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Factors Affecting the Dysfunction of the Reduce, Reuse and Recycle Waste Treatment Facility in Palu City

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Abstract: The growing population and waste in Palu City pose challenges to sustainable waste management. 3R Waste Treatment Facility provides a community-based approach to reduce waste sent to Final Disposal Sites. However, several 3R Waste Treatment Facility facilities in Palu City do not operate efficiently. This study identifies the condition of 3R Waste Treatment Facility management and analyzes factors behind its dysfunction in Palu City. It uses 3R-based waste management theory, assesses 3R Waste Treatment Facility functionality, and examines factors found in earlier research. The study uses descriptive quantitative methods. Data were collected through observations, interviews, and questionnaires from 134 respondents at two non-functional 3R Waste Treatment Facility sites. Analysis was done using factor analysis in SPSS. Results show two 3R Waste Treatment Facilitys are non-functional, one underperforms, and one operates optimally. Eight factors contribute to dysfunction at Valangguni and Kavole 3R Waste Treatment Facilitys. Key factors include institutional aspects, government support, infrastructure, funding, human resources, and community participation. Recommended strategies include stronger institutional governance, improved human resources, infrastructure improvements, increased community participation, greater government support, and private-sector partnerships to ensure 3R Waste Treatment Facility operations in Palu City.

***Keywords**: 3R Waste Treatment Facility, Operational Dysfunction, Factor Analysis, Waste Management, Palu City.*

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I. INTRODUCTION

Implementing eco-friendly waste management systems is crucial for achieving environmentally sustainable urban development. Aligning with the 2030 Sustainable Development Goals (SDGs), sustainable waste management directly supports Goal 3 (Good Health), Goal 6 (Clean Water), Goal 11 (Sustainable Cities), Goal 12 (Responsible Consumption), and Goal 15 (Life on Land).

Under Minister of Public Works Regulation No. 3/2013, waste reduction at the source is a shared public-private responsibility. However, source-based segregation remains inadequate, necessitating enhanced collaboration between community leaders, local communities, and governments. To address this, the community-based Reduce, Reuse, Recycle Waste Treatment Facility (3R Waste Treatment Facility) was introduced. Operating at a communal scale to serve at least 200 households, 3R Waste Treatment Facility integrates waste collection, processing, and residue transport to final disposal sites. Its primary objective is to minimize waste volume and alter its characteristics, aligning with Presidential Regulation No. 97/2017 (Jakstranas), which positions landfills as a last resort for inert residues due to urban land scarcity.

As the capital of Central Sulawesi, Palu City reached a population of 389,959 in 2024 with a growth rate of 0.88%. This demographic growth has driven waste generation beyond management capacities, risking environmental degradation (Zulfinar & Sembiring, 2015). Currently, the Kawatuna Landfill receives 475 tons of waste daily, exceeding its planned capacity of 468 tons. While intermediate facilities like 3R Waste Treatment Facility are critical to mitigating this landfill load in accordance with Law No. 18/2008 and Jakstranas targets (30% reduction, 70% handling), two of the nine established 3R Waste Treatment Facility units in Palu City are currently dysfunctional.

Consequently, this study aims to identify the parameters causing 3R Waste Treatment Facility operational failure and analyze their underlying factors. provide strategic

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recommendations for policymakers and stakeholders to enhance 3R Waste Treatment Facility performance.

II. LITERATURE REVIEW

➢ *Waste*

According to Law No. 18 of 2008, waste is defined as the residue of daily human activities and/or natural processes originating from various sectors, including households, industries, commerce, agriculture, and other waste-generating activities. In a broader technical context, Tchobanoglous (1993) defines waste as solid or semi-solid discarded materials resulting from human or animal activities that are disposed of because they are no longer wanted or useful.

In Indonesia, waste is generally categorized into several major groups, as outlined by Damanhuri and Padmi (2010):

- Organic Waste (Wet Waste): Consists of biodegradable materials such as leaves, wood, bones, food scraps, vegetables, and fruits. Although paper and cardboard are also organic in nature, they are often grouped technically based on handling.
- Inorganic Waste (Dry Waste): Comprises non-biodegradable materials, including cans, plastics, iron and other metals, glass, and mica.
- Based on its biochemical properties and composition, waste can be differentiated into three distinct categories:
- Organic (Biodegradable) Waste: Readily decomposable matter, such as food scraps, vegetables, dry leaves, and straw.
- Inorganic (Non-biodegradable) Waste: Non-decomposable matter that resists natural decay, such as plastic food packaging, paper, plastic toys, beverage bottles, glass, and cans.
- Specific Waste: Materials containing Hazardous and Toxic Substances, including used syringes, intravenous (IV) tubes, batteries, and chemical waste.

➢ *Waste Management System*

Law No. 18 of 2008 on Waste Management emphasizes the development of more efficient, environmentally sound, and sustainable waste management systems. It highlights the critical importance of multi-stakeholder collaboration involving the government, civil society, and the private sector to mitigate the adverse impacts of waste on environmental quality and public health.

Crucially, Law No. 18 of 2008 advocates for a paradigm shift in municipal solid waste management. It explicitly challenges the conventional public perception that waste must be directly disposed of in landfills. This traditional linear approach rapidly depletes landfill capacities, causing final disposal sites to become overfilled prematurely and fail to reach their intended operational lifespan.

According to this legal framework, the foundational principles of modern waste management comprise the following:

- Paradigm Shift: Moving away from a reactive "collect-transport-dispose" model toward resource recovery.
- Source-Based Reduction: Maximizing waste reduction and utilization at the source to significantly lower downstream management requirements and operational costs.
- Organic Waste Recovery: Capitalizing on the high organic content of municipal waste (typically 60% to 80%) as prime raw material for composting through active community participation.
- Informal Sector Integration: Formalizing and integrating informal recycling actors (e.g., waste pickers) into the broader urban waste management framework.
- Landfill Optimization: Positioning the Final Disposal Site strictly as the ultimate stage for residual waste processing, designed to operate for a minimum lifespan of 10 years.
- Thermal Treatment Limitation: Utilizing incinerators strictly as a last resort technology for municipal solid waste processing.

Furthermore, operationalizing waste management under Law No. 18 of 2008 aims to deliver definitive socioeconomic and ecological benefits, specifically:

- Economic Value and Behavioral Change: Redefining waste as a valuable resource to stimulate economic opportunities while fostering positive behavioral shifts across the community.
- Risk Mitigation: Substantially reducing the negative externalities of unmanaged waste on public health and natural ecosystems.
- Systemic Efficiency: Ensuring that waste management practices are executed proportionally, effectively, and efficiently.
- As waste generation escalates concurrently with urban growth, transition strategies must abandon direct landfilling in favor of systematic segregation. Through decentralized sorting, recyclable and compostable waste can be converted into renewable economic commodities. Maximizing household-level reuse and circular processing ensures that only completely inert residues reach the final disposal site, moving closer toward a zero-waste objective.

➢ *Definition and Objectives of 3R Waste Treatment Facility*

According to the Regulation of the Minister of Public Works of the Republic of Indonesia No. 03/PRT/M/2013, a 3R Waste Treatment Facility is defined as a communal or area-based facility designated for waste collection, segregation, reuse, and recycling operations. The foundational principles of the 3R framework are operationalized as follows:

- Reduce: Minimizing the overall volume of waste generated through systematic source segregation and the reduction of single-use products.
- Reuse: Utilizing discarded items that remain functional to lower the demand for new production and decrease the total volume of waste requiring municipal handling.
- Recycle: Processing recyclable waste fractions such as plastics, paper, and metals into new, valuable raw materials or secondary products.

