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RESEARCH ARTICLE

Application of the Mactor Method in sustainable solid waste management at ISWM-Bantargebang, Indonesia

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ABSTRACT

The issue of waste management at the Integrated Solid Waste Management (ISWM) Bantargebang, Indonesia, is becoming increasingly complex due to the high volume of waste, limited management systems, and conflicting interests among stakeholders. This study provides conceptual and methodological contributions by adapting the MACTOR (Matrix of Alliances and Conflicts: Tactics, Objectives, and Recommendations) method to map power dynamics, stakeholder interests, and potential conflicts in sustainable waste management, particularly by considering the often-marginalized role of informal actors. This approach provides a structured analysis of multistakeholder relationships, which has rarely been applied in the context of developing countries. The study aims to analyze the influence and dependency among actors, their positions regarding five strategic waste management objectives, and to identify patterns of collaboration and resistance. The research employs a mixed-method approach, including in-depth interviews with ten key stakeholders and a MACTOR analysis. The results indicate that the Jakarta Environmental Service and the Cross-Regional Environmental Task Force are the dominant actors, while informal sectors such as waste pickers and collectors remain marginalized. Community empowerment and the economic multiplier effect emerged as strategic convergence points among actors; however, the development of alternative waste-to-energy solutions still faces resistance from the informal sector. This study highlights the importance of integrating the informal sector and building adaptive and participatory collaborative models as a strategic contribution to sustainable waste management.

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INTRODUCTION

Waste management in urban areas such as Jakarta faces systemic challenges, one of which occurs at the Integrated Solid Waste Management (ISWM) Bantargebang, which receives more than 7,000 tons of waste per day referring to data from the Ministry of Environment and Forestry in 2022. The current waste management model still relies heavily on the collect–transport–dispose pattern, which is poorly integrated with recycling systems, energy recovery, and community empowerment programs. As a result, various environmental and social problems continue to emerge [1, 2].

Waste management at ISWM-Bantargebang involves multiple actors from formal sectors, private companies, local communities, and informal groups such as waste pickers and collectors, who are often overlooked in policy-making processes. The lack of policy integration among actors and weak coordination are the main factors contributing to the low effectiveness of sustainable waste management systems [3, 4]. Most previous studies have focused on technical approaches such as Life Cycle Assessment, dynamic systems, and community participation [5-8]. However, very few studies have been able to quantitatively map conflict positions, alliances, and potential resistance among actors in detail. The commonly used methods, such as Social Network Analysis and stakeholder mapping, tend to be limited in describing power dynamics and the convergence of interests [9, 10].

This study applies the MACTOR method (Matrix of Alliances and Conflicts: Tactics, Objectives, and Recommendations) within the context of the Integrated Solid Waste Management (ISWM) system at ISWM-Bantargebang. The contribution of this research is contextual: it does not introduce innovations to the mechanics of MACTOR itself, but rather demonstrates its application in a policy environment with distinctive stakeholder configurations—namely, the highly asymmetrical relationship between formal and informal actors, along with the effort to explicitly incorporate the economic dependency of informal livelihoods as part of influence assessment. By integrating indicators relevant to the informal sector (e.g., access to raw materials, economic dependency on waste, formal authority, technical capacity)

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into the operational steps of MACTOR analysis, this study addresses an empirical gap in the literature, which has generally applied MACTOR in other fields (e.g., water resources, maritime, flood risk) but has rarely incorporated the dimension of informal economic dependency into influence weighting. The outcome is a mapping of relationships and patterns of convergence/divergence that can be directly translated into participatory policy recommendations (e.g., benefit-sharing schemes, inclusion mechanisms for waste pickers)—a practical added value that responds to pressing policy questions in the field [9-12].

This study does not claim novelty in terms of methodological innovation, but rather in the empirical application of the MACTOR method (Matrix of Alliances and Conflicts: Tactics, Objectives, and Recommendations) to the specific context of solid waste management in Indonesia. Previous research has applied MACTOR in areas such as maritime industry risk management [13], sports tourism supply chains [14], flood risk governance[15], and peri-urban waste systems [16]. Building on this body of literature, the contribution of the present study lies in extending MACTOR to examine the dynamics of formal and informal stakeholders in a large-scale urban waste facility, thereby highlighting the method's applicability to contexts characterized by strong power asymmetries and contested objectives. Other applications include spatial planning [17], collaborative governance [18], higher education [19], and community resource management [20]. Collectively, these works underline MACTOR's versatility and reinforce its relevance for addressing actor asymmetries in solid waste management, particularly in developing country contexts.

The integrated waste management system at ISWM-Bantargebang still faces serious challenges, particularly in cross-actor coordination. The involvement of various parties with differing interests often leads to conflict, weak collaboration, and fragmentation in the formulation and implementation of waste management policies. This situation is exacerbated by the absence of a clear map of power relations, the positions of each actor's interests, and the level of support or resistance of each party toward the strategic objectives of waste management. Without a comprehensive understanding of these inter-actor relationships, strategic decision-making processes may not be optimal and risk prolonging waste management problems in the area.

Based on this background, this study seeks to address the following research questions: (a) How do power dynamics and levels of dependency among actors operate within the waste management system at ISWM-Bantargebang?. (b) How do different actors, both formal and informal, position themselves regarding the five strategic objectives of sustainable waste management?. And (c) What are the patterns of collaboration, convergence, and resistance among actors, and how can these inform strategies for sustainable waste management?.

Furthermore, this study aims to determine how effective cross-actor collaboration strategies can be developed based on the mapping of relationships and potential resistance among the actors involved. This study specifically aims to analyze the power dynamics and levels of dependency among the actors engaged in waste management at ISWM-Bantargebang. It also seeks to map the positions of interest and the actors' levels of support or resistance toward the five strategic objectives of sustainable waste management. The ultimate goal of this study is to formulate multi-actor collaboration strategies that are adaptive and participatory in order to enhance the effectiveness of sustainable waste management in the ISWM-Bantargebang area.

The remainder of this paper is organized as follows: Section 2 describes the materials and methods, including the rationale for actor and objective selection. Section 3 presents the results of the MACTOR analysis, beginning with matrices and then stakeholder maps, supported by subsections for clarity. Section 4 discusses the findings in relation to the literature. Section 5 concludes with answers to the research questions, study limitations, and directions for future research.

MATERIALS AND METHODS

This study employs a descriptive qualitative approach combined with a structural prospective method and quantitative analysis using the MACTOR method (Matrix of Alliances and Conflicts: Tactics, Objectives, and Recommendations). The study aims to map the power dynamics, stakeholder interests, and potential conflicts among actors within the integrated waste management system at ISWM-Bantargebang [9, 10, 17]. The results of the MACTOR analysis serve as the basis for formulating future policy recommendations. The research was conducted in the ISWM-Bantargebang area, West Java, Indonesia which is the largest waste processing center serving Jakarta. The research subjects consisted of key actors involved in waste management within this area.

Data Collection and Validation of Results

Primary data were collected through in-depth interviews and focused discussions with ten key stakeholders selected using the snowball sampling method [21], to ensure the participation of actors with in-depth knowledge of the waste management system at Bantargebang. Secondary data were obtained from policy documents, official reports, and relevant previous studies. Data validity was ensured through source and method triangulation.

The ten selected experts represent diverse institutional backgrounds and functions in waste management. They were chosen based on a minimum of five years of professional experience, with several having over a decade of involvement in the sector. Their expertise covers a wide range of domains, including government policy and regulation (Jakarta Environmental Service, Bekasi Regional Government, and the Cross-Regional Environmental Task Force), private sector operations in waste-to-energy and recycling companies, academic research and higher education institutions, community organizations, and informal waste activities (waste pickers and collectors). Selection criteria emphasized three main aspects: (i) substantive domain knowledge in solid waste management; (ii) active participation in decision-making or operational implementation at ISWM-Bantargebang; and (iii) representation of formal, private, academic, community, and informal sector interests.

This composition ensured that the perspectives of both powerful institutional actors and marginalized informal groups were captured. For example, government officials contributed insights on regulatory frameworks and cross-regional coordination, private sector representatives shared operational and investment perspectives, while informal actors highlighted their livelihood dependency and access challenges. Academic experts added analytical depth, particularly regarding sustainability and community empowerment. Such diversity enhances transparency and strengthens the credibility of the study by reflecting the

heterogeneity of stakeholders in the ISWM-Bantargebang system.

Validation was conducted through triangulation of sources and methods. Preliminary results were presented to stakeholders in follow-up discussions to verify consistency with real-world practices. This member-checking approach confirmed the accuracy of actor influence assessments, dependency relations, and convergence patterns.

Application of the MACTOR Method

This study applies the MACTOR method by integrating informal actors, such as waste pickers and collectors, as essential components in the mapping of power and influence. This inclusion is crucial, considering that many previous studies have often neglected the role of the informal sector, despite its significant contribution to the waste management system. In this research, the weighting of influence and stakeholder interests is not only based on structural power and formal policies but also considers economic dependency and informal material access to waste resources, which are essential to the livelihoods of vulnerable groups.

The rationale for stakeholder and objective selection is grounded in the literature. The inclusion of informal actors reflects findings from Majeed et al. [20] and Harfadli et al. [22], which emphasize their key role in waste collection and recycling. The five strategic objectives—economic multiplier effect, alternative energy, infrastructure improvement, community empowerment, and legal or policy formulation—are widely recognized in integrated waste management frameworks [2, 18].

