

The alternative priority for selecting a waste management development strategy at the landfill in the HR Skills sub-criterion is HR Planning Strategy at 63.2% with an inconsistency of 0.00573 < 0.1 which is acceptable.

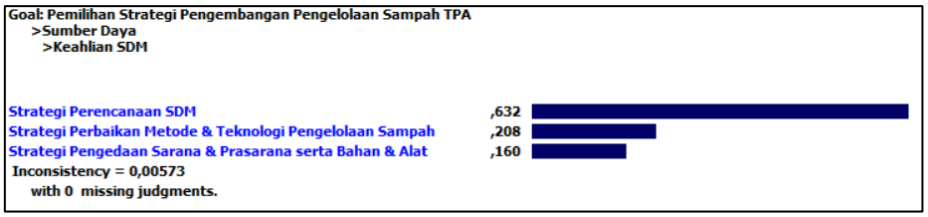


Figure 9. Expert Choice Results Priority Sub-Criteria Human Resource Expertise Development of Lubuk Linggau Landfill Waste Management

B. Technology Criteria

The priority of the sub-criteria for selecting waste management development strategies in landfills on the Technology criteria is Mastery of Waste Technology of 64.7% with an inconsistency of 0.02 < 0.1 which is more prioritized than the management innovation sub-criteria. The sub-criteria for mastering waste technology needed in developing landfill waste management is in line with the sub-criteria for human resource expertise which is prioritized in the resource criteria.

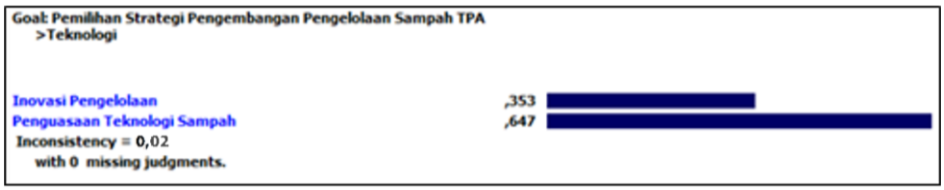


Figure 10. Expert Choice Results Priority Criteria for Lubuk Linggau Landfill Waste Management Technology

Mastery of waste technology is often prioritized over management innovation because technology that is already established and proven can be a strong basis for managing waste efficiently and effectively. Technology that has been tested and is sure to produce consistent and reliable results and reduce the risk of errors or failures in waste management (World Bank, 2012). It is important if Lubuk Linggau City prioritizes mastering waste technology because this is also a problem in the current management process. One of the strategies that can be developed is by providing HR training on using related technology.

1. Innovation Management Sub-Criteria

The alternative priority for selecting a waste management development strategy at the landfill in the Management Innovation sub-criteria is the Strategy for Improving Waste Management Methods & Technology at 45.9% with an inconsistency of 0.0027 < 0.1 which is acceptable.

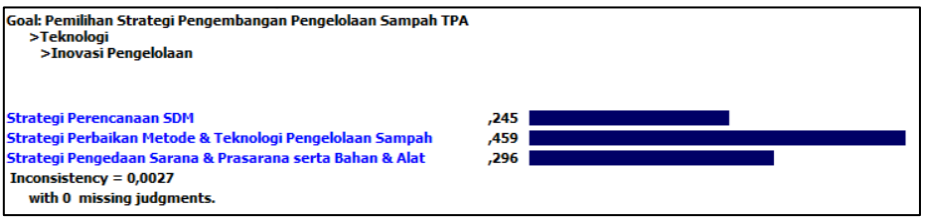


Figure 11. Expert Choice Results Priority Sub Criteria for Management Innovation and Development of Lubuk Linggau Landfill Waste Management

2. Mastery Technology Waste Sub-Criteria

The alternative priority for selecting strategies for developing waste management in landfills in the sub-criteria for Waste Technology Mastery is the Strategy for Improving Waste Management Methods & Technology at 48.1% with an inconsistency of 0.00133 < 0.1.