The primary objective of a 3R Waste Treatment Facility facility is to divert municipal solid waste away from Final Disposal Sites by maximizing resource recovery through reuse and recycling. Specifically, the implementation of this system aims to:

- Extend Landfill Lifespan: Diverting substantial waste volumes from entering the landfill, thereby prolonging its planned operational longevity.
- Foster Environmental Consciousness: Enhancing public awareness and community participation regarding the vital importance of source-based waste segregation and eco-friendly management.
- Empower the Local Economy: Generating local economic value by converting organic and inorganic waste into marketable commodities, such as organic compost and upcycled handicrafts.
- Mitigate Environmental Risks: Improving local sanitation and ecological health by minimizing the adverse externalities of unmanaged waste on ecosystems and public health.

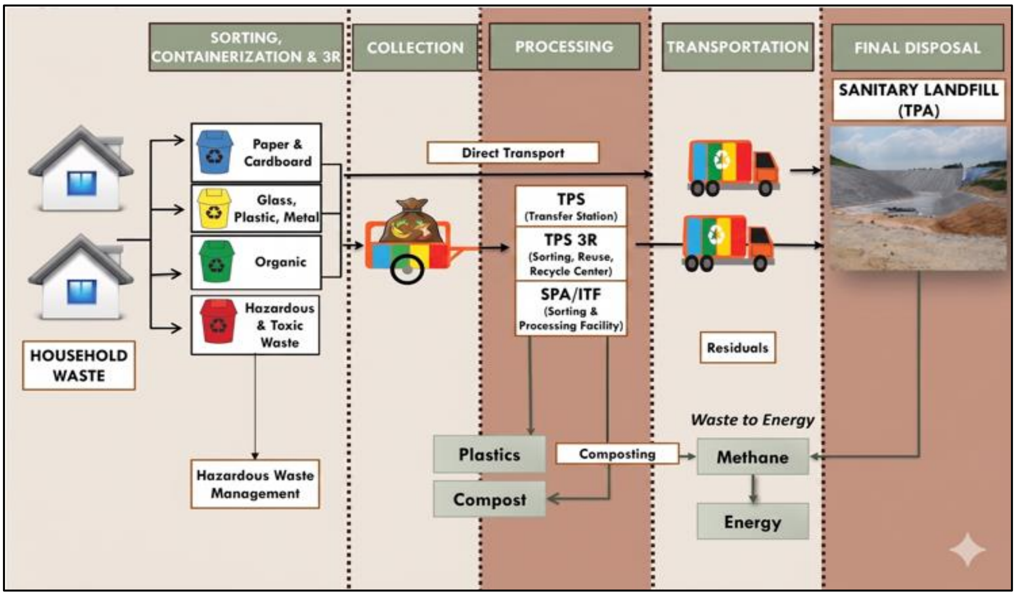

Fig 1 3R Waste Treatment Facility Facilities

➤ *Technical Criteria and Stabdards for 3R Waste Treatment Facility Facilities*

Under Law No. 25 of 2009 concerning Public Services, the government is mandated to establish standardized public service benchmarks for every public sector service provided to the community. These standards must comprehensively encompass service duration, operational costs, transparent procedures, and overall service quality.

In the specific context of waste infrastructure, the Regulation of the Minister of Public Works No. 03 of 2013 concerning the Implementation of Waste Infrastructure and Facilities for Managing Household and Household-like Waste stipulates that a 3R Waste Treatment Facility operates as a residential-scale service managed through community-based methods. The regulation outlines strict technical and spatial criteria required for the development of a 3R Waste Treatment Facility facility, which include:

- The total area of the 3R Waste Treatment Facility site must be greater than 200 square meters.
- The facility must serve a minimum design capacity of 200 households.
- Segregation Infrastructure: Provision of adequate facilities to sort municipal waste into at least three distinct waste streams.
- The facility must be equipped with dedicated functional spaces, including a sorting zone, a composting area, and necessary supporting or administrative rooms.
- Residue Containment: Structures designated for temporary residue storage prior to final disposal must be non-permanent containers.
- The minimum distance from the 3R Waste Treatment Facility to its target service area must not exceed 1 kilometer, ensuring easy operational accessibility.
- The maximum distance between the 3R Waste Treatment Facility facility and a public main road must not exceed 100 meters.
- The land size and processing capacity must be proportionally scaled to meet localized service demands.
- Logistical Schedules: Establishment of clear and fixed schedules for waste collection and transport.

Practically, the continuous annual increase in municipal solid waste generation severely threatens the remaining operational lifespan of the Kawatuna Landfill in Palu City. In this regard, maximizing the potential of 3r Waste Treatment Facility facilities acts as a critical interceptor. By converting organic and recyclable waste fractions into marketable end-products, these facilities not only divert waste from the landfill but also stimulate a self-sustaining local circular economy for the surrounding community.

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➢ *Determinants of 3R Waste Treatment Facility Operational Dysfunction*

Based on extensive empirical literature, the operational failure or dysfunction of 3R Waste Treatment Facility facilities is driven by several interrelated factors. The primary determinants commonly identified in municipal solid waste studies include:

- *Infrastructural and Facility Limitations*

Many 3R Waste Treatment Facility units lack adequate hardware and structural facilities to execute proper waste processing. Common deficiencies include insufficient sorting bays, substandard manual or mechanical segregation tools, and limited recycling equipment. These structural constraints directly inhibit facilities from reaching their maximum operational design capacity.

- *Insufficient Local Government Support*

Local governments play a pivotal role in ensuring institutional longevity through policy enforcement, regulatory frameworks, and consistent budgetary allocations. Absent robust municipal support, 3R Waste Treatment Facility facilities face immense challenges in maintaining daily operations and scaling up local waste programs.

- *Technical Constraints and Human Resource Deficiencies*

A shortage of skilled personnel trained in modern waste processing techniques presents a major operational bottleneck. Efficient facility operation requires adequate technical knowledge regarding composting kinetics, equipment maintenance, and residue sorting procedures.

- *Low Community Participation*

The viability of a decentralized 3R Waste Treatment Facility relies heavily on upstream community compliance in source segregation (separating organic and inorganic streams at the household level). However, low public awareness and deeply ingrained socio-cultural habits regarding unsegregated disposal prevent facilities from receiving well-sorted inputs, undermining the entire processing chain.

- *Weak Institutional Governance*

Long-term sustainability requires well-structured community-based management organizations to oversee daily administration and routine maintenance. Poorly defined roles, lack of accountability, or institutional friction frequently lead to systemic inefficiencies and, ultimately, total operational abandonment.

- *Financial and Budgetary Inadequacies*

Insufficient funding for operations and maintenance (O&M) is a primary driver of facility closure. While initial capital investment often covers physical construction, many 3R Waste Treatment Facility units are established without a sustainable, long-term financial plan or cost-recovery mechanism (such as reliable user fee collection) to cover recurring expenses.

To understand these dynamics contextually within the study area, the complete inventory of established 3R Waste Treatment Facility facilities across Palu City is documented below:

Table 1 Inventory of 3R Waste Treatment Facility Facilities in Palu City

No	Facility Name	Urban Village	Sub-district
1	3R Waste Treatment Facility Palupi Berseri	Palupi	Tatanga
2	3R Waste Treatment Facility Valangguni	Valangguni	Mantikulore
3	3R Waste Treatment Facility Buvu Bionga	Petobo	Palu Selatan
4	3R Waste Treatment Facility Kavole	Pengawu	Tatanga
5	3R Waste Treatment Facility Topan Timali	Panau	Tawaeli
6	3R Waste Treatment Facility Avosalae	Silae	Ulujadi
7	3R Waste Treatment Facility Huntap Tondo 1	Tondo	Mantikulore
8	3R WASTE TREATMENT FACILITY Huntap Duyu	Duyu	Tatanga
9	3R WASTE TREATMENT FACILITY Huntap Tondo 2	Tondo	Mantikulore

Source: Palu City Environmental Department (DLH), 2025.

➢ *Factor Analysis*

Factor analysis is a statistical technique used to simplify complex data structures by reducing a large number of observed variables into fewer latent constructs known as factors. This method identifies groups of variables that exhibit high intercorrelation, forming clusters that represent underlying dimensions. The primary goal is to uncover hidden patterns and relationships among variables that are not directly observable.