Several steps were implemented, including adjustments to the Influence Direct Matrix (MID) to represent informal economic relations that are not formally documented. Additionally, the development of the Actor-Objective Matrix (2MAO) was adjusted to incorporate social dimensions, particularly the sustainability of livelihoods in the informal sector as a key component of sustainable waste management objectives. This study also emphasizes the importance of analyzing the strategic distances between actors to illustrate potential conflicts in benefit distribution, especially between highly influential formal actors and vulnerable informal actors who are often excluded from decision-making processes [9, 10]. Figure 1 presents the conceptual framework of the MACTOR analysis, adapted from the model developed by Godet [23].

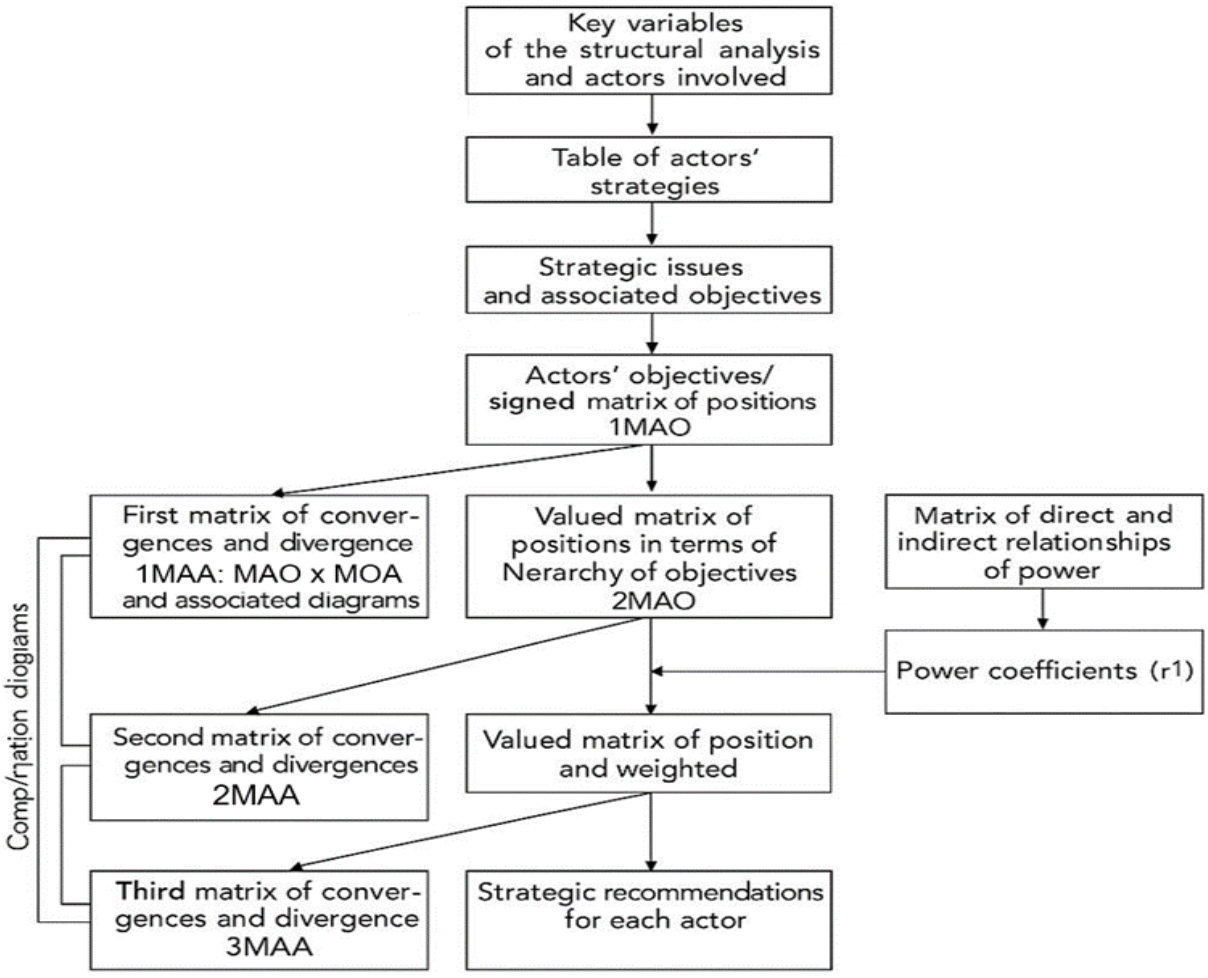


Figure 1. Analytical framework using MACTOR [23]

In the analytical framework (Figure 1), terms such as 1MAA, 2MAA and 3MAA are explicitly introduced to ensure clarity. The 3MAA is a logical progression from earlier MACTOR matrices. For example, after identifying the "actors" (MAO) and their basic "convergences and divergences" (1MMA, 2MAA), the 3MAA incorporates the "power relations" to further refine the analysis. Introducing these terms within the text ensures consistency with the figure and prevents ambiguity for readers interpreting the methodological steps. The 3MAA serves as a crucial analytical tool to understand the overall strategic landscape among the actors. It helps reveal which actors are dominant, which are influential, and how these relationships shape the overall convergence and divergence of interests

Subsequently, the 3MAO Matrix was calculated to obtain a map of convergence and divergence among actors, illustrating the levels of alignment and conflict of interest in achieving sustainable waste management objectives. The analysis continued with the measurement of the Graph of Net Distance to identify the proximity or strategic distance between actors, indicating either potential harmonious relationships or possible conflicts. The results of the entire process were visualized in the form of relational maps, influence strength, and actor support patterns toward each strategic objective [9, 10, 17].

Expert Selection and Participation

To support the MACTOR analysis, a total of ten experts were selected using a purposive sampling approach. The selection criteria included: (1) direct involvement in solid waste management at ISWM-Bantargebang; (2) institutional affiliation representing key stakeholder groups; and (3) a minimum of five years of professional experience in environmental management, waste governance, community engagement, or related fields.

These experts were invited to provide assessments on actor influence, dependencies, and strategic objectives based on their professional knowledge and operational experience. Their contributions served as the foundation for constructing the Matrix of Direct Influence (MDI), Matrix of Indirect Influence (MII), and subsequent MACTOR analytical stages. The inclusion of a diverse set of practitioners ensured balanced representation from government agencies, private sector actors, community groups, informal sector organizations, and academic institutions.

Table 1 presents the list of experts who participated in the MACTOR evaluation, along with their institutional affiliations, actor groups represented, and primary areas of expertise. This information enhances transparency and supports the credibility of the stakeholder-based analysis.

Table 1. Profile of the experts participating in the MACTOR analysis

No.	Expert Code	Affiliation / Institution	Actor Group Represented	Area of Expertise
1	EXP-01	Jakarta Environmental Service (JES)	JES	Municipal solid waste policy, environmental governance
2	EXP-02	Cross-Regional Environmental Task Force	CET	Inter-regional coordination, environmental supervision
3	EXP-03	Bekasi Regional Government	BRG	Local government affairs, waste infrastructure planning
4	EXP-04	Local Community Representative	LCO	Community engagement, socio-environmental issues
5	EXP-05	Waste for Change	WFC	Waste management systems, circular economy initiatives
6	EXP-06	Private Waste-to-Energy Operator	PWE	Waste-to-energy technology, private sector waste operations
7	EXP-07	Waste Collection Group	WCG	Waste collection operations, logistics of waste handling
8	EXP-08	Garbage Pickers Group	GPG	Informal sector recycling, material recovery practices
9	EXP-09	Waste Bank Entrepreneurs	WBE	Community-based recycling, waste valorization
10	EXP-10	Higher Education Institution	HEI	Environmental research, sustainability assessment

RESULTS AND DISCUSSION

Power and Dependency Dynamics Among Stakeholders

The first result of the MACTOR analysis is the power and dependency map of actors. Actor influence describes the capacity of an actor to influence other actors, as well as the design, planning, and implementation of project development. The sources of actor power are determined by the ownership of material resources, social position, and the actors' knowledge regarding the future of a system [24, 25]. Based on their power, actors are positioned on a power and dependency map and categorized into dominant actors (high influence), dominated actors (high dependency), isolated actors (low influence and dependency), and relay actors (high influence and high dependency) [10, 26, 27].

The MDI (Matrix of Direct Influence) is an instrument used to map the extent of direct influence that one actor has over another within a system (Table 2). The higher the value assigned in the matrix, the greater the impact of that actor on the existence, policy direction, and implementation strategies of other actors. In the structure of the table, the rows represent the actors exerting influence, while the columns represent the actors receiving influence. For example, the

row of JES (Jakarta Environmental Agency) against the column of CET (Cross-Regional Environmental Task Force) has a value of 4, which indicates that JES holds a very strong, even existential, influence over CET.

