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Research article

Hexahelix Analysis: Accelerating Food Loss and Waste Management in Support of Circular Economy Implementation in the Local Region

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Abstract: The substantial amount of food waste generated in Sragen Regency due to inadequate food loss and waste (FLW) management has a detrimental impact on the environment. This study aims to analyze the efforts to optimize FLW management, examine the relationships between variables, and assess stakeholder synergy in accelerating FLW management to support the implementation of a circular economy in the Sragen Regency. This research employs a mixed-methods approach, with data analysis conducted using MICMAC and MACTOR methodologies. The MICMAC analysis results indicate that stakeholder relationships, waste prevention, location factors, cultural factors, and community scale are the core variables for accelerating improvements in FLW management. In contrast, the MACTOR analysis identifies the Environmental Agency (DLH), Kecik Waste Bank, and Si Repi Waste Bank as the primary stakeholders in these efforts. Additionally, the MACTOR analysis highlights changes in community behavior and the utilization of FLW in the circular economy as primary objectives agreed upon by all stakeholders. The findings from the MICMAC and MACTOR analyses provide a basis and reference for determining the model and grand design of an FLW management acceleration strategy to support the implementation of a circular economy in the Sragen Regency.

Keywords: environment, food loss and waste, actors, MICMAC, MACTOR

JEL Classification: O13, O17, O21, Q01, Q53, Q58

Abstrak: Tingginya jumlah timbulan limbah makanan di Kabupaten Sragen akibat rendahnya pengelolaan FLW berdampak negatif terhadap lingkungan. Penelitian ini bertujuan menganalisis upaya yang dilakukan untuk mengoptimalkan pengelolaan FLW, menganalisis pengaruh antar variabel, dan menganalisis sinergitas stakeholder dalam upaya akselerasi pengelolaan FLW untuk mendukung penerapan sirkular ekonomi di Kabupaten Sragen. Penelitian ini menggunakan metode campuran (mixed method) dengan analisis data menggunakan MICMAC dan MACTOR. Hasil MICMAC menetapkan variabel hubungan pemangku kepentingan, pencegahan limbah, faktor lokasi, faktor budaya, dan skala komunitas menjadi variabel inti terhadap upaya akselerasi pengelolaan FLW. Sementara itu, hasil MACTOR menetapkan Dinas Lingkungan Hidup (DLH), Bank Sampah Kecik, dan Bank Sampah Si Repi sebagai stakeholder inti terhadap upaya akselerasi pengelolaan FLW. Hasil analisis MACTOR juga menetapkan perubahan perilaku masyarakat dan pemanfaatan FLW dalam sirkular ekonomi menjadi tujuan utama yang disetujui oleh masing-masing stakeholder. Analisis MICMAC dan MACTOR dapat digunakan sebagai dasar serta rujukan penetapan model dan grand design strategi akselerasi pengelolaan FLW untuk mendukung penerapan sirkular di Kabupaten Sragen.

Kata kunci: lingkungan, food woss dan waste, aktor, MICMAC, MACTOR

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1. INTRODUCTION

Population growth and lifestyle changes are primary factors contributing to the increase in food waste and its adverse environmental impacts (Clement et al., 2023; Saputro et al., 2023; Zuhra & Angkasari, 2023). The household sector is a significant contributor to food waste (Chaerul & Zatadini, 2020), a finding corroborated by Jereme et al. (2018) and Schanes et al. (2018), who describe the household sector as a dominant source of food waste. Stancu et al. (2016) attempted to mitigate food waste behavior in households through a campaign integrated with daily household activities. This approach aligns with previous studies encouraging individuals to reduce food waste via information dissemination (Ramadhita et al., 2021). Research on consumer knowledge levels provides additional insight into food waste behaviors (Fox et al., 2018). The causes of food waste include living conditions, geographical location, transportation modes, self-service practices, and deficiencies in knowledge, ability, and behavior towards food planning (van der Werf et al., 2019; Hebrok & Boks, 2017; Ilyuk, 2018).