The process involves several key steps. First, determining the number of factors is typically based on the eigenvalue criterion, where factors with eigenvalues greater than 1 are retained, as they explain a significant portion of the variance. Second, factor rotation—either orthogonal (e.g., Varimax) or oblique—is applied to enhance interpretability by clarifying which variables load strongly onto which factors. Third, factor scores are calculated to represent individual cases on each latent factor, serving as weighted averages that reflect the strength of association between variables and their respective constructs.

Additionally, factor analysis supports instrument validation, confirms theoretical dimensions (confirmatory factor analysis), and enables generalization of findings to broader populations. It distinguishes between common factors (shared variance) and unique factors (specific variance), assuming independence among factors to ensure robust structural interpretation. This method is particularly valuable

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in infrastructure project studies, where multiple interrelated variables influence performance outcomes.

III. RESEARCH METHOD

➢ *Type of Research*

This study utilizes a descriptive quantitative design with a case study approach. Descriptive quantitative research systematically describes standalone independent variables without making external comparisons or structural correlations (Sugiyono, as cited in Sastrawinata & Dwisusanto, 2018).

The framework is applied to provide an in-depth evaluation of 3R Waste Treatment Facility operational dysfunction and assess its compliance with municipal waste service standards. By analyzing the causal links within empirical field facts, this study maps the relationships between variables, establishes data equivalencies, and contextualizes prior empirical findings. Data collection serves as the evaluative foundation to address the research questions, providing an objective depiction of the operational conditions retrieved directly from the field.

➢ *Research Location*

The spatial scope of this study encompasses multiple sub-districts within Palu City. The precise geographical boundaries and coordinates of the investigated 3R Waste Treatment Facility facilities are detailed below:

Fig 2 Research Location

➢ *Data Collection Techniques*

Data collection in this study is executed through four integrated approaches to assess the operational status and management systems of 3R Waste Treatment Facility facilities in Palu City:

- Direct site assessments are conducted at each active and inactive 3R Waste Treatment Facility facility. This approach aims to evaluate physical infrastructure conditions, operational workflows, and the technical behavior of management groups in maintaining the facilities, while comprehensively documenting existing field conditions.
- Semi-structured interviews are conducted with key institutional stakeholders, specifically the Palu City Environmental Department (DLH) and local 3R Waste Treatment Facility management groups. These sessions seek to gather baseline data regarding facility development, structural bottlenecks, service logistics, and management perceptions on operational effectiveness.
- Structured written questionnaires are administered to respondents to gather standardized quantitative insights. The questions focus specifically on the underlying socio-technical and financial determinants driving 3R Waste Treatment Facility operational dysfunction.
- Secondary data and theoretical frameworks are gathered from peer-reviewed journals, academic theses, government reports, and relevant reference books to support data triangulation and comparative analysis.

➢ *Data Analysis Technique*

To facilitate the factor analysis process, this study utilized the Statistical Package for the Social Sciences (SPSS) software. SPSS is one of the most widely used statistical programs for data analysis, offering features such as statistical computation, case selection, file transformation, derived variable creation, and data documentation—making it highly suitable for research purposes.

Factor analysis is a statistical method used to examine interdependencies among variables with the aim of identifying a smaller set of new variables, known as factors, that represent shared variance among the original variables (Suryanto, 1988). In this method, a large number of variables are grouped into factors that exhibit similar characteristics, simplifying data interpretation. Variables with high correlations are grouped into the same factor, while those with lower correlations are assigned to different factors.

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The factor analysis process begins by selecting variables deemed suitable for inclusion. This method is particularly useful when many variables are independent, requiring dimensionality reduction to form smaller, interpretable groups. The following statistical techniques were applied:

✓ *Kaiser-Meyer-Olkin (KMO) Test*

The KMO index assesses the adequacy of the data for factor analysis. A KMO value greater than 0.50 indicates that the correlation among variables is sufficient for factor extraction. Conversely, a KMO value below 0.50 suggests that the variables are not suitable for factor analysis.

✓ *Measure of Sampling Adequacy (MSA)*

MSA evaluates the intercorrelation among variables and the appropriateness of factor analysis. Variables with MSA values below 0.50 should be excluded and the analysis repeated.

Subsequently, factor rotation was performed to simplify the structure and improve interpretability. Rotation helps clarify which variables load strongly onto specific factors, especially when some variables exhibit high correlations with multiple factors. The resulting component matrix displays the distribution of variables across the extracted factors, with loading factors indicating the strength of correlation between each variable and its corresponding factor.

The final step involved naming the factors. While there is no fixed rule for naming, each factor was labeled based on the dominant variables it contained, as indicated by the highest loading values.

IV. RESULTS

➢ *Research Results*

- *3R Waste Treatment Facility Valangguni*

3R Waste Treatment Facility Valangguni is one of the dysfunctional waste processing facilities located within Palu City. Situated on Dayodara Street, the facility was constructed in 2010. In terms of spatial footprint and basic built infrastructure, the site largely complies with national technical standards. This compliance is demonstrated by its total land area of 450 square meters, which significantly exceeds the mandated minimum threshold of 200 square meters. The physical complex is fully equipped with an administrative office, a storage warehouse, dedicated organic and inorganic waste processing zones, an equipment room, and sanitation facilities. However, despite possessing an adequate structural layout, the facility's operational capacity is non-existent due to widespread equipment theft and loss.

Currently, the facility lacks essential waste processing machinery required by technical guidelines, specifically mechanical organic shredders and compost screening units. Furthermore, necessary low-tech biological processing tools, such as bamboo aerators and composting drums, are entirely absent. The remaining logistical asset at the site consists of a single three-wheeled waste collection vehicle; however, it remains idle and does not perform any collection or source-sorting services. Operational logistics are further constrained by degraded road conditions directly in front of the facility, making transport accessibility highly difficult for waste collection vehicles. According to empirical insights provided by the current head of 3R Waste Treatment Facility Valangguni, municipal waste services for this administrative area have been temporarily redirected and are currently being handled at the 3R Waste Treatment Facility Tondo 1 facility located in Tondo Urban Village.

- *Validity Testing*

A validity test is executed to evaluate the correlation between the score of each individual questionnaire item and the total cumulative score of all items. This process is essential to ensure that every question in the instrument consistently measures the same underlying target variable, thereby verifying the internal validity of the questionnaire and enhancing the reliability of the empirical findings. To test the validity of each statement item, this study utilizes the Pearson Product-Moment Correlation technique.

The evaluation criteria dictate that an instrument item is declared valid if the calculated r-value (r-statistic) is greater than the critical r-value from the statistical table (r-table). Conversely, if the calculated r-value is less than the r-table value, the item is deemed invalid and excluded from further analysis. In this study, the researcher analyzed the questionnaire responses from a total sample size of 67 respondents. The statistical analysis was conducted with a 95 percent confidence interval, corresponding to a significance level (alpha) of 0.05. Based on the standard r-distribution table for a sample size of 67 respondents at this significance level, the critical r-table threshold value is established at 0.240.

Based on the statistical outputs, every tested measurement item exhibits a calculated r-value significantly greater than the critical r-table threshold of 0.240. Consequently, it can be concluded that all operational variables and their respective indicators are empirically valid, confirming their eligibility for deployment in the subsequent stages of multivariate data analysis.

- *Reability Testing*

The subsequent stage of analysis involves executing a reliability test using SPSS software. The primary objective of reliability testing is to determine the internal consistency of the measurement instrument. A reliable instrument ensures stable and consistent results when deployed under uniform conditions across different periods. To evaluate data reliability, this study applies the Cronbach's Alpha formula.

Cronbach’s Alpha is widely recognized as the standard metric for measuring the internal consistency and reliability of multi-item research scales. The value of Cronbach’s Alpha ranges from 0 to 1, and a research instrument is statistically deemed reliable or acceptable if its alpha coefficient is greater than 0.60 (Ghozali, 2011).