Table 2. Matrix of direct influence (MDI)

MDI	JES	CET	LCO	WFC	BRG	PWE	WBE	CPG	WCG	HEI
JES	0	4	3	3	3	4	3	3	4	3
CET	2	0	3	3	3	3	3	3	3	3
LCO	1	1	0	3	3	1	1	2	2	2
WFC	2	2	3	0	3	2	3	3	3	2
BRG	2	2	3	3	0	2	3	4	4	2
PWE	3	3	3	3	3	0	3	4	3	2
WBE	1	1	2	2	2	2	0	3	4	2
CPG	1	1	3	2	2	3	3	0	4	2
WCG	2	2	3	2	3	4	3	4	0	2
HEI	3	3	2	2	3	3	2	2	2	0

Remarks:

(1) JES: Jakarta Environmental Agency, CET: Cross-Regional Environmental Task Force, LCO: Local Community, WFC: Waste for Change, BRG: Bekasi Local Government, PWE: Private Waste Management, WBE: Waste Bank Entrepreneurs, CPG : Garbage Pickers Group, WCG: Waste Collection Group, HEI: Higher Education Institutions

(2) Influences are graded from 0 to 4 according to the importance of the actor's possible jeopardy: 0: No influence, 1: Operating procedures, 2: Projects, 3: Missions, 4: Existance

Figure 2 shows the power and dependency map of actors which is the first outcome of the MACTOR analysis. Stakeholder map separates the actors into four quadrants depending on the dependency and influence.

Dominant Actors (High Influence, Low Dependency)

Jakarta Environmental Service (JES) and Cross-Regional Environmental Task Force (CET) are placed in this category. Such institutions wield great influence in the process of waste management policy and implementation, with minimal dependence on other actors. The Higher Education Institutions (HEI) also become actors in this quadrant, since they are a high influence/low dependency actor. However, in contrast to JES and CET, the power of HEI is based on the production of knowledge and the ability to connect research and practice. Although they have structural independence, the fact that they are minimally incorporated into the policy processes makes them less visible, which points to the lack of scientific knowledge in the ISWM governance.

Relay Actors (High Influence, High Dependency)

It is the location of Bekasi Regional Government (BRG), Private Waste Energy Management (PWE), Waste for Change (WFC) and the Waste Collection Group (WCG). These actors continue to play an important role yet tend to be very reliant on other stakeholders in terms of resources or legitimacy. As an example, PWE could not operate without government contracts and regulatory approvals whereas WCG, despite being considered a relay, relies economically on access to recyclable materials dominated by the power players.

Dominated Actors (Low Influence, High Dependency)

This quadrant is occupied by Garbage Pickers Group (GPG), Local Community (LCO) and Waste Bank Entrepreneurs (WBE). Both GPG and WCG are widely characterized as dominant actors, but the analysis indicates subtle distinctions: GPG has the least influence and highest dependency which is extreme vulnerability because of its dependency on availability of waste and lack of participation in decision-making. WCG, in its turn, being dependent as well, demonstrates rather a bit stronger stand due to its structured character and possibility to act in unison. This differentiation brings out the heterogeneity of the informal sector.

Isolated Actors (Low Influence, Low Dependency)

There are not many actors that are in this quadrant of the present analysis indicating that majority of the stakeholders are either highly dependent or powerful. Nevertheless, some community-based projects occasionally take up this space where they act on their own with slight engagement with formal actors.

Breaking down the quadrants and analyzing them individually, the analysis explains the imbalance in the systems in ISWM-Bantargebang. JES, CET and HEI take up the policy and knowledge agenda whereas informal actors like GPG and WCG are exposed, though to varying degrees of dependency. The identification of these differences is essential to the development of collaborative approaches that can efficiently take advantage of the strengths of dominant actors and also respond to the weaknesses of dominated groups.

These groups require capacity building and improved access to decision-making systems (Tabel 3).

Table 3. Actor influence and support matrix

Actor	Position	Influence Level	Supported Objectives
JES	Dominant	High	DWE, DAW, CLC
CET	Dominant	High	DWE, DAW, CLC
HEI	Dominant	High	DWE, DAW, CLC
BRG	Relay	Medium	DWE, DAW
PWE	Relay	Medium	DWE, DAW
WFC	Relay	Medium	DWE, DAW, CLC
WCG	Relay	Medium	CLC
GPG	Dominated	Low	CLC
WBE	Dominated	Low	DWE
LCO	Dominated	Low	CLC

This power imbalance confirms the findings of Larasati and Puspaningtyas [28] that waste management policies in Indonesia remain predominantly top-down and risk marginalizing informal actors. Unlike international studies such as Ben-Daoud, et al. [9] that emphasize actor equality in resource management, this study finds that in the local context, the informal sector is highly marginalized and requires more participatory collaboration models.