Food loss and waste (FLW) has long been a significant concern due to its widespread occurrence and multifaceted impacts on environmental, economic, and social sectors (LinGen et al., 2018; Mirabella et al., 2014; Stöckli et al., 2018). The carbon footprint of inadequate food waste management is estimated at 3.3 billion tons of CO2, equivalent to annual greenhouse gas emissions (Dou et al., 2016). The household sector is a notable contributor to food waste (Jiménez et al., 2016). In Europe, 53% of total FLW occurs at the household level, with Switzerland reporting 45% from this sector (Beretta et al., 2013; Stenmarck et al., 2016). Similar trends are observed in other developed and developing countries, including Tunisia (Jribi et al., 2020; Sassi et al., 2016), Algeria (Arous et al., 2017), and Lebanon (Charbel et al., 2016). A synthesis of research on European Union (EU) countries shows that FLW is concentrated in the household sector (42%), food producers (32%), catering (15%), and retailers (5%) (Chirsanova & Calcatiniuc, 2021). In Indonesia, high FLW levels are driven by regional customs and culture, such as communal eating, purchasing excessive quantities of raw materials, and consuming processed products beyond individual consumption capacities (Suryana & Ariani, 2018). These attitudes are influenced by factors such as education, religious understanding, income, lifestyle, gender, and the lack of social stigma surrounding food waste (Luna & Suryana, 2023).

The reduction of food loss and waste (FLW) has become a significant commitment of the government in realizing low-carbon development, as evidenced by various regulations, including the RPJMN (Luna & Suryana, 2023). This aligns with Target 12.3 of the Sustainable Development Goals (SDGs), which focuses on reducing per capita food waste along the entire food supply chain (Astria et al., 2023). The issue of FLW is gaining prominence due to the global challenge of ensuring food reserves for 9.1 billion people by 2050, which underscores the urgency of international food security (Abdelradi, 2018; Nikolaus et al., 2018).

Beyond its impact on food security, FLW also increases waste management costs and significantly contributes to climate change, the depletion of natural resources, and biodiversity loss (Abiad & Meho, 2018; Radzymińska et al., 2016). In Indonesia, where the hunger index is high, the value of food waste is substantial but not fully reflected in national statistics. This places Indonesia as the second-highest contributor to global food waste. The amount of food wasted could meet the consumption needs of over 28 million people. The government, in collaboration with the community and the private sector, has endeavored to implement sustainable strategies for managing food waste (Zuhra & Angkasari, 2023). However, the implementation of existing regulations has not been fully optimized by all stakeholders to capitalize on Indonesia's significant potential in waste management, particularly in the area of FLW (Chaerul & Zatadini, 2020).

According to data published by the National Waste Management Information System (SIPSN) of the Ministry of Environment and Forestry, Sragen Regency has been the highest contributor of food waste in Central Java Province over the past four years (2020-2023). In 2023, the percentage of food waste in Sragen Regency reached 74.30% of the total waste composition. The high population growth and the phenomenon of panic buying during the COVID-19 pandemic are the main causes of the high percentage of food loss and waste (FLW) in Sragen Regency (Saputro et al.,

2023). Panic buying in the household sector has been identified as a significant contributor to the elevated levels of food waste observed during the pandemic (Amicarelli et al., 2021; Ben Hassen et al., 2020; Iranmanesh et al., 2022; Laila et al., 2022; Liu et al., 2021; Pappalardo et al., 2020; Pires et al., 2021; Roe et al., 2021; Scacchi et al., 2021; Vidal-Mones et al., 2021).

Additionally, high FLW is influenced by consumers' misreading of expiry dates and storage issues (Babbitt et al., 2021; Falasconi et al., 2019; Hebrok & Heidenstrøm, 2019; Liegeard & Manning, 2020; Martindale, 2017; Principato et al., 2022; Romani et al., 2018; Stancu et al., 2016; Szakos et al., 2021), stock management (Amato et al., 2021; Amicarelli et al., 2021; Bender et al., 2022; Berjan et al., 2022; Cosgrove et al., 2021; Laila et al., 2022; Scacchi et al., 2021; Vittuari et al., 2021), purchase errors, and excessive purchases (Boulet et al., 2021; Falasconi et al., 2019; Filho et al., 2021; Janssens et al., 2019; Kandemir et al., 2022; Lahath et al., 2021; Le Borgne et al., 2018; Principato et al., 2022; Romani et al., 2018; Tsalis et al., 2021). Furthermore, the wholesale and retail sectors contribute to FLW due to the short shelf life of products, with an estimated 1% to 2% of food items marketed being discarded (Astria et al., 2023; Rosenlund et al., 2020; Katajajuuri et al., 2014).

Silvennoinen et al. (2015) also highlight the considerable FLW resulting from food service activities, particularly during the consumption stage, which generates surplus food waste. The food service sector plays a pivotal role in managing food waste due to the substantial quantities discarded during preparation and serving stages (Betz et al., 2015).