Based on the empirical reliability outputs summarized in the tables above, the individual Cronbach’s Alpha coefficient for every single measurement item systematically exceeds the

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required statistical threshold of 0.60. Furthermore, the overall scale demonstrates an aggregate alpha value of 0.860 across all 35 items. Consequently, it can be concluded that the complete research instrument possesses high internal consistency and exceptional reliability, thereby confirming its suitability and structural validity for advanced multivariate research operations.

- *Factor Analysis and KMO-Barlett's Testing*

The subsequent stage of investigation involves performing an exploratory factor analysis using SPSS software to analyze the underlying determinants driving 3R Waste Treatment Facility operational dysfunction in Palu City. Factor analysis is systematically deployed to identify, reduce, and classify the extensive set of research variables into a more meaningful structure. The analytical workflow comprises several consecutive phases: evaluating data suitability through the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy and Bartlett's Test of Sphericity, verifying the individual Measure of Sampling Adequacy (MSA) thresholds, determining the number of latent dimensions via factor extraction and orthogonal rotation, and ultimately clustering and assigning conceptual labels to the newly formed factor structures.

The initial step in this multivariate procedure requires assessing the overarching datasets via KMO and Bartlett's testing to confirm whether the matrix is eligible for factoring. This verification ensures that the empirical data satisfies the necessary statistical assumptions required to proceed with advanced dimensional reduction. Methodologically, the dataset is considered appropriate for factor analysis if the aggregate KMO index is greater than 0.5 and the Bartlett's test achieves a significance value of less than 0.05. Based on the field responses processed through SPSS, the comprehensive outputs for both tests are presented in the table below:

Table 2 KMO and Bartlett's Test of Sphericity Outputs

Kaiser-Meyer-Olkin Measure Of Sampling Adequacy		**0,558**
Bartlett's Test Of Sphericty	Approx Chi-Square	1373.079
	Df	595
	Sig.	<,001

According to the statistical outputs summarized in Table 4.6, the calculated KMO index is 0.558, which is greater than the required threshold of 0.5. Concurrently, the Bartlett's Test of Sphericity yields an approximate Chi-Square value of 1373.079 with a significance value of less than 0.001, which is substantially less than the standard significance alpha of 0.05. These empirical metrics demonstrate that the research variables possess sufficient multi-collinearity and strength of relationship, thereby confirming that the dataset is highly suitable for further factor analysis. Consequently, the application of factor analysis will successfully identify the foundational structures of the data and reduce the numerous individual variables into a concise set of latent factors that accurately represent the core information.

- *Measure of Sampling Adequacy (MSA) and Anti-Image Matrices Testing*

The Measure of Sampling Adequacy (MSA) test is a statistical procedure deployed to evaluate the suitability of individual research items for subsequent factor analysis. The MSA index measures the strength of inter-correlations among variables within a dataset to ensure they exhibit a sufficient degree of relationship to justify dimensional reduction (Tabachnick & Fidell, 2007). In conjunction with the overall MSA index, the Anti-Image Correlation Matrix is systematically utilized to identify and determine which specific variables satisfy the necessary criteria to be included in the factor analysis model.

The Anti-Image Correlation Matrix displays coefficients diagonally, with each diagonal value representing the specific MSA score for an individual variable. Methodologically, if the individual MSA value of a variable is greater than 0.50, the item is considered statistically adequate and eligible to be retained for advanced factor analysis. Conversely, if the MSA score of a specific variable is less than 0.50, the variable lacks sufficient correlation with the other items and must be excluded from the model to preserve the mathematical validity of the subsequent factor extraction.

- *Factor Extraction and Scree Plot Analysis*

The determination of the exact number of latent factors to be retained in the analysis is primarily governed by the Initial Eigenvalue criterion. Under this methodological approach, only factors exhibiting an Initial Eigenvalue greater than 1.00 are considered statistically significant and eligible for retention. This threshold is chosen because any factor with an eigenvalue greater than one is capable of explaining a larger portion of total variance than a single, individual variable.

In this specific study, a total of 28 extracted variables were analyzed to satisfy the cumulative variance percentage target. The structural extraction process aims to achieve a cumulative variance that exceeds 60 percent, thereby ensuring that the newly formed factor structures are mathematically robust and capable of representing the vast majority of the original information contained within the dataset.

Based on the statistical parameters derived from the Total Variance Explained table, there are exactly eight components that exhibit an Initial Eigenvalue greater than 1.00. Concurrently, the cumulative variance percentage accounted for by these eight extracted dimensions reaches 72.404 percent, which comfortably exceeds the standard academic threshold of 60 percent. This substantial explanatory power indicates that the newly formed components can effectively account for and represent the variance of the underlying variables tested within the dataset. Consequently, the original 28 individual variables influencing the operational dysfunction of the 3R Waste Treatment Facility facility in

Valangguni Urban Village were successfully reduced and extracted into eight distinct latent factors. To visually illustrate the mathematical relationship between each extracted component and its respective eigenvalue, the corresponding scree plot is presented below.

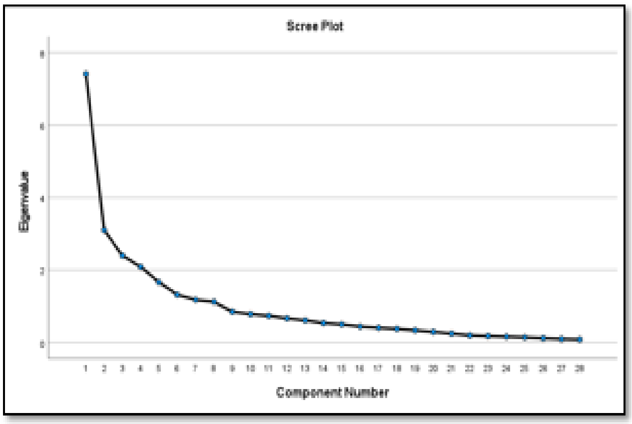

Fig 3 Scree Plot

According to the graphical distribution displayed in the scree plot above, the structural break and data inflection points precisely substantiate the eigenvalue criteria. The plot demonstrates eight distinct component points situated above the critical threshold line of 1.00. Beyond the eighth component, the curve flattens significantly, and the subsequent eigenvalues drop below the baseline value. This graphical trend confirms that the mathematical structure of the data reaches optimal stability and representation at exactly eight extracted factors.

- *Variable Extraction and Factor Rotation*

Once the exact number of latent factors has been determined, factor extraction is executed. Factor extraction represents the core procedural phase in exploratory factor analysis, aiming to systematically reduce a large set of original variables into a smaller, more parsimonious set of newly formed dimensions or composite factors. In this study, the Principal Component Analysis (PCA) method is deployed as the mathematical engine to achieve this dimensional reduction.

Following the initial extraction phase within the PCA framework, an orthogonal rotation is applied to yield the Rotated Component Matrix. This matrix illustrates the localized correlations and loading weights between the original independent variables and the newly extracted latent components. The Rotated Component Matrix serves as a critical analytical tool, facilitating a clearer interpretation of the factor loading strengths and identifying which specific variables are most robustly associated with each distinct component. The empirical loading values for the eight extracted components derived from this matrix are detailed below.

Table 3 Summary of Variable Groupings by Factor

Factor	Variables Assigned	Total Variables
1	K2, K3, K5, K1, K4, K6, IF5	7
2	DP1, DP2, SDM1, DP3, SDM2, SDM 3	6
3	P4, P1, P2, IF4	4
4	IF6, PM3, PM5	3
5	SDM6, PM2	2
6	SDM4, PM4, DP5	3
7	SDM5, DP6	2
8	P5	1

- *Factor Interpretation and Conceptual Naming*

Based on the exploratory factor analysis conducted on the responses from the 67 surveyed participants, eight newly formed latent factors were identified as the primary determinants driving the operational dysfunction of 3R Waste Treatment Facility Valangguni. The comprehensive breakdown and contextual analysis of these eight extracted dimensions are structured as follows:

✓ *Institutional Governance and 3R Waste Treatment Facility Operational Support*

Comprising variables K1, K2, K3, K4, K5, K6, and IF5, this dimension emphasizes structured internal management. The variable for a clear division of labor (K2) features the highest loading (0.818), validating that explicit operational roles within the management group eliminate administrative overlaps and maximize processing efficiency (Khodijah & Pharmawati, 2023). Furthermore, robust leadership and clear public communication loops remain critical for community-based 3R waste initiatives, as mandated by Law No. 18/2008 and Ministry of Public Works guidelines (2018).