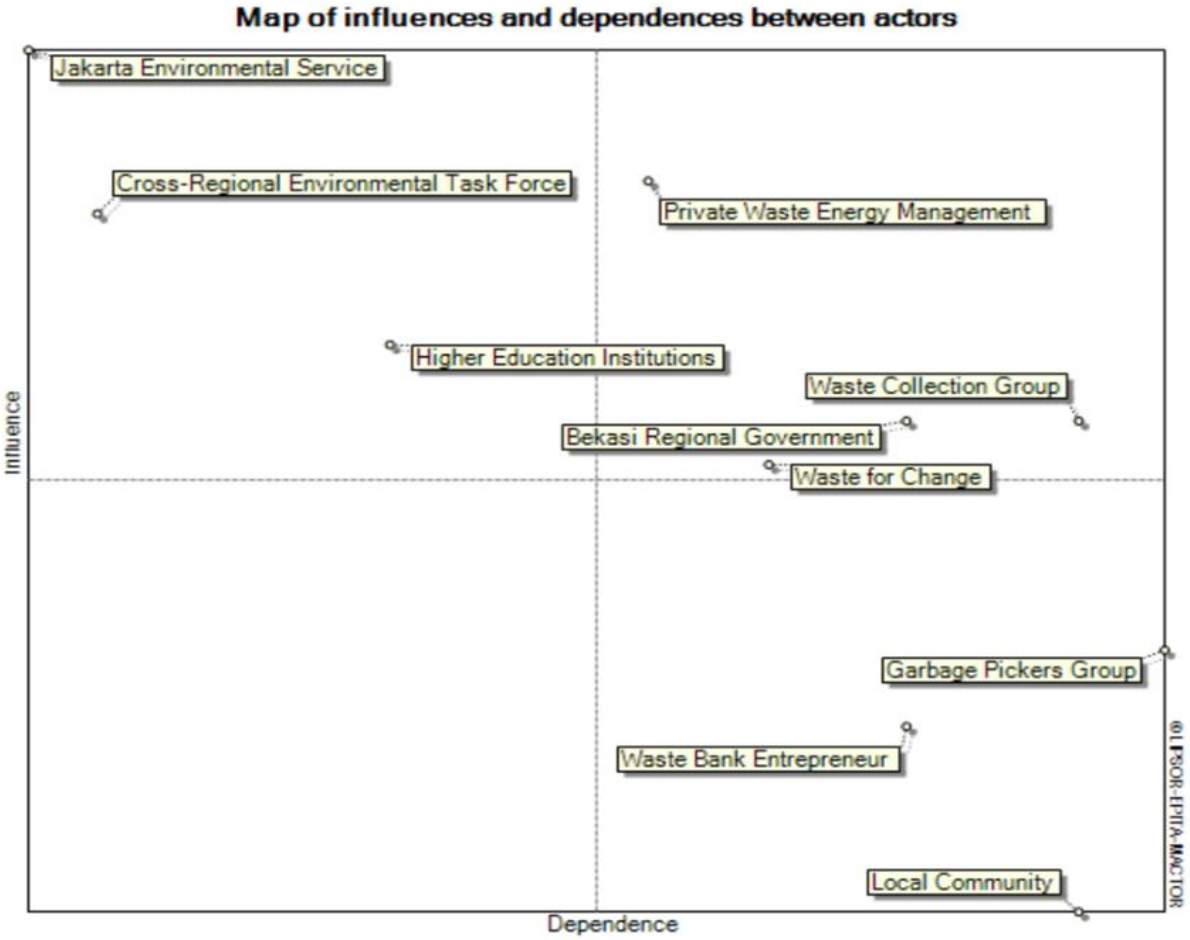


Figure 2. Actor power and dependency map

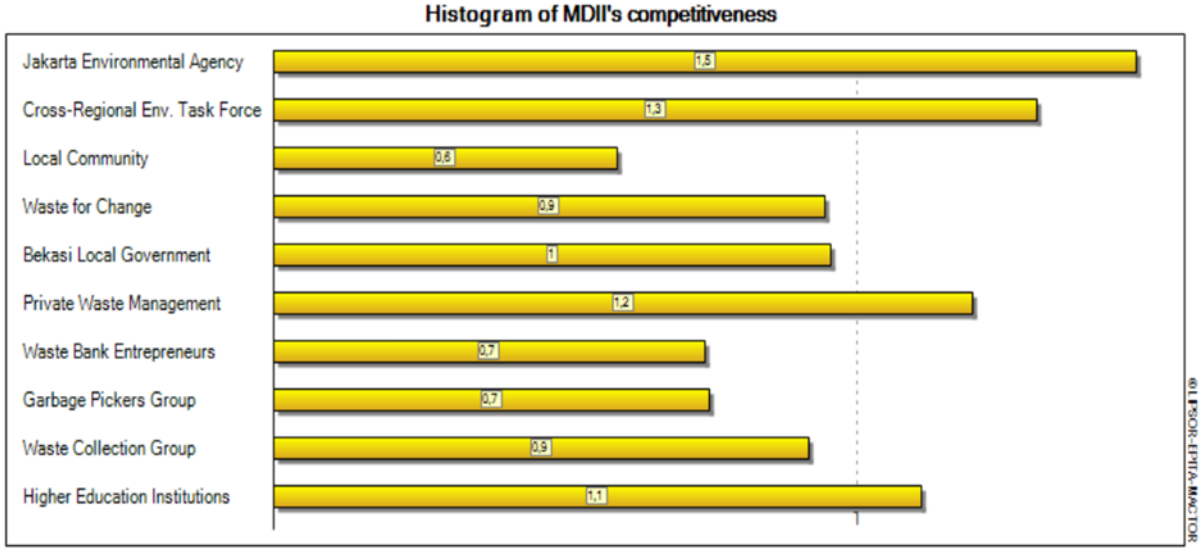


Figure 3. Actor competitiveness

Figure 3 maps the level of actor competitiveness in ISWM Bantargebang based on MACTOR analysis. The competitiveness scores range as follows: Jakarta Environmental Service dominates (score 5) as the most competitive actor. The Cross-Regional Environmental Task Force ranks second (score 3). Private Waste Energy Management/intermediate treatment facility (ITF) and Waste for Change are in moderate positions (scores ranging from 2 to 9). Higher Education Institutions and the Garbage Pickers Group have the lowest competitiveness scores (1 and 0, respectively).

Competitiveness analysis shows that JES and CET have the highest competitiveness, while GPG and WCG have the lowest. This finding confirms systemic imbalances that can trigger social resistance to Waste-to-Energy (WTE) projects, as found in studies by Ko, et al. [29] and Yang, et al. [30]. A key

difference in this study is the visualization of competitiveness along with the strategic distance between actors, providing a more detailed picture of potential hidden conflicts not detected by conventional stakeholder mapping methods.

The high competitiveness of Private Waste Energy Management, such as Waste to Energy Power Plants (WEPP), is driven by large investments in National Strategic Projects (NSP). Their business model, which combines tipping fees and electricity sales to PLN, strengthens their bargaining position. This aligns with previous relevant studies showing that public-private partnerships in WEPP improve technological efficiency but risk marginalizing non-formal actors like waste pickers due to competition for plastic waste as Refuse Derived Fuel (RDF) [6, 31, 32].

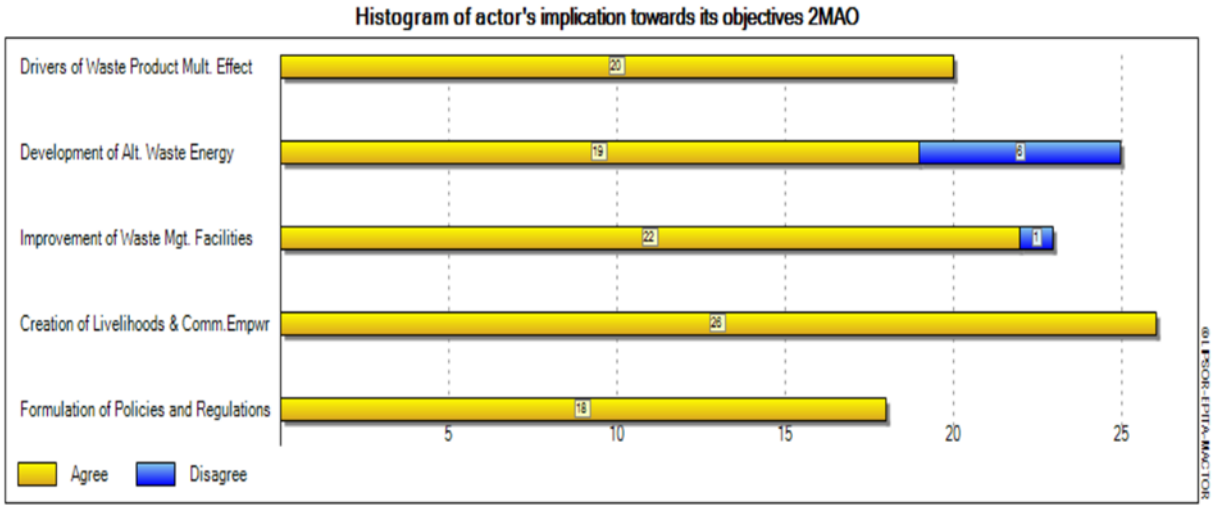
The low competitiveness of waste pickers reflects the vulnerability of non-formal actors within structured waste management systems, particularly when policies like WEPP or RDF reduce their access to plastic waste. Meanwhile, the weak role of higher education institutions contradicts findings that academic institutions are critical knowledge hubs in the transition toward a circular economy. This disparity indicates a lack of integration of academic recommendations into ISWM operational practices [19, 33]. Actor competitiveness mapping at ISWM Bantargebang confirms the hierarchical pattern commonly found in Indonesian waste management studies, where state and private actors dominate, while local communities and academic institutions remain marginalized. Integrating bottom-up approaches and empowering low-competitive actors is key to achieving inclusive waste management, as recommended in the sustainability literature [6, 18, 34].

Actor Positions Toward Strategic Waste Management Objectives

The 2MAO analysis in Figure 4 shows that most actors strongly support the five strategic objectives of waste management, with varying levels of agreement. The Creation of Livelihoods and Community Empowerment (CLC) objective ranks the highest, supported by nearly all actors without any resistance. This highlights that community empowerment and livelihood creation are regarded as a shared priority, particularly in integrating the informal sector, which has long depended on waste as a source of income. Strong support is also evident for the Improvement of Waste Management Facilities (IWM) and the Drivers of Waste Product Multiplier Effect (DEW) objectives, emphasizing actors' awareness of the importance of infrastructure improvement and harnessing the circular economy potential of waste management.

In contrast, the Development of Alternative Waste Energy (DAW) objective reveals divergent positions among actors. While it receives substantial support from formal and technocratic actors, there is notable resistance from informal actors who fear losing access to valuable materials due to the transition toward Waste-to-Energy technology. This situation indicates a potential conflict in benefit distribution that must be addressed. Meanwhile, the Formulation of Policies and Regulations (FPR) objective gains moderate support without resistance, though it is not seen as a top priority compared to other agendas. Overall, these results underline that CLC, DEW, and IWM can serve as entry points for short-term collaboration, while DAW requires inclusive strategies that accommodate the interests of the informal sector to prevent marginalization.

Figure 5 shows the intensity of actor mobilization toward five strategic objectives in integrated waste management at ISWM-Bantargebang, as analyzed using the MACTOR method. The bar graph illustrates the degree of agreement (yellow) and disagreement or resistance (blue) of each actor toward each objective. In general, the results show that most actors support or do not show significant resistance to the overall established objectives. This is evident from the dominance of the yellow color and only two objectives with notable resistance values (blue), namely the Development of Alternative Waste Energy (DAW) at 5.2 points and the Improvement of Waste Management Facilities (IWM) at 0.9 points. This indicates a significant potential to achieve consensus among actors, which is an essential requirement in multisector policy implementation [10, 24, 27].



Remarks: Drivers of Waste Product Multiplier Effect (DEW), Development of Alternative Waste Energy (DAW), Improvement of Waste Management Facilities (IWM), Creation of Livelihoods and Community Empowerment (CLC), Formulation of Policies and Regulations (FPR)

Figure 4. Actor mobilization toward strategic objectives 2MAO

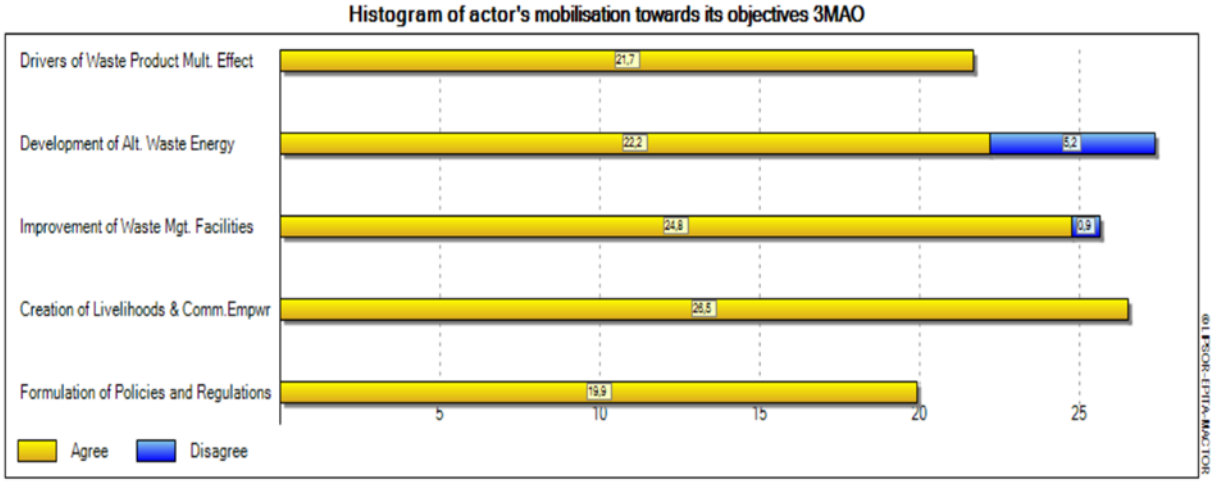


Figure 5. Actor mobilization toward strategic objectives 3MAO

The objective with the highest level of mobilization is the Creation of Livelihoods and Community Empowerment (CLC), with a support score of 26.5. This indicates that almost all actors recognize the importance of social empowerment in waste management. The strong support for CLC reflects the objective conditions at ISWM-Bantargebang, where informal communities such as scavengers still face limited access to decent work, skills training, and social protection. This aligns with findings from studies emphasizing that integrating the informal sector into waste management systems not only increases efficiency but also strengthens social equity and community empowerment [6, 7, 18, 20].