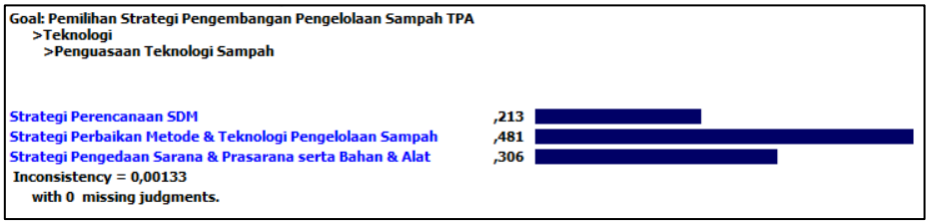


Figure 12. Expert Choice Results Priority Sub Criteria Mastery of Technology for Lubuk Linggau Landfill Waste Management Development

C. Financial Criteria

The priority of the sub-criteria for selecting waste management development strategies at landfills in the financial criteria is Investment Costs of 84.2% with an inconsistency of 0.031 < 0.1 which is more prioritized than the sub-criteria of technological price suitability. Sub-criteria for investment costs are needed in developing waste management at Landfill as funds that can be used.

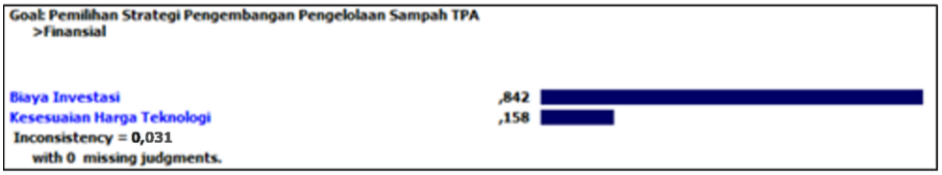


Figure 13. Expert Choice Results Priority Financial Criteria for Lubuk Linggau Landfill Waste Management Development

Investment costs are prioritized over technology price suitability because the initial investment costs required to adopt waste management technology can have a significant impact on an entity's budget and financial resources (Putra, 2021). Therefore, decision-making regarding waste management in Lubuk Linggau City focuses on the initial investment costs that must be incurred.

1. Investment Cost Sub-Criteria

The alternative priority for selecting a waste management development strategy at the Landfill in the Investment Cost sub-criteria is the Strategy for Improving Waste Management Methods & Technology at 51.5% with an inconsistency of 0.00378<0.1 which is acceptable.

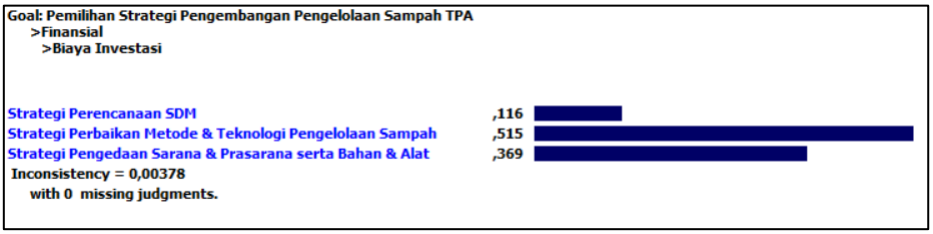


Figure 14. Expert Choice Results Priority Sub Criteria Investment Costs for Lubuk Linggau Landfill Waste Management

2. Sub-Criteria Technology Price Match

The alternative priority for selecting a strategy for developing waste management at the Landfill in the sub-criteria of Suitability of Technology Prices is the Strategy for Improving Waste Management Methods & Technology at 48.1% with an inconsistency of 0.00814 < 0.1 which is acceptable.

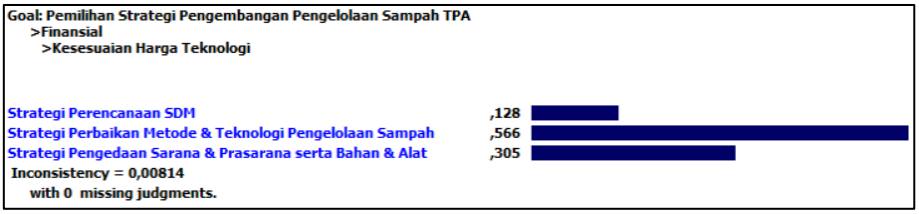


Figure 15. Expert Choice Results Priority Sub Criteria Price Suitability of Technology for Lubuk Linggau Landfill Waste Management Development

D. Criteria Institutional

The priority of the sub-criteria for selecting strategies for developing waste management in landfills in the Institutional criteria is Cooperation between stakeholders at 71.7% with an inconsistency of 0.02 < 0.1 which is more prioritized than the government policy sub-criteria. The priority selection for institutional criteria, namely the sub-criteria for collaboration between stakeholders, is in line with the priority selection for financial criteria.