✓ *The Role of Government in Institutional Capacity Building*

Integrating variables DP1, DP2, DP3, SDM1, SDM2, and SDM3, this factor is dominated by routine government-led public socialization (DP1, loading: 0.819). This highlights that municipal support is essential for long-term facility survival through human resource development and technical training (Utami et al., 2025). The current dysfunction reflects a clear lack of municipal backing, failing the statutory oversight and policy enforcement roles mandated by Law No. 18/2008.

✓ *3R Waste Treatment Facility Financial Resource Support*

Formed by variables P1, P2, P4, and IF4, this factor underscores that financial resilience is a baseline prerequisite for sustaining daily operations. Alternative funding mechanisms (P4) exhibits the highest loading (0.895). Over-reliance on government subsidies combined with zero

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commercial revenue from compost or recycled goods—due to the complete theft of processing machinery—severely disrupted the facility's cash flow (Zumaira & Widodo, 2026).

✓ *Community Participation and Infrastructure Integration*

This factor combines PM3, PM5, and IF6, with adequate waste segregation areas (IF6) showing the highest loading (0.690). This confirms that civil engineering adequacy is vital; here, degraded access roads and stolen machinery (shredders and composters) caused total functional deviation, reverting the facility from a processing center into a passive dumping site. This technical failure was worsened by low household-level source segregation (Wardani et al., 2026).

✓ *Operational Sustainability and Tariffs*

Driven by community willingness to pay tariffs (PM2) and smooth daily execution (SDM6, loading: 0.808), this factor demonstrates that physical operations are deeply co-dependent on public financial compliance. When households refuse regular service fees, operational cash flow collapses, triggering equipment neglect and eventual facility shutdown.

✓ *Collaborative Governance and Management Efficiency*

Comprising PM4, DP5, and SDM4, this dimension is led by waste management workflow efficiency (SDM4, loading: 0.735). Severe resource constraints and the absence of regulatory monitoring and evaluation from municipal authorities eliminated the feedback loops required to maintain performance standards, culminating in unmitigated operational decline (Utami et al., 2025).

✓ *The Role of Government in Operational Logistics*

Encompassing DP6 and technical support (SDM5, loading: 0.830), this factor confirms that pervasive technical and managerial deficits demand direct state intervention (Utami et al., 2025). Since the technical assets were stolen, municipal authorities must act as institutional mediators to facilitate public-private partnerships, unlocking private capital investments and operational recovery pathways.

✓ *Institutional Funding Support for Operators*

Centered on the allocation of adequate institutional funds for performance enhancement (P5, loading: 0.621), this final factor highlights the necessity of a stabilized internal budget (Utami et al., 2025). To mitigate the risks of single-source financing, management must forge cooperative frameworks with external stakeholders and NGOs to secure alternative financial channels.

➢ *3R Waste Treatment Facility Valangguni*

3R Waste Treatment Facility Kavole is another of the three dysfunctional waste processing facilities located within Palu City. Situated on Dayodara Street, the facility was constructed in 2015. Based on field observations, the structural infrastructure and technical facilities are completely non-functional. The primary building has suffered severe structural damage, which was triggered by the devastating 2018 earthquake and subsequent component looting. In terms of spatial footprints, 3R Waste Treatment Facility Kavole possesses a total land area of 441 square meters, which complies with the national minimum technical requirement of 200 square meters.

The systemic condition of 3R Waste Treatment Facility Kavole reveals a total functional deviation; the site can no longer execute any waste processing workflows and is used strictly as a passive transit point for temporary waste collection before the unsegregated refuse is hauled to the Kawatuna Landfill. The processing hangar completely lacks a roofing structure, and the administrative office building is heavily damaged and repurposed as a makeshift storage room for salvaged goods. Regarding mandated technical equipment, the facility completely lacks organic shredding machinery, mechanical compost screeners, bamboo aerators, and composting drums. The sole remaining logistics asset is a single three-wheeled waste collection vehicle, which is currently broken down and entirely unusable.

According to the current head of 3R Waste Treatment Facility Kavole, temporary initiatives to sustain basic community service are being attempted by operating a simple waste bank within the yard of the Pengawu Urban Village administrative office. This temporary operation is strictly restricted to collecting non-organic dry waste deposited by local residents. Ultimately, restoring the baseline functionality of 3R Waste Treatment Facility Kavole requires extensive structural rehabilitation and complete logistical reinvestment, which must encompass rebuilding the physical facility and re-procuring essential technical assets, including mechanical shredders, screening units, composting systems, bamboo aerators, and functional transport vehicles.

• *Validity Testing*

A validity test was executed to evaluate the correlation between the score of each individual questionnaire item and the total cumulative score of all items. This process serves to ensure that every question in the instrument consistently measures the same underlying target variable, thereby verifying the internal validity of the questionnaire and enhancing the reliability of the empirical findings. To test the validity of each statement item, this study utilizes the Pearson Product-Moment Correlation technique.

The evaluation criteria dictate that an instrument item is declared valid if the calculated r-value (r-statistic) is greater than the critical r-value from the statistical table (r-table). Conversely, if the calculated r-value is less than the critical r-table value, the item is deemed invalid. In this study, the researcher analyzed the questionnaire responses from a total sample size of 67 respondents. The statistical analysis was conducted with a 95 percent confidence interval, corresponding to a significance level (alpha) of 0.05. Based on the standard r-distribution table, the critical r-table threshold value for a sample size of 67 respondents is established at 0.240.

Based on the empirical outputs of the validity testing, every tested measurement item across the research variables exhibits a calculated r-value significantly greater than the critical r-table threshold. Consequently, it can be concluded that all operational variables and their respective indicators are

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empirically valid, confirming their eligibility for deployment in the subsequent stages of data analysis.

- *Reability Testing*

The subsequent stage of analysis involves executing a reliability test using SPSS software. The primary objective of reliability testing is to determine the internal consistency of the measurement instrument. A reliable instrument ensures stable and consistent results when deployed under uniform conditions across different periods. To evaluate data reliability, this study applies the Cronbach's Alpha formula.

Cronbach's Alpha is widely recognized as the standard metric for measuring the internal consistency and reliability of multi-item research scales. The value of Cronbach's Alpha ranges from 0 to 1, and a research instrument is statistically deemed reliable or acceptable if its alpha coefficient is greater than 0.60 (Ghozali, 2011).

Based on the empirical reliability outputs, the individual Cronbach's Alpha coefficient for every single measurement variable systematically exceeds the required statistical threshold of 0.60. Consequently, it can be concluded that the complete research instrument possesses high internal consistency and exceptional reliability, thereby confirming its suitability and structural validity for advanced multivariate research operations.

- *Factor Analysis and KMO-Barlett's Testing*

The subsequent stage of investigation involves performing an exploratory factor analysis using SPSS software to analyze the underlying determinants driving 3R Waste Treatment Facility operational dysfunction in Palu City. Factor analysis is systematically deployed to identify, reduce, and classify the extensive set of research variables into a more meaningful structure. The analytical workflow comprises several consecutive phases: evaluating data suitability through the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy and Bartlett's Test of Sphericity, verifying the individual Measure of Sampling Adequacy (MSA) thresholds, determining the number of latent dimensions via factor extraction and orthogonal rotation, and ultimately clustering and assigning conceptual labels to the newly formed factor structures.