The next strategic objective with strong support is the Drivers of Waste Product Multiplier Effect (DWE), with a score of 21.7. This indicates that actors see the economic potential of waste management activities, such as recycling, composting, and waste-based industry development. These findings are consistent with several studies that highlight the importance of the circular economy approach in waste management systems to create added value and new employment opportunities [28, 34-36].

Meanwhile, for the objective Development of Alternative Waste Energy (DAW), although it has a relatively high support score (22.2), there is a resistance level of 5.2 points. This resistance may reflect concerns about the environmental impacts of developing Waste-to-Energy Power Plants (WEPP), such as emissions and potential health risks to surrounding communities. This is in line with critiques in the literature regarding WEPP in developing countries, which emphasize the need for strict regulations and technological oversight to prevent negative externalities [4, 6, 30].

The objective Formulation of Policies and Regulations (FPR) actually shows the lowest support (19.9), although without any resistance. This could be interpreted as some actors perceiving that policies are not the main barrier, or perhaps they do not yet see the urgency of formulating new regulations, instead focusing more on the implementation of existing policies. This contrasts with the findings of Sukwika [11] and Tamba, et al. [37] who highlighted weak legal foundations and regulatory overlaps as major causes of inefficiency in Indonesia's waste management system.

The support map for these strategic objectives provides important insights into collaboration opportunities and critical points to be monitored. Objectives with high support and low resistance can be prioritized in short-term implementation strategies, while objectives with higher resistance, such as DAW, need to be approached with risk mitigation strategies, technology outreach, and community involvement during the planning stage.

This study finds that most actors support community empowerment objectives and the waste economy multiplier effect. These objectives become "quick win" targets that are mutually agreed upon and can be prioritized for collaborative efforts. In contrast, the objective of developing alternative energy faces significant resistance, especially from the informal sector. This reinforces the findings of Khan and Inamuddin [38] and Rahardjo [31] that Waste-to-Energy projects have the potential to reduce the economic access of scavenger groups to valuable waste. The difference in this study lies in the quantitative and structured identification of resistance, as well as the actor convergence map visualized with strategic distances, providing additional analytical value. The strong position of the Cross-Regional Environmental Task Force reflects its influence as a cross-jurisdictional watchdog (Jakarta-Bekasi). The independence of this institution in monitoring ISWM operations strengthens similar findings that regional monitoring mechanisms are effective in preventing environmental violations at multi-regional landfills, although they have the potential to trigger authority conflicts with provincial governments [3, 39, 40].

Convergence and Strategic Distance Among Actors

The actor convergence map in Figure 6 shows the level of alignment or closeness of perceptions among actors regarding the strategic objectives in waste management. The lines connecting the actors indicate the intensity of convergence based on color intensity and thickness: from very weak convergence (dashed lines) to very strong convergence (thick red lines). Table 4 provides a quantitative representation of these relationships in the form of convergence scores between each pair of actors.

From the mapping results, it is evident that the Jakarta Environmental Service (JES) has the highest level of convergence with the Cross-Regional Environmental Task Force (CET), with a score of 23.7 points, indicated by a red line representing the strongest convergence. This shows that these two institutions have highly aligned understandings, interests, and objectives regarding the integrated waste management issue at ISWM-Bantargebang. This is quite logical considering both are institutions directly responsible for cross-regional policy and supervision. This finding is consistent with Fauzi [17], who stated that formal government actors tend to form strong policy alliances due to similar structural mandates.

Table 4. Actor convergence

3CAA	JES	CET	LCO	WFC	BRG	PWE	WBE	GPG	WCG	HEI
JES	0	23,7	14,6	17,3	17,8	19,8	11,8	6,3	9,4	20,4
CET	23,7	0	13,2	15,9	16,4	18,3	11,4	6,5	9,3	18,9
LCO	14,6	13,2	0	6,8	7,3	9,3	4,0	2,5	3,5	9,9
WFC	17,3	15,9	6,8	0	10	12,5	6,0	3,8	5,6	12,5
BRG	17,8	16,4	7,3	10	0	12,5	6,0	2,8	5,1	13
PWE	19,8	18,3	9,3	11,9	12,5	0	7,3	3,7	5,8	20,5
WBE	11,8	11,4	4,0	6,0	6,0	7,3	0	3,4	4,6	8,9
GPG	6,3	6,5	2,5	3,8	2,8	3,7	3,4	0	6,8	5,2
WCG	9,4	9,3	3,5	5,6	5,1	5,8	4,6	6,8	0	7,8
HEI	20,4	18,9	9,9	12,5	13	20,5	8,9	5,2	7,8	0
Number of convergences	141,1	133,6	71,5	89,8	91	103,2	63,1	40,8	58,3	111,5
Degree of convergence (%)	0,0									

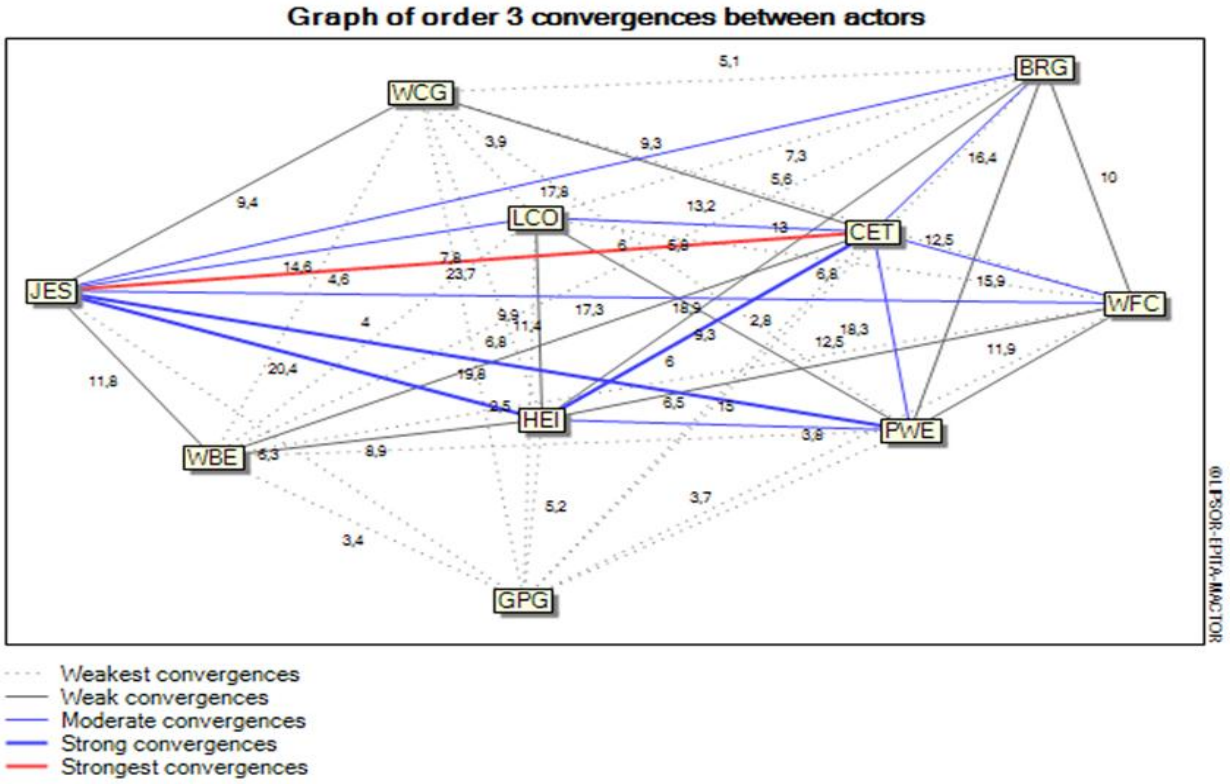


Figure 6. 3CAA convergence map

Furthermore, the Higher Education Institutions (HEI) also demonstrate a high level of convergence with many actors, such as JES (20.4 points) and CET (18.9 points). This indicates that higher education institutions have significant potential to serve as cross-sector collaborative catalysts, particularly in integrating knowledge and waste management technology. This finding aligns with the research of Moreira, et al. [19], Sezer and Bosch-Sijtsema [27], and Sukwika [11], which emphasize the crucial role of scientific actors in building collaborative, data-driven resource management systems.