Reducing the impact of food loss and waste (FLW) on the environment can be achieved by promoting the implementation of a circular economy. The significance of the circular economy is evident in various studies that identify factors influencing its success (Aloini et al., 2020; Rizos et al., 2016; Sandvik & Stubbs, 2019; Urbinati et al., 2021). The fundamental principle of the circular economy is to minimize negative externalities by transforming waste generated from consumption and production into valuable and useful products (Coletta et al., 2021). This approach is grounded in the 3R concept (reduce, reuse, recycle) and aims to optimize production levels, reduce environmental exploitation, minimize pollution, and lower emission and waste levels through sustainable methods (Strielkowski, 2016).

The circular economy surpasses the linear economy (production-consumption-disposal) by maximizing the potential of each material and introducing new value to obsolete materials through eco-friendly innovations (Marino & Pariso, 2016). It mitigates environmental damage by eliminating waste and can decrease waste generation through environmentally friendly product designs and a closed-loop system (De Angelis, 2018). In the long term, producing resources from waste can reduce emissions by 70%, increase labor demand by 4%, and significantly decrease waste volumes (Stahel, 2016). This approach enhances environmental resilience, improves community welfare, reduces ecological damage, and fosters new product value creation, all while promoting green economic growth aligned with sustainable development goals (Lakshmi et al., 2020).

Moreover, the recovery of waste resources can provide substantial value by boosting investment in the waste processing industry (Tomić & Schneider, 2020). The success of circularity efforts, however, depends on various economic factors, including procurement costs and market price fluctuations (de Jesus & Mendonça, 2018; Esposito et al., 2017; Ghisellini et al., 2016; Linder & Williander, 2017; Urbinati et al., 2021). Circularity efforts in the economy are proposed as a systemic change to maintain production within industrial ecosystems, recreating and sustaining value in the long term (Lopes de Sousa Jabbour et al., 2019; Stahel, 2016). This impacts resource use and waste generation (Bocken et al., 2016; Geissdoerfer, Vladimirova, et al., 2018).

Collaboration is crucial for the success of the circular economy, as it facilitates the creation of circular value and reduces financial, environmental, and social inequalities (Bertassini et al., 2021; Blomsma, 2018; Brown et al., 2021; Geissdoerfer, Morioka, et al., 2018; Heath, 2016; Weetman, 2016). Despite these benefits, the implementation of the circular economy faces challenges, including ambiguous regulations, insufficient socialization and education on environmental resilience, and a lack of market demand due to profit-focused orientations (Zhang et al., 2019).

To optimize the application of the circular economy in reducing the impact of food loss and waste (FLW), it is essential to foster stakeholder synergy to protect and manage the environment in support of sustainable development (Hermanu, 2022). Freeman (1984) introduced the stakeholder

analysis approach to examine the relationships between stakeholders who influence and are influenced by a policy. Mitchell et al. (1997) further elucidated this approach, emphasizing three aspects that influence decision-making and policy formation: power, legitimacy, and urgency. As posited by Freeman and Dmytriyev (2017), the foundation of entity management lies in establishing relationships and generating value for all stakeholders. Stakeholder theory asserts that all stakeholders are interdependent and interconnected. The quality and effectiveness of programs aimed at achieving sustainable development are significantly influenced by stakeholder linkages (Putra & Raharjo, 2023).

The Hexahelix approach was chosen for its suitability in analyzing the importance and influence (influence-dependence) of each factor and actor on FLW management efforts, supporting the implementation of a circular economy in Sragen Regency. The Hexahelix concept integrates the Quadruple Helix (QH) and Quintuple Helix Innovation (QHI) models, aiming to achieve synergistic relationships among constituent elements. The QH and QHI frameworks analyze the roles, nature, and dynamics of social-ecological cooperative factual ecosystems (Carayannis et al., 2021). Essentially, the concept or model of collaboration is based on cooperation between two or more parties, with each party assuming responsibility for all processes necessary to achieve the set goals. The Hexahelix collaboration concept can be employed to describe the intricacies of processes, objectives, and challenges, facilitating the convergence of actors in multi-sector development (Kagungan et al., 2023).

Identifying the key variables (factors) and stakeholders (actors) is essential for developing a strategy to accelerate the management of food loss and waste (FLW) and facilitate the implementation of a circular economy in Sragen Regency. In light of the urgent need for this research, the study's objectives are as follows: (1) To identify the efforts made to optimize FLW management to support the implementation of a circular economy in Sragen Regency; (2) To determine the influence of variables in accelerating FLW management to support the implementation of a circular economy in Sragen Regency; and (3) To analyze stakeholder synergy in accelerating FLW management to support the implementation of a circular economy in Sragen Regency. The findings of this study are expected to provide a comprehensive model or strategic framework for accelerating FLW management, thereby supporting the implementation of a circular economy in Sragen Regency.