The initial step in this multivariate procedure requires assessing the overarching datasets via KMO and Bartlett's testing to confirm whether the matrix is eligible for factoring. This verification ensures that the empirical data satisfies the necessary statistical assumptions required to proceed with advanced dimensional reduction. Methodologically, the dataset is considered appropriate for factor analysis if the aggregate KMO index is greater than 0.5 and the Bartlett's test achieves a significance value of less than 0.05. Based on the field responses processed through SPSS, the comprehensive outputs for both tests are presented in the table below:

Table 4 KMO and Bartlett's Test of Sphericity Outputs

Kaiser-Meyer-Olkin Measure Of Sampling Adequacy		0,522
Bartlett's Test Of Sphericty	Approx Chi-Square	943.786
	Df	595
	Sig.	<,001

Based on the statistical parameters derived from the KMO and Bartlett's testing for this facility, the calculated Kaiser-Meyer-Olkin (KMO) index is 0.522, which is greater than the required baseline threshold of 0.5. Concurrently, the Bartlett's Test of Sphericity yields an approximate Chi-Square value of 943.786 with a statistical significance value of less than 0.001, which is substantially less than the standard significance alpha of 0.05. These empirical metrics demonstrate that the research variables possess sufficient multi-collinearity and strength of relationship, thereby confirming that the dataset is highly suitable for further factor analysis. Consequently, the application of factor analysis will successfully identify the foundational structures of the data and reduce the numerous individual variables into a concise set of latent factors that accurately represent the core information.

- *Measure of Sampling Adequacy (MSA) and Anti-Image Matrices Testing*

The Measure of Sampling Adequacy (MSA) test is a statistical procedure deployed to evaluate the suitability of individual research items for subsequent factor analysis. The MSA index measures the strength of inter-correlations among variables within a dataset to ensure they exhibit a sufficient degree of relationship to justify dimensional reduction (Tabachnick & Fidell, 2007). In conjunction with the overall MSA index, the Anti-Image Correlation Matrix is systematically utilized to identify and determine which specific variables satisfy the necessary criteria to be included in the factor analysis model.

The Anti-Image Correlation Matrix displays coefficients diagonally, with each diagonal value representing the specific MSA score for an individual variable. Methodologically, if the individual MSA value of a variable is greater than 0.50, the item is considered statistically adequate and eligible to be retained for advanced factor analysis. Conversely, if the MSA score of a specific variable is less than 0.50, the variable lacks sufficient correlation with the other items and must be excluded from the model to preserve the mathematical validity of the subsequent factor extraction.

- *Factor Extraction and Scree Plot Analysis*

The determination of the exact number of latent factors to be retained in the analysis is primarily governed by the Initial Eigenvalue criterion. Under this methodological approach, only factors exhibiting an Initial Eigenvalue greater than 1.00 are considered statistically significant and eligible for retention. This threshold is chosen because any factor with

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an eigenvalue greater than one is capable of explaining a larger portion of total variance than a single, individual variable.

In this specific study, a total of 28 extracted variables were analyzed to satisfy the cumulative variance percentage target. The structural extraction process aims to achieve a cumulative variance that exceeds 60 percent, thereby ensuring that the newly formed factor structures are mathematically robust and capable of representing the vast majority of the original information contained within the dataset.

Based on the statistical parameters derived from the Total Variance Explained table, there are exactly eight components that exhibit an Initial Eigenvalue greater than 1.00. Concurrently, the cumulative variance percentage accounted for by these eight extracted dimensions reaches 68,345 percent, which comfortably exceeds the standard academic threshold of 60 percent. This substantial explanatory power indicates that the newly formed components can effectively account for and represent the variance of the underlying variables tested within the dataset.

Consequently, the original 28 individual variables influencing the operational dysfunction of the 3R Waste Treatment Facility Kavole facility in Pengawu Urban Village were successfully reduced and extracted into eight distinct latent factors. To visually illustrate the mathematical relationship between each extracted component and its respective eigenvalue, the corresponding scree plot is presented below.

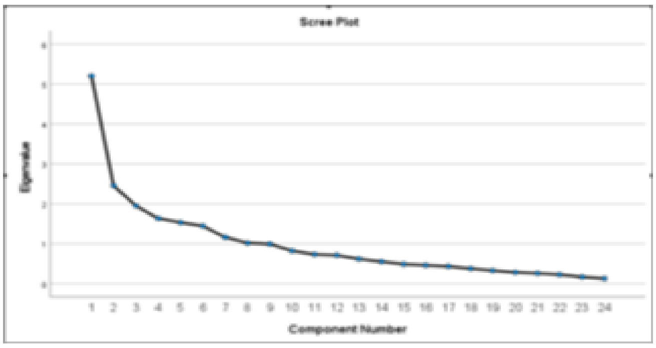

Fig 4 Scree Plot

According to the graphical distribution displayed in the scree plot above, the structural break and data inflection points precisely substantiate the eigenvalue criteria. The plot demonstrates eight distinct component points situated above the critical threshold line of 1.00. Beyond the eighth component, the curve flattens significantly, and the subsequent eigenvalues drop below the baseline value. This graphical trend confirms that the mathematical structure of the data reaches optimal stability and representation at exactly eight extracted factors.

- *Variable Extraction and Factor Rotation*

Once the exact number of latent factors has been determined, factor extraction is executed. Factor extraction represents the core procedural phase in exploratory factor analysis, aiming to systematically reduce a large set of original variables into a smaller, more parsimonious set of newly formed dimensions or composite factors. In this study, the Principal Component Analysis (PCA) method is deployed as the mathematical engine to achieve this dimensional reduction.

Following the initial extraction phase within the PCA framework, an orthogonal rotation is applied to yield the Rotated Component Matrix. This matrix illustrates the localized correlations and loading weights between the original independent variables and the newly extracted latent components. The Rotated Component Matrix serves as a critical analytical tool, facilitating a clearer interpretation of the factor loading strengths and identifying which specific variables are most robustly associated with each distinct component. The empirical loading values for the eight extracted components derived from this matrix are detailed below.

Table 5 Summary of Variable Groupings by Factor

Factor	Variables Assigned	Total Variables
1	K1, K5, K2, PM5, K3, IF6	6
2	SDM1, IF5, SDM2, SDM3	4
3	SDM4, PM3, PM2	3
4	P1, K6	2
5	DP2, IF3, SDM6	3
6	P2, P3	2
7	PM4, K4	2
8	P4, DP6	2

- *Factor Interpretation and Conceptual Naming*

Based on the exploratory factor analysis conducted on the responses from the 67 surveyed participants, eight newly formed latent factors were identified as the primary determinants driving the operational dysfunction of 3R Waste Treatment Facility Valangguni. The comprehensive breakdown and contextual analysis of these eight extracted dimensions are structured as follows:

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- ✓ *Institutional Governance and 3R Waste Treatment Facility Operational Support*

This principal factor is composed of variables K1 (organizational structure), K2 (clear division of labor among operators), K3 (effective facility leadership), K5 (coordination within the management group), PM5 (public perception of the facility's importance), and IF6 (adequate waste segregation areas). Within this dimension, the variable representing a well-functioning organizational structure (K1) exhibits the highest factor loading value of 0.829. This prominent loading highlights that a systematic organizational framework is a critical pillar of facility management, directly maximizing work efficiency and eliminating administrative overlap among committee members. These roles must align structurally with the formal setup of the community-based management group. This finding is strongly supported by Khodijah and Pharmawati (2023), who argued that the proactive engagement of operators serves as the primary engine driving 3R Waste Treatment Facility performance, requiring a clear administrative core comprising a chairperson, treasurer, secretary, operational section, and maintenance section. Furthermore, robust leadership and stable communication loops with beneficiary households are imperative; without them, community-based waste sorting, collection, and processing workflows will fail to function. According to Law Number 18 of 2008 concerning Waste Management, active public engagement stands as a baseline requirement underpinning the 3R-based waste management matrix. Finally, adequate technical infrastructure remains inseparable from operational management, as outlined in the Ministry of Public Works and Public Housing guidelines (2018), which state that technical conformity with engineering standards and active household-level source segregation heavily dictate facility success.