WFC and HEI serve as strategic bridging actors with short distances to various other actors, indicating their potential as system integration catalysts. Interestingly, the longest strategic distance is found between JES and CET, despite the fact that, institutionally, they should be closely coordinated. This suggests the existence of potential cross-regional policy conflicts that have not been widely addressed in previous studies. This finding reinforces Zhang and Zhu [40] conclusions regarding the importance of overcoming relational distances between institutions in urban waste management. However, this study offers a new contribution by including the informal sector as a measurable component of strategic distance.

On the other hand, informal actors such as the Garbage Pickers Group (GPG) and the Waste Collection Group (WCG) show relatively low levels of convergence with other actors,

with convergence scores often below 10 points in many relationships. This indicates limited integration of these groups into strategic planning systems, despite their crucial role in the waste collection chain. This condition supports the findings of Harfadli, et al. [22] and Tong, et al. [41], which state that informal groups are often not actively involved in strategic decision-making, even though they are key operational actors. Compared to similar studies conducted by Hertati and Arif [35] and Rini, et al. [34], it was found that a high level of convergence among formal actors such as the Environmental Service and Regional Government is also a key factor in the success of recycling programs and waste reduction. However, in those studies, the involvement of non-government actors, particularly NGOs and the private sector, remained minimal.

Figure 7 illustrates actor positions regarding the objective Drivers of Waste Product Multiplier Effect (DWE). The visualization shows nine actors, which initially appeared incomplete. Upon closer inspection, all ten stakeholders were analyzed, but the Waste Bank Entrepreneurs (WBE) are missing from the figure due to their negligible convergence/divergence score in relation to this objective. To avoid confusion, this is now explicitly clarified: WBE exhibited neutral alignment and did not significantly affect the balance scale, which explains their absence in the visual output. In the revised figure, WBE is included in the neutral position for completeness.

The figure shows that JES, CET, PWE, HEI, and LCO strongly support DWE. Informal groups (GPG and WCG) also align positively, though with weaker support levels. This broad consensus underscores the economic potential of waste-based industries as a unifying platform. The clarification of all ten actors ensures methodological transparency and prevents misinterpretation of missing data.

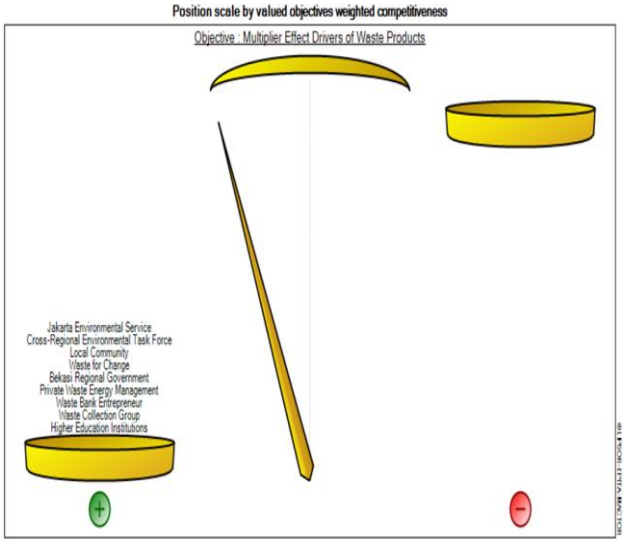


Figure 7. Balance scale between actors and objectives: Convergence and divergence among stakeholders in the drivers of waste product multiplier effect

This high level of convergence makes DWE a "quick win objective", meaning it is a highly feasible strategic target for immediate cross-sector collaboration. This objective has strong economic leverage, consistent with the findings of Hertati and Arif [35] and Rini, et al. [34], which stated that integrating the informal sector into the circular economy-based waste management ecosystem could increase local income by up to 23% and reduce landfill waste volume by 18%. These findings are also in line with research from several other countries, which concluded that focusing on the multiplier effect—such as the development of eco-entrepreneurship and the industrialization of recycled products—is key to increasing the economic value of waste management systems and expanding private sector involvement [17, 20, 29, 42].

In several landfill areas, it is known that one of the main obstacles in implementing integrated waste management programs is the lack of common ground among actors regarding economic and innovation aspects [35, 36, 43]. This contrasts with the situation at ISWM Bantargebang, as depicted in Figure 7, where the economic dimension, such as the DWE, actually receives broad support. This indicates that the MACTOR approach is capable of systematically capturing collaboration potentials that may not be visible through conventional actor analysis methods. Therefore, this should be followed up with a collaborative roadmap based on DWE as the central objective that integrates the interests of various actors.

This visualization confirms that the DWE objective is a strategic node that can serve as an entry point in formulating collaborative policies. Since there is no significant resistance from any actor, the development of multiplier effect-based programs, such as waste-to-energy utilization, high-value recycling, or social enterprise incubation based on waste, holds strong potential to be promoted as a primary program.

Figure 8 presents actor alignment on the Development of Alternative Waste Energy (DAW) objective. Similar to Figure 7, the original version showed only nine actors. In this case, the Local Community (LCO) was omitted from the visual output due to a near-zero resistance/support score. While LCO expressed general support, the score fell below the visualization threshold of the system. In the revised figure, LCO is added in a neutral supportive position to ensure that all ten stakeholders are consistently represented. The updated interpretation emphasizes the divergence between formal/technocratic actors (JES, CET, BRG, PWE, WFC, HEI) who strongly support DAW, and informal actors (GPG and WCG) who resist due to concerns over resource access. Including LCO in the neutral zone provides a fuller picture of stakeholder distribution. These actors are generally policymakers, technical implementing agencies, innovation players, and private sector actors who have the capacity and interest in renewable energy technologies and policies derived from waste.

On the other hand, on the divergent side (less supportive or resistant), there are two actor groups positioned on the right, indicating resistance to this objective: Garbage Pickers Group (GPG) and Waste Collection Group (WCG). These groups generally come from the informal sector, which likely feels threatened or does not directly benefit from the DAW program. This could be due to the potential reduction in accessible raw materials (sellable waste) and their limited inclusion in new technologies, which are often capital-intensive and centralized. This support gap indicates that even though the DAW objective receives strong backing from institutional and technocratic actors, there remain social challenges, particularly potential conflicts in benefit distribution between the formal and informal sectors. This is a critical signal that the DAW program must be designed inclusively to avoid marginalizing scavengers and traditional waste collectors.

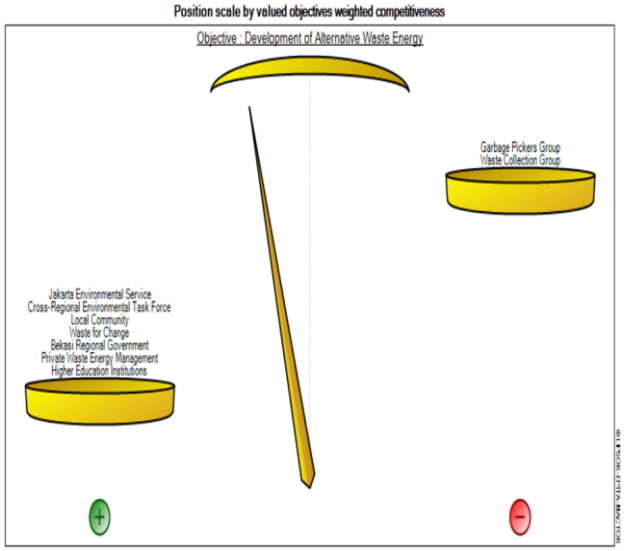


Figure 8. Balance scale between actors and the development of alternative waste energy objective among stakeholders

The apparent discrepancies in Figures 6 and 7 arose from automated system outputs that excluded actors with negligible or neutral scores. To improve clarity, the revised figures now explicitly include all ten actors, even those with minimal influence on the balance scale. This adjustment ensures consistency and transparency, allowing readers to verify that no actors were unintentionally excluded.

This finding is consistent with studies stating that Waste-to-Energy (WTE) projects tend to fail socially if they do not consider the integration of the informal sector [29, 30, 38]. Studies in India and Brazil showed that resistance from scavengers toward WTE projects emerged because they lost access to economically valuable waste once WTE projects were implemented. Furthermore, studies in landfill areas where WTE power plant projects were developed without community involvement led to horizontal conflicts and eventually triggered social protests [1, 11, 12, 31].

Therefore, the results from Figure 8 show that the success of the DAW objective is not solely determined by technical strength and policy support but also heavily depends on how vulnerable actors (such as GPG and WCG) are meaningfully involved in this energy transformation process. DAW holds great potential to improve waste management efficiency and generate added energy value. However, the fragmentation of actor support needs to be bridged through inclusive strategies such as: Public-informal partnerships, Benefit-sharing schemes, WTE technology training for scavengers, Cooperative models for the informal sector in the waste-to-energy supply chain. Through such approaches, the DAW project can become a collaborative platform across actors, while also reducing resistance and strengthening ecological justice.

Figure 9 illustrates the proximity or net strategic distance among actors within the waste management system based on the MACTOR method. Each line connects two actors, with the color and thickness indicating the distance magnitude, as follows: Thin dashed gray lines: Shortest net distance (closest relationship), Thick gray lines: Short distance, Light blue lines: Medium distance, Dark blue lines: Long distance, Red lines: Farthest distance (weakest relationship or high conflict of interest).