2. RESEARCH METHODS

This research employs a mixed-methods approach, integrating qualitative and quantitative approach, to address the formulated problem set. The use of mixed methods enables the collection of comprehensive, valid, reliable, and objective data (Azhari et al., 2023). Qualitative data collection techniques include triangulation of data sources through interviews, observations, and documentation, while quantitative data collection is conducted using questionnaires. Qualitative data analysis in this study utilizes the Miles & Huberman interactive method, which involves data reduction, data display, and conclusion drawing or verification. This method facilitates the description of strategies to enhance the management of food loss and waste (FLW) and support the implementation of a circular economy in Sragen Regency.

Quantitative data analysis employs the prospective method of sustainability context analysis to identify the "actor-factor" linkage, using the MICMAC and MACTOR methods developed by Godet in 1999. The MICMAC method, based on analytical thinking and a systematic approach to problem-solving (Fauzi, 2019), is used for mapping analysis and determining core variables (Sukwika, 2021). Previous studies by Nazarko et al. (2017) and Ariyani et al. (2019) have also employed the MICMAC method to identify planning variables for programs.

The MICMAC method begins with problem definition, followed by the identification of both internal and external variables. It involves analyzing the relationships between variables, with weightings assigned based on their degrees of mobility and dependency. The method establishes three principles for data analysis: (1) Identification of influential and dependent variables; (2) mapping the relationships and relevance between variables; and (3) explaining the causal chain of a system. The objective of the MICMAC analysis is to identify the core variables that influence the

acceleration of FLW management, thereby facilitating the implementation of a circular economy in Sragen Regency

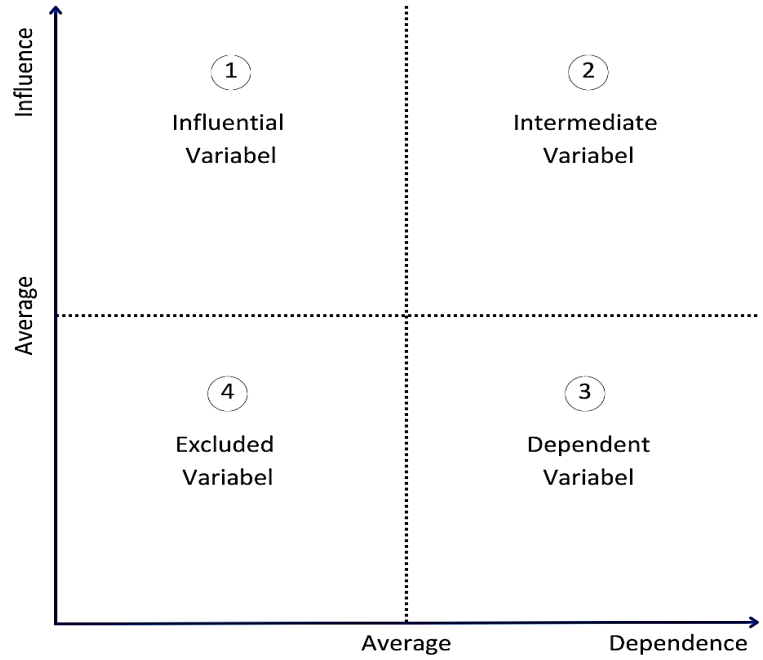


Figure 1. MICMAC Variable Quadrant Distribution Map
Source: Ardiansyah et al. (2022)

The determination of each variable set in the MICMAC analysis is based on a synthesis of findings from the research literature, including studies by Pilone et al. (2023), Skalli et al. (2023), and Schrank et al. (2023), as well as preliminary observations and interviews with relevant informants (academics, business people, community/society, government, media, and NGOs). In this study, several strategic variables were identified and classified into four different quadrants according to their degree of importance, as listed in Table 1. The results of the MICMAC variable analysis can serve as a foundation or reference point for determining the influence of each stakeholder on one another in the MACTOR analysis.