- ✓ *Human Resources and Supporting Infrastructure*

This factor encompasses indicators SDM1 (adequate technical skills of operators), SDM2 (appropriate staffing levels), SDM3 (technical training for waste processing personnel), and IF1 (supporting infrastructure and road access that facilitates public transport). The variable representing adequate technical skills of operators (SDM1) displays the highest factor loading value of 0.816. This highlights that human resource development—specifically through structural capacity-building and continuous technical training—is an absolute requirement for optimizing sorting and processing workflows. A severe lack of training for facility staff triggers processing bottlenecks, resulting in sub-optimal waste treatment, poorly managed composting, and high volumes of unmanaged residual waste (Utami et al., 2025). Furthermore, staffing shortages directly paralyze daily processing lines. Logistically, infrastructure components within this factor, such as the rehabilitation of the main access road leading to the site, require urgent municipal attention to facilitate smooth waste transit for both the collection crews and the served community.

- ✓ *Public Support and Management Efficiency*

This component is shaped by variables PM2 (community willingness to pay waste management tariffs), PM3 (public participation in maintaining cleanliness), and SDM4 (the systemic efficiency of waste management workflows). The variable for workflow efficiency (SDM4) yields the highest factor loading value of 0.763. This metric demonstrates that operational success relies heavily on the management committee's ability to enforce structured work mechanisms, clear task delegations, and optimal resource allocation. According to Utami et al. (2025), a highly efficient management system requires clear role definitions to streamline daily operations. Additionally, community-level variables, such as active public participation in maintaining environmental cleanliness and a baseline willingness to engage in household-level source segregation, serve as the vital starting point for all subsequent waste processing phases at the 3R Waste Treatment Facility facility.

- ✓ *3R Waste Treatment Facility Operational Sustainability*

This dimension integrates variables P1 (the adequacy of core funding for daily operations) and K6 (a clear institutional vision and mission), with the variable for core funding adequacy (P1) exhibiting the highest factor loading value of 0.718. Secure financial capacity is the fundamental prerequisite for sustaining daily waste processing workflows, as it dictates the facility's ability to cover operational costs, pay staff wages, maintain equipment, and manage collection transport assets. As noted by Zafira and Damanhuri (2020), financial constraints severely disrupt collection services; when funding drops, collection frequency falls out of balance with the volume of waste generated, leading to unmitigated service decline. To prevent long-term operational failure, this financial asset must be balanced by variable K6, ensuring the organization operates under a clear vision and mission to achieve institutional self-reliance and continuous sustainability.

- ✓ *Government Support for Facility Operations*

This factor comprises DP2 (government policies supporting 3R Waste Treatment Facility through clear regulations), IF3 (the functional adequacy of the facility structure), and SDM6 (the smooth execution of daily facility operations). The variable regarding clear government regulatory support (DP2) generated the highest factor loading value of 0.725. This indicates that clear municipal intervention via local regulatory frameworks—such as Palu City Regional Regulation (Perda) Number 3 of 2016 concerning Waste Management—is a baseline requirement for facility functionality. As highlighted by Ningsih et al. (2020), facility success is deeply tied to external policy support, municipal budgeting, and consistent regulatory oversight. Beyond policy, maintaining the physical building in compliance with technical engineering standards and ensuring structured daily operations are critical to establishing an effective waste management matrix.

- ✓ *Operational Financing and Tariff Structures*

This dimension is driven by variables P2 (the adequacy of user tariff fees to cover management costs) and P3 (financial subsidy support from the regional government), with the user tariff fee adequacy (P2) yielding the highest factor loading value of 0.758. As explained by Zumaira and Widodo (2026), the financial stability of a 3R Waste Treatment Facility relies on three main sources: public user

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fees, government subsidies, and the commercial sale of recycled goods. At 3R Waste Treatment Facility Kavole, this financial model collapsed because local residents pay their waste fees directly to the municipality via the PASIGALA digital application, leaving the facility operators without direct tariff revenue. This issue is worsened by a complete lack of regional government financial subsidies due to the facility's current non-operational status. This severe funding shortage halts daily operations, prevents staff compensation, and stops the procurement of essential processing gear, emphasizing the urgent need for a committed municipal budget to restore facility function.

✓ *Institutional Strengthening and Civic Voluntarism*

This component is shaped by variables K4 (well-enforced written regulations, bylaws, and SOPs) and PM4 (civic willingness to act as environmental volunteers). The variable for civic voluntarism (PM4) shows the highest factor loading value of 0.863. This high statistical weight demonstrates that long-term sustainability relies heavily on active community engagement rather than just internal organizational systems. Public willingness to volunteer reflects high environmental awareness and provides vital hands-on support for source-sorting initiatives, which are essential for reducing waste at the source (Utami et al., 2025). Currently, 3R Waste Treatment Facility Kavole suffers from a complete absence of these cooperative structures; revitalizing the facility requires immediate institutional strengthening to enforce written operational rules alongside intensive public campaigns to recruit neighborhood environmental volunteers.

✓ *Partnership Support and External Funding*

This final component centers on variables P4 (alternative funding mechanisms) and DP6 (government-facilitated partnerships with the private sector), with alternative funding (P4) emerging as the dominant variable with a factor loading value of 0.779. The total lack of alternative funding pathways and the absence of public-private partnerships are major causes of the facility's current dysfunction. To overcome these financial limitations, the local government must actively serve as an institutional facilitator to connect facility operators with third-party private investors or non-governmental organizations (NGOs). As detailed by Utami et al. (2025), breaking the over-reliance on a single funding source through private or NGO partnerships is essential to secure capital investments, introduce technological innovations, and build long-term operational capacity.

- *3R Waste Treatment Facility Buvu Bionga*

3R Waste Treatment Facility Buvu Bionga is an actively functioning waste processing facility located within Palu City. Constructed in 2012, this facility is situated on M. Soeharto Street, Petobo Urban Village, Palu Selatan Sub-district. Based on empirical field observations, both the built infrastructure and technical facilities are operating optimally, and the main physical building is well-maintained. The site encompasses a total land area of 800 square meters, which significantly exceeds the national minimum technical requirement of 200 square meters.

Operationally, 3R Waste Treatment Facility Buvu Bionga runs on a daily schedule, managing an incoming solid waste volume of approximately 1 ton per day. The facility is staffed by a dedicated workforce of 6 active personnel. Its mechanical and operational assets include one mechanical organic shredder, one compost screening unit, one waste pressing machine, biological processing components consisting of bamboo aerators and composting drums, and a logistics fleet of three three-wheeled waste transport vehicles. With these operational resources, the facility successfully services a target community of 1,200 households.

Financially, the current waste processing workflows at 3R Waste Treatment Facility Buvu Bionga generate a regular revenue stream of up to IDR 5,000,000 per month. This stable income is derived entirely from material recovery and resource valorization, where incoming waste fractions are successfully transformed into renewable commercial products. These revenue-generating streams include the commercial sale of solid organic fertilizer, compost, liquid organic fertilizer, and various upcycled materials derived from secondary sorting processes.

According to empirical data provided by the current head of 3R Waste Treatment Facility Buvu Bionga, the primary operational bottleneck currently facing the facility is spatial capacity. Due to the expansive service coverage and high daily waste volume, the existing waste sorting bay is no longer sufficient to handle peak inflows safely. Consequently, there is an urgent structural need for facility expansion, specifically through the construction of an additional sorting area and a dedicated storage warehouse to house the recovered upcycled goods and processed compost products.

In general, the operational condition of 3R Waste Treatment Facility Buvu Bionga is highly exemplary. Led by a proactive management committee, the facility has established itself as the leading benchmark model for successful community-based solid waste management, serving as a primary pilot project for both Palu City and the Central Sulawesi Province.