Several actors have very low net distances, indicating a high degree of similarity in objectives, interests, and action patterns. These include: WFC – WBE (distance 0.5), WFC – CET (distance 0.5), WFC – WCG (1.5), GPG – WCG (2), and LCO – WFC (2.5). These findings indicate that actors from the informal sector such as WCG and GPG, social enterprises like WBE, and professional institutions such as WFC form a strong strategic coalition in waste management. Among them, WFC occupies a central position as an effective bridge or catalyst in connecting the formal and informal sectors, enabling smoother flows of information, coordination, and innovation. Conversely, the most distant relationship is identified between JES and CET, with a distance reaching 17, visualized by a red line, indicating significant potential for coordination conflicts. This is a critical issue, as both are part of local government institutions that ideally should collaborate across regions.

In addition, the relationships between CET and other actors such as HEI, BRG, and PWE also show distances exceeding 14, indicating a gap in vision or differing interests in long-term strategies. Within this relational landscape, WFC and HEI stand out as central coalition actors, with relatively short to moderate relationship distances with various other actors, highlighting their strategic roles as multi-stakeholder connectors capable of facilitating cross-sector communication consistently.

The relational patterns among actors in waste management demonstrate that collaborative strategies should focus on strengthening several key aspects. First, coalitions among actors with close relational distances must be maintained and reinforced, as the synergies already formed among them have the potential to become drivers of system transformation more quickly and effectively. Second, potential conflicts or disconnected relationships between actors with distant relationships—such as between JES and CET—must be mitigated through the development of cross-regional coordination forums or the establishment of joint working units that can facilitate communication and policy harmonization. Third, the roles of connecting institutions such as WFC and HEI must be strengthened, considering their strategic positions in bridging the formal and informal sectors and in accelerating the adoption of innovations in on-the-ground waste management practices.

These findings are consistent with studies by Ben-Daoud, et al. [9], Fatmawati, et al. [43], Lawado and Dwimawanti [36], and Sukwika [11], which indicate that in complex environmental governance systems, the strategic distance between actors is not solely influenced by institutional positions, but also by the degree of openness to collaboration, role flexibility, and economic interests. Other studies in the context of international waste management collaboration reveal that differences in interests between regulators and operators often create "distance traps" that hinder joint innovation [3, 40, 44-47]. This is analogous to the distance observed between JES and CET in this graph.

The practical implications based on the above analysis are: The net distance graph findings, which quantitatively clarify the dynamics of relationships between actors, emphasize the importance of relationship mapping as a foundation for formulating collaborative policies. Actors such as WFC and HEI, who occupy strategic positions, can be maximized as connectors to strengthen the integration of the waste management system. The significant relational distance between key actors such as JES and CET requires special attention to address policy fragmentation, necessitating the design of bridging strategies that are adaptive and participatory. Therefore, the implementation of integrated waste management requires mechanisms to adjust inter-

actor relationships, including the regular facilitation of multi-stakeholder dialogues to prevent structural conflicts and strengthen institutional synergy.

Figure 10 presents a visualization of the MACTOR analysis results showing third-level convergence among actors in the waste management system. Third-level convergence refers to the degree of similarity among actors in terms of high-value strategic objectives and tends to indicate actors with long-term collaboration potential, even if they are not in direct alliances.

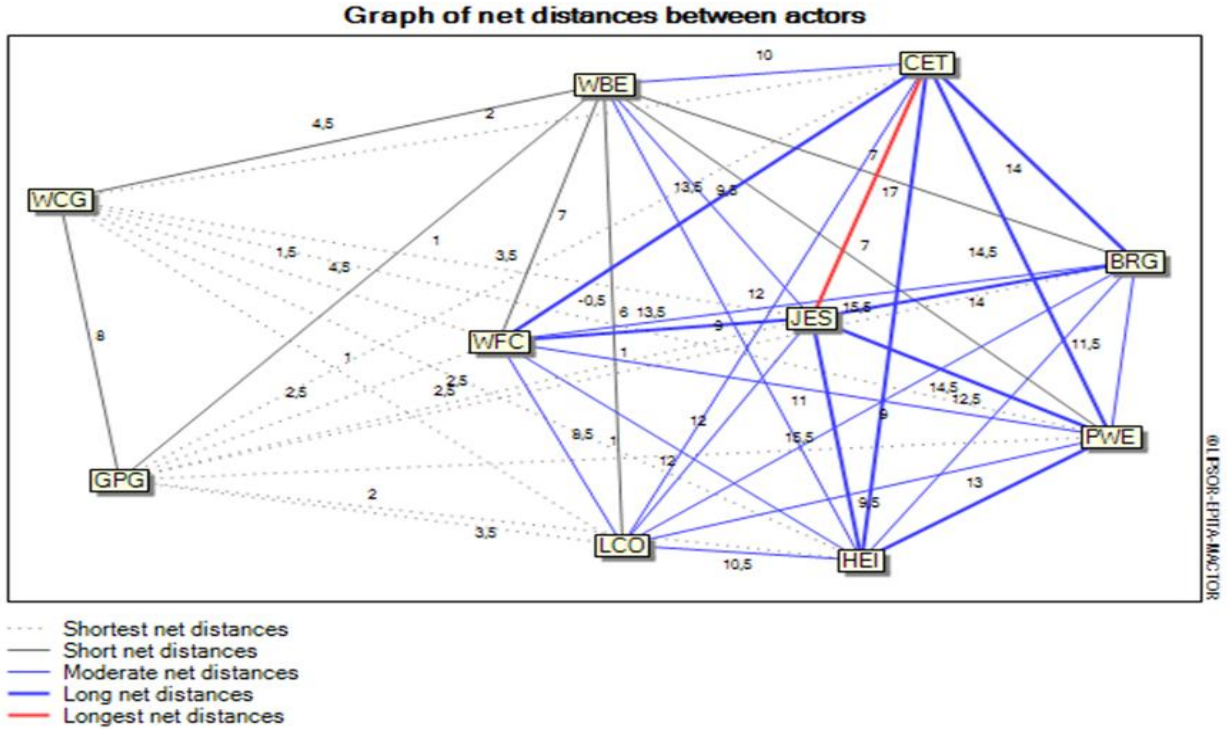


Figure 9. Graph of net distance between actors

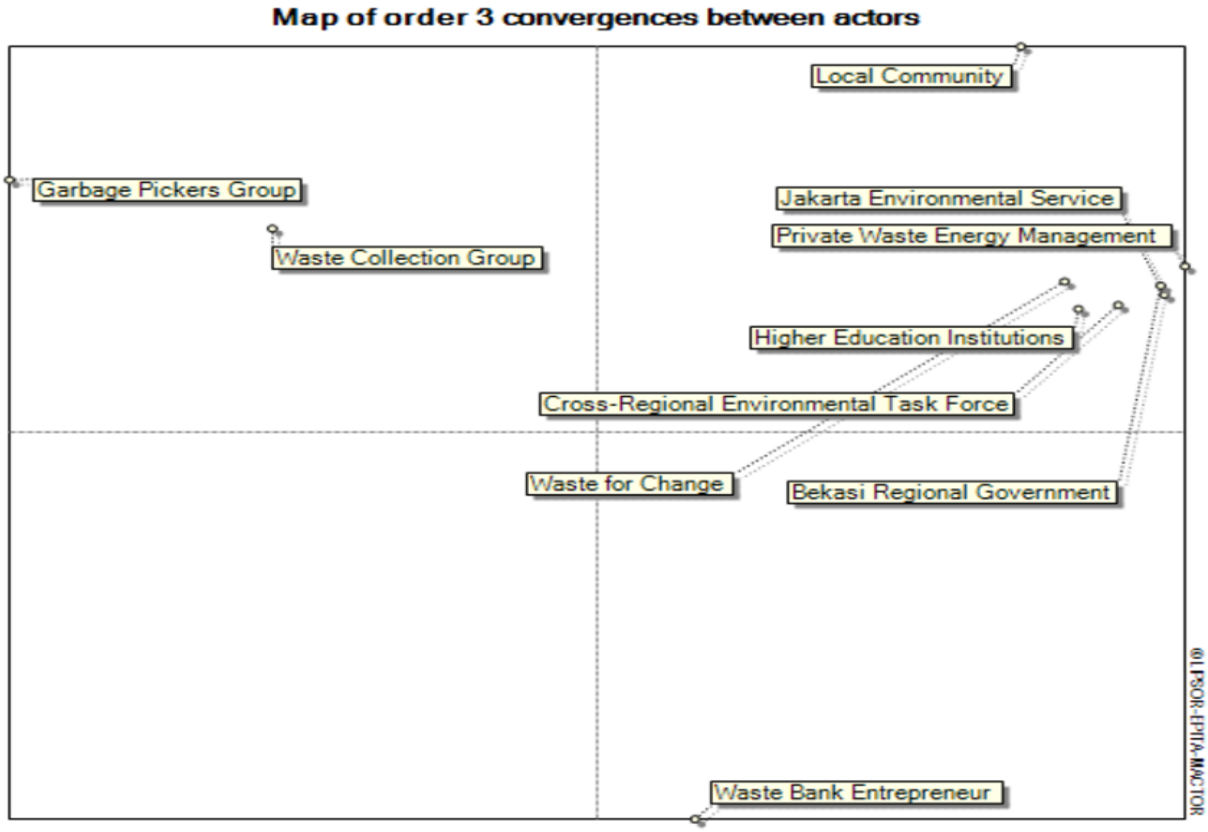


Figure 10. Divergence between actors

High-Convergence Actor Group (Upper Right Quadrant): This group includes the Local Community (LCO), Jakarta Environmental Service (JES), Private Waste Energy Management (PWE), and Higher Education Institutions (HEI). These actors are positioned in the quadrant indicating strong convergence toward key strategic objectives within the system, such as energy sustainability, public education, and increasing the added value of waste. Their positions indicate high synergy potential that can be facilitated through cross-sector collaborative programs.