Table 1. MICMAC Variables

No	Variables	Source
1.	Location factor (Environment)	Filimonau & Sulyok (2021)
2.	Cultural factors (Social)	Filimonau & Sulyok (2021)
3.	Effectiveness of Regulation Implementation (Environment)	Sukwika (2021)
4.	Financial Factors (Economy)	De Jesus & Mendonça (2018)
5.	Community-scale (Institutional)	Joshi & Visvanathan (2019)
6.	The scale of production (Economy)	Fujii & Kondo (2018)
7.	Waste prevention (Institutional)	Fujii & Kondo (2018)
8.	Food waste recycling (Economy)	Fujii & Kondo (2018); Giordano et al. (2019)
9.	Food waste treatment cost (Economic)	Julianelli et al. (2020); Urbinati et al. (2021); Zhu et al. (2020)
10.	Infrastructure and Facilities (Facilities)	Raj et al. (2020)
11.	Environmental Quality (Environment)	Ardiansyah et al. (2022)
12.	Stakeholder relationships (Institutional)	Aloini et al. (2020); Ghinoi et al. (2020); Grafström & Aasma (2021); Sehnem et al. (2019); Urbinati et al. (2021)

No	Variables	Source
13.	Awareness (Social)	Ananno et al., (2021); Kirchherr et al. (2018); Masi et al. (2017); Rizos et al. (2016); Sehnem (2019); Todeschini et al. (2017)
14.	Knowledge and Training (Social)	Aloini et al. (2020); Rizos et al. (2016); Sehnem (2019)
15.	Community attitude (Social)	Diaz-Ruiz et al. (2018); Halder et al. (2016); Srijuntrapun (2018)

Source: Previous research, processed (2024)

In addition to MICMAC, another method used to analyze quantitative data is MACTOR. MACTOR operates on the concept of inter-actor influence, allowing it to provide insights into the relative strength among actors or stakeholders by examining similarities and differences in the problems and goals they aim to achieve. In MACTOR, "actors" refer to entities positioned within the studied system that exert influence over outcomes, whether directly or indirectly, through their impact on other actors (Fauzi, 2019). The identification of these actors is informed by the results of the MICMAC strategic variables analysis (Nopriani et al., 2022). The MACTOR framework adheres to several guiding principles: (1) Construction of a table detailing "actors' strategies"; (2) Identification of strategic issues and objectives; (3) Objective mapping of actors' positions in relation to the pros and cons of goals; (4) Determination of the priority of actor goals; (5) Analysis of the balance of power among actors; (6) Integration of balance of power analysis regarding convergence and divergence; and (7) Formulation of pivotal questions for reconstruction.

In this study, the MACTOR technique is employed to discern the synergistic and interactive relationships between actors influencing the acceleration of food loss and waste (FLW) management, thereby supporting the implementation of a circular economy in Sragen Regency. Stakeholders in MACTOR are categorized into six distinct groups: academicians, businesses, communities, governmental bodies, media, and non-governmental organizations (NGOs) (Zakaria et al., 2019). The Hexahelix method (ABCGM + NGO) was utilized to identify these stakeholders, drawing upon findings from the MICMAC analysis and incorporating input from stakeholders (academicians, business professionals, community members, government officials, media representatives, and NGOs). This methodological approach facilitated the identification of stakeholders pivotal to driving efforts in FLW management to bolster the circular economy implementation in Sragen Regency. These stakeholders are detailed in Table 2.

Table 2. Actors (Stakeholders) MACTOR

No	Hexahelix Classification	Actors (Stakeholders)
1.	Academician	Universitas Negeri Semarang
2.	Business	Business Actors (tofu industry and sugar factory)
3.	Community	Si Repi (Resik Nguripi) Waste Bank
4.	Community	Kecik (Karang Becik) Waste Bank
5.	Government	Environmental Agency (DLH) of Sragen Regency
6.	Media	PT Joglosemar Media Sejahtera
7.	Non Governmental Organization	Family Welfare Empowerment (PKK)

Source: Research observation based on Hexahelix approach, processed (2024)

This research utilizes MICMAC and MACTOR applications, developed by François Bourse and Michel Godet, known as "Strategic Foresight Software." Qualitative data obtained through triangulation of methods is converted into Matrix Direct Influence (MDI) data, serving as primary information for implementing quantitative methods via MICMAC and MACTOR analyses. The determination of MDI in MICMAC and MACTOR analysis relies on variables agreed upon by stakeholders identified through the Hexahelix Analysis Approach (academics, business professionals, community, government, media, and NGOs). Therefore, the identification of 15 variables and 7 stakeholders not only draws on prior research and the Hexahelix Analysis Approach,

but also reflects stakeholder consensus on variable relevance and stakeholder importance, as evidenced in the MDI Data Matrix.

3. RESULTS AND DISCUSSION

3.1. Efforts Made to Optimize Food Loss and Waste Management to Support the Implementation of Circular Economy

Data illustrating the application of the circular economy in Sragen Regency can be derived from the annual waste recycling figures (tons/year) and recycling rates (%) published by the Ministry of Environment and Forestry on the National Waste Management