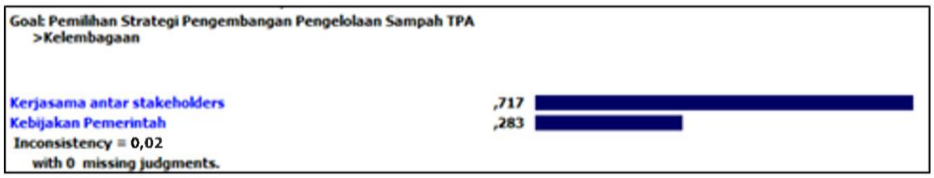


Figure 16. Expert Choice Results Priority Institutional Criteria for Lubuk Linggau Landfill Waste Management Development

Waste management in Lubuk Linggau City involves many parties who have different roles and responsibilities. Good cooperation between stakeholders can help overcome complex challenges in waste management, such as collection, transportation, processing, and recycling (Puspasari, 2016). Effective collaboration between stakeholders can also accelerate innovation, share knowledge and resources, and ensure broader support for sustainable waste management efforts (Qodriyatun, 2015). Government policy remains important as a framework for regulating and directing waste management, but institutions and collaboration between stakeholders can provide more effective and holistic implementation.

1. Stakeholders Collaboration Sub-Criteria

The alternative priority for selecting a strategy for developing waste management at the landfill in the sub-criteria for collaboration between stakeholders is HR Planning Strategy at 38.8% with an inconsistency of 0.03 < 0.1.

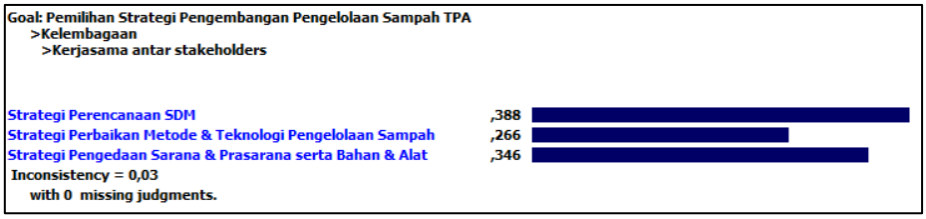


Figure 17. Expert Choice Results Priority Sub Criteria for Collaboration between Stakeholders for Development of Lubuk Linggau Landfill Waste Management

2. Policy Government Sub Criteria

The alternative priority for selecting a waste management development strategy at the landfill in the Government Policy sub-criteria is HR Planning Strategy at 50.2% with an inconsistency of 0.00204 < 0.1.

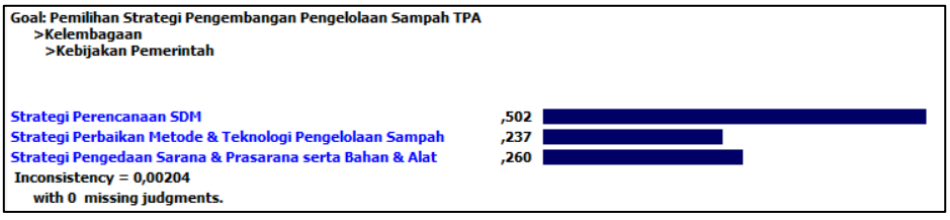


Figure 18. Expert Choice Results Priority Sub Criteria for Government Policy for Lubuk Linggau Landfill Waste Management

4.3 Analysis Priority Overall Strategy Alternatives

Based on the overall synthesis results, the alternative Strategy for Improving Waste Management Methods & Technology is a priority in selecting strategies for developing waste management in Landfills with a value of 37.1% compared to other alternatives. The results of this calculation are consistent enough or within the acceptance limits because the consistency ratio value obtained from this calculation is 0.02, which is below the specified standard (< 0.1). The alternative strategy for improving waste management methods & technology is assumed to be a priority because Lubuk Binjai Landfill still uses the Open Dumping system, so it is necessary to improve a better system to handle waste management at Lubuk Binjai Landfill.