Strategic Support Group (Center-Right Quadrant): This group consists of the Cross-Regional Environmental Task Force (CET), Waste for Change (WFC), and the Bekasi Regional Government (BRG). They serve as cross-regional policy connectors and can act as "technocratic coordinators" bridging local and provincial policies. Their role is crucial in ensuring cross-jurisdictional alignment and the operationalization of harmonized policies.

Lagging or Isolated Group (Upper Left Quadrant): This group includes the Garbage Pickers Group (GPG) and Waste Collection Group (WCG), which are positioned in the upper left quadrant, indicating a convergence gap with the main actors, although they are critical in the operational waste management chain. The Waste Bank Entrepreneur (WBE) is located in the lower right quadrant, which suggests they have potential strategic vision but are not yet effectively connected to other actors.

The mapping in Figure 10 indicates that sustainable integrated waste management initiatives need to: Integrate informal actors (GPG, WCG) with the main actors through participatory approaches and economic incentives. Facilitate strategic networking among actors in the upper right quadrant in the form of a consortium or permanent forum. Optimize the roles of HEI and PWE as catalysts linking innovation and policy implementation.

These results align with the findings of Bentil, et al. [33], Fatmawati, et al. [43], Ferreira, et al. [18], and Rai, et al. [48], who stated that in sustainable waste management systems, the convergence of strategies among actors is strongly influenced by local community involvement and the role of scientific institutions. This supports the strategic positions of HEI and LCO in the map. Furthermore, studies on cross-institutional environmental collaboration show that informal groups such as waste pickers and waste transporters tend to be marginalized in policy design, even though they play a crucial role in implementation. This is reflected in the positions of GPG and WCG, which are distant from the convergence center [35, 44, 45].

Practical implications that can be drawn from the above description are: Actors in the high-convergence zone, such as JES, HEI, PWE, and LCO, have significant capacity to drive change agendas in waste management. Informal sector actors need to be facilitated through approaches that emphasize recognition and active involvement in the decision-making process. Additionally, it is necessary to establish integrative platforms that involve cross-actor and cross-regional collaborations to unify visions and synergize sustainable waste management practices.

Implications for Collaborative Waste Management

The MACTOR analysis conducted at ISWM-Bantargebang offers more than a diagnostic snapshot of stakeholder relationships—it provides actionable insights for designing inclusive, adaptive, and resilient waste governance. The stark power asymmetry, with Jakarta Environmental Service (JES) and the Cross-Regional Environmental Task Force (CET) as dominant actors and informal groups like the Garbage Pickers Group (GPG) as marginalized, underscores a systemic barrier to equitable collaboration. However, the convergence around specific strategic objectives reveals critical entry points for intervention.

First, the strong consensus on Creation of Livelihoods and Community Empowerment (CLC) and the Drivers of Waste Product Multiplier Effect (DWE) presents an opportunity for "quick win" initiatives. These objectives enjoy near-universal support and negligible resistance, making them ideal foundations for building trust among historically disconnected actors. Programs such as cooperative-based recycling hubs, waste-to-enterprise incubators, or certified waste picker collectives could leverage DWE's economic appeal while advancing CLC's social equity goals. Evidence suggests such models can increase local income by up to 23% and reduce landfill reliance by 18% [34, 35], aligning efficiency with justice.

Second, the Development of Alternative Waste Energy (DAW), while technically promising, faces meaningful resistance from informal actors who fear economic displacement due to reduced access to recyclable materials. This tension highlights a recurring pitfall in Global South waste-to-energy transitions: technological solutions implemented without social safeguards risk deepening inequality and provoking community backlash [29, 30, 38]. To avoid this, DAW must be reimagined as a shared-value platform. Practical measures include formalizing public–informal partnerships, establishing benefit-sharing mechanisms (e.g., allocating a share of WTE revenue to waste picker welfare funds), providing technical training on RDF processing, and integrating GPG/WCG into the Refuse-Derived Fuel (RDF) supply chain through inclusive procurement policies.

Third, the analysis identifies Waste for Change (WFC) and Higher Education Institutions (HEI) as strategic bridging actors. Both demonstrate high convergence with diverse stakeholders and occupy central positions in the net strategic distance map. Institutionalizing their roles—as neutral facilitators in multi-stakeholder forums or as knowledge brokers linking policy, technology, and community needs—can accelerate system integration. HEI, in particular, remains underutilized despite its potential to generate evidence-based solutions; strengthening its policy advisory function could correct the current top-down governance bias [19, 33].

Finally, the unexpected strategic distance between JES and CET—despite their shared mandates—signals latent intergovernmental friction that could fragment implementation. Establishing a Jakarta–Bekasi ISWM Coordination Unit with joint decision-making authority would help harmonize policies, align incentives, and prevent jurisdictional overlaps.

In sum, effective collaboration at Bantargebang requires moving beyond stakeholder mapping toward relational engineering: actively designing institutions, incentives, and interactions that reduce power imbalances, convert convergence into co-action, and transform resistance into co-ownership. The MACTOR method, by making these dynamics visible and quantifiable, provides a roadmap—not just for Bantargebang, but for other complex urban waste systems grappling with formal–informal divides.

CONCLUSIONS

This study applied the MACTOR method to examine stakeholder dynamics within the Integrated Solid Waste Management (ISWM) system at Bantargebang. The findings address the three research questions concerning power relations, actor positions, and collaboration patterns.

First, the analysis shows an asymmetrical power structure dominated by the Jakarta Environmental Service (JES) and the Cross-Regional Environmental Task Force (CET), both of which exert high influence with minimal dependency. Conversely, informal actors—such as the Garbage Pickers Group (GPG), Waste Collection Group (WCG), and Local Community (LCO)—are highly dependent and possess limited influence, reflecting a top-down governance model that sidelines essential operational contributors. Second, actors' positions toward strategic objectives reveal strong convergence on socially and economically oriented goals, specifically Creation of Livelihoods and Community Empowerment (CLC) and Drivers of Waste Product Multiplier Effect (DWE). These objectives serve as strategic "quick wins." However, the Development of Alternative Waste Energy (DAW) faces resistance from informal actors who fear reduced access to recyclable materials, demonstrating tension between technological advancement and socio-economic inclusion. Third, collaboration mapping highlights Waste for Change (WFC) and Higher Education Institutions (HEI) as key bridging actors capable of linking formal and informal sectors. Despite shared mandates, a notable strategic gap exists between JES and CET, while informal actors remain isolated with low convergence levels.

These findings indicate that effective waste governance requires more than technical solutions; it demands inclusive institutional design, benefit-sharing mechanisms, and participatory forums to reduce power imbalances. Study limitations include the single-case focus, small expert panel, and reliance on qualitative judgments. Future research should expand actor representation, incorporate quantitative performance indicators, and apply longitudinal approaches to track evolving actor relations. In conclusion, MACTOR proves valuable for making power dynamics and alignment visible, offering a solid basis for equitable and sustainable waste management policymaking.

DATA AVAILABILITY STATEMENT

The author confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The author declare that there is no conflict of interest with any individual, institution, or organization in the preparation, evaluation, or publication of this study.

USE OF AI FOR WRITING ASSISTANCE

Not declared.

ETHICS

There are no ethical issues with the publication of this manuscript.

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NOMENCLATURE

Actors

JES – Jakarta Environmental Service
CET – Cross-Regional Environmental Task Force
BRG – Bekasi Regional Government
LCO – Local Community
WFC – Waste for Change
PWE – Private Waste Energy Management
WCG – Waste Collection Group
GPG – Garbage Pickers Group
WBE – Waste Bank Entrepreneurs
HEI – Higher Education Institutions

MACTOR Terms

MACTOR – Matrix of Alliances and Conflicts: Tactics, Objectives, and Recommendations
MDI – Matrix of Direct Influence
MII – Matrix of Indirect Influence
1MAA – First Actor–Actor Matrix
2MAA – Second Actor–Actor Matrix
3MAA – Third Actor–Actor Matrix
2MAO – Second Actor–Objective Matrix
3MAO – Third Actor–Objective Matrix
3CAA – Third Convergence Analysis of Actors

Strategic Objectives

DWE – Drivers of Waste Product Multiplier Effect
DAW – Development of Alternative Waste Energy
IWM – Improvement of Waste Management Facilities
CLC – Creation of Livelihoods and Community Empowerment
FPR – Formulation of Policies and Regulations

Additional Terms

Convergence – Alignment of actors' interests
Divergence – Conflict or disagreement among actors
Strategic Distance – Relational distance between actors
Dominant Actors – High influence, low dependency
Relay Actors – High influence, high dependency
Dominated Actors – Low influence, high dependency