- *3R Waste Treatment Facility Avosalae*

3R Waste Treatment Facility Avosalae is an actively operational community-based waste processing facility situated within Palu City. Constructed in 2016, this facility is located on Sultan Alaudin Street, Silae Urban Village, Ulujadi Sub-district. Based on empirical field observations, the overarching built infrastructure and facility structures are well-maintained and function properly. In addition to its primary function as a 3R Waste Treatment Facility facility, the site integrates a specialized waste bank system. The facility encompasses a total land footprint of 735 square meters, which safely complies with the national minimum technical requirement of 200 square meters.

In terms of operational scheduling, 3R Waste Treatment Facility Avosalae does not operate on a daily basis. The facility receives an average incoming solid waste volume of approximately 400 kilograms per day, managed by a dedicated workforce consisting of 4 active personnel. The mechanical

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assets deployed at the site include one mechanical organic shredder, one compost screening unit, and one waste pressing machine.

However, the operational capacity of this 3R Waste Treatment Facility has not been fully optimized because source segregation is not actively carried out inside the main hangar. Instead, waste sorting is performed directly from the transport vehicles into the arm-roll containers stationed at the facility site. Logistically, the current transport fleet is limited to only two three-wheeled waste collection vehicles. Despite these operational constraints, the facility successfully generates resource recovery products, including solid compost derived from processed organic waste fractions, as well as liquid organic fertilizer uniquely manufactured from carbonated beverage residues intercepted at the facility.

➢ *Discussion of Site-Specific Findings*

- *3R Waste Treatment Facility Valangguni*

The statistical factor analysis performed on the 3R Waste Treatment Facility Valangguni dataset yielded eight newly formed latent factors. Among these, the dominant determinant is "Institutional Governance and 3R Waste Treatment Facility Operational Support." This principal factor comprises specific variables, including K2 (clear division of labor among 3R Waste Treatment Facility operators), K3 (effective leadership in waste management), K5 (structured coordination between management and the community), K1 (organizational structure), K4 (the existence of well-enforced written regulations), K6 (a clear institutional vision and mission), and IF5 (supporting infrastructure that facilitates processing operations). To revitalize this facility, interventions must prioritize activating the management organization, delineating clear roles and administrative responsibilities among committee members, and compiling rigorous standard operating procedures (SOPs) for waste treatment. Furthermore, establishing robust communication loops between the operators, municipal authorities, and beneficiary households is imperative, alongside installing standard waste processing hardware. These strategies collectively aim to establish a more systematic workflow, thereby eliminating operational overlaps and optimizing systemic efficiency. A resilient institutional framework will streamline facility workflows, ranging from localized collection and regulatory monitoring to regular performance evaluations. Additionally, reinforcing the facility’s physical capacity requires immediate logistical reinvestment, such as re-procuring organic shredding machinery, compost screening tools, operational collection vehicles, and bamboo aerators, while simultaneously rehabilitating the transport access road to allow heavy waste trucks to safely reach the site.

- *3R Waste Treatment Facility Kavole*

Parallel to the previous site, the factor analysis conducted for 3R Waste Treatment Facility Kavole generated eight distinct operational components, with "Institutional Governance and 3R Waste Treatment FaCILITY Operational Support" emerging as the primary loading factor. This dominant dimension is explicitly characterized by K1 (organizational structure), K2 (clear division of labor among operators), K3 (effective facility leadership), K5 (coordination within the management group), PM5 (public perception of the facility's importance), and IF6 (adequate waste segregation areas). Consequently, operational restoration requires a dual approach focusing on institutional reorganization and infrastructure recovery. Institutional strengthening should be initiated by reforming a new management structure with quantifiable duties and metrics, implementing standardized operational guidelines, and intensifying tripartite synchronization among the operators, the served community, and local government policymakers. Concurrently, extensive infrastructure rehabilitation is necessary to rebuild the facility structure in accordance with technical civil engineering standards. This includes installing proper manual sorting platforms and providing reliable collection assets. Re-establishing these structural components remains the absolute prerequisite for the site, given that the severe natural disaster damage and subsequent looting completely stripped the facility of its operational capacity. Ultimately, long-term revitalization necessitates an integrated paradigm that balances physical reconstruction with institutional capacity building and sustained municipal backing, allowing 3R Waste Treatment Facility Kavole to effectively intercept waste flows destined for the Kawatuna Landfill.

- *3R Waste Treatment Facility Buvu Bionga*

As the only investigated facility operating at maximum capacity, 3R Waste Treatment Facility Buvu Bionga serves as the baseline model for optimal performance in Palu City. To accommodate escalating municipal waste generation volumes and sustain long-term processing efficiency, the strategic priority for this facility must pivot toward spatial expansion. Enlarging the facility's physical footprint is critical to prevent spatial bottlenecks during peak waste influxes. Furthermore, modernizing the existing mechanical components is highly recommended to increase daily productivity and enhance the market value of recycled end-products and compost. In tandem with technical upgrades, community-level interventions must be continuously intensified through structured public education and waste segregation campaigns. Fostering a higher baseline of source-based household segregation will significantly improve the quality of incoming waste fractions, thereby reducing processing durations and increasing overall facility efficiency.

- *3R Waste Treatment Facility Avosalae*

In contrast, 3R Waste Treatment Facility Avosalae represents an active yet sub-optimally performing facility. Optimizing its operational capacity requires targeted strategies centered on upgrading logistical resources and securing long-term community participation. Providing additional, reliable waste transport vehicles is an immediate necessity to expand the current service area, increase daily waste collection volumes, and further divert municipal waste from the final disposal site. Furthermore, systemic optimization relies heavily on improving household-level waste sorting compliance. By systematically elevating public engagement in source segregation, the volume of well-sorted, manageable waste arriving at the facility will increase significantly, which in turn reinforces the financial viability and operational sustainability of 3R Waste Treatment Facility Avosalae.

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V. CONCLUSION

Based on the findings and discussions presented in this study, the following conclusions can be drawn:

- Field assessments across four selected locations in Palu City revealed highly varied operational statuses, transitioning from complete dysfunction to maximum capacity. The investigation identified that both 3R Waste Treatment Facility Valangguni in Valangguni Village and 3R Waste Treatment Facility Kavole in Pengawu Village are entirely dysfunctional due to distinct site-specific catalysts. For 3R Waste Treatment Facility Valangguni, operational failure stems from the theft of the processing machinery's prime mover, an inaccessible entry road for waste transport vehicles due to non-strategic topography, and an acute labor shortage. Meanwhile, the total cessation of activities at 3R Waste Treatment Facility Kavole was triggered by severe structural damage from natural disasters, which was subsequently compounded by theft that stripped away all remaining building components and processing equipment. In contrast, 3R Waste Treatment Facility Avosalae in Silae Village remains active but functions sub-optimally, characterized by low waste influx and irregular, non-daily processing workflows. Conversely, 3R Waste Treatment Facility Buvu Bionga in Petobo Village serves as a highly successful model, operating at maximum efficiency with structured daily waste processing that currently services 1,200 households.

- Statistical evaluation using SPSS-based factor analysis on the dysfunctional facilities revealed the underlying determinants driving operational failure. The analysis indicated that both 3R Waste Treatment Facility Valangguni and 3R Waste Treatment Facility Kavole share an identical structure of eight latent factors influencing their dysfunction, which comprise institutional governance and operational support, 3R Waste Treatment Facility resources and infrastructure, community support, institutional sustainability, government operational backing, operational and maintenance financing, institutional strengthening coupled with public participation, and external funding partnerships. To revitalize these facilities based on these dominant loading factors, strategic interventions must prioritize the reactivation of the community-based management groups. This process requires establishing a transparent division of labor, roles, and administrative responsibilities among committee members, alongside compiling standardized operating procedures for waste treatment. Furthermore, long-term operational resilience necessitates robust institutional coordination loops involving facility operators, local municipal agencies, and beneficiary communities, fully supported by the rehabilitation of viable waste processing infrastructure.

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