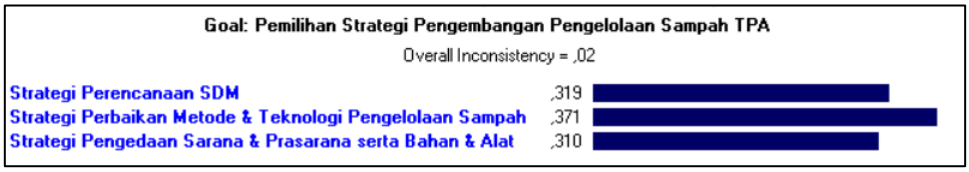


Figure 19. *Overall* Selection of Lubuk Linggau Landfill Waste Management Strategy

Based on four criteria that have been determined, the Technology criteria are prioritized by respondents compared to the Resource, Financial, and Institutional criteria. Based on the three alternatives assessed, the Waste Management Method & Technology Improvement Strategy alternative is prioritized compared to other alternatives. The results of the analysis, show that the prioritized strategy is the strategy for improving waste management methods & technology, which is needed by the problems at Lubuk Binjai TPA, namely still implementing the Open Dumping method. So that the prioritized alternative strategies can be applied in developing landfill waste management in Lubuklinggau City, apart from that, improving landfill waste management methods can be supported by the readiness and expertise of human resources.

Some alternatives can be implemented and are more environmentally friendly in waste management, namely recycling processing, composting, and more sophisticated waste management technologies such as controlled burning or anaerobic management. The use of technology in waste management must also be carried out optimally by procuring facilities and infrastructure as well as waste management materials and tools. There is also a need for an HR planning strategy. The city government needs to improve the quality of human resources by managing waste and landfills so that the benefits from technology management can also be optimal.

Another waste management innovation can be the construction of a Waste Power Plant (PLTSa). The construction of PLTSa is a good effort to reduce the amount of existing waste while utilizing it in other forms (Sucahyo, 2021). However, what needs to be noted is that a thorough evaluation of the existing waste management system must be carried out, identifying areas that can be optimized or adapted to support PLTSa. Selecting the right location for PLTSa also needs to consider the sustainability of the waste supply (Rajagukguk, 2020). Ultimately, waste management in PLTSa must be environmentally friendly and sustainable.

Application of further innovation in the Lubuk Binjai case study, increasing waste separation at source, ensuring that organic and non-organic waste is processed separately to increase the efficiency of PLTSa. PLTSa infrastructure can then be developed and integrated into existing systems by taking into account waste management capacity and local electricity needs. Sustainable funding and business models need to be considered, perhaps through partnerships with the private sector or the use of innovative financial schemes. Apart from that, educating the public about the benefits of PLTSa and their participation in waste separation is the key to the success of this integration.

5. CONCLUSION

In the context of waste management in Lubuk Linggau City, strategies for improving Waste Management Methods & Technology must be adopted by the City Government and Final Disposal Site (TPA) managers. This involves a change from open dumping waste management methods to more environmentally friendly

alternatives such as recycling, composting, and advanced waste management technologies. Increasing human resources for waste and landfill management and optimizing the use of technology are also emphasized. Apart from that, innovation in the form of a Waste Power Plant (PLTSa) is proposed as a solution to reduce the amount of waste and utilize it. However, it is necessary to carry out a thorough evaluation of the existing waste management system and select a sustainable location for PLTSa

Further research can be developed by considering other criteria and sub-criteria that are not in this study and adapting them to the conditions of the landfill. In addition, the respondents involved can be expanded by considering stakeholders outside government, for example, academics, NGOs, the community, and so on who can help in selecting priorities. This research is limited to determining waste management priorities in Lubuk Linggau City based on several important criteria for waste management in cities/regencies in Indonesia. As for recommendations for further studies that can be given, further research can discuss in detail the program plans based on the criteria that have been explained. Apart from that, further research can be carried out regarding effective waste management innovations in Lubuk Linggau City. This innovation can be in the form of an adaptation of a precedent or in the form of a study of the potential that Lubuk Linggau City has and can be utilized as a waste management development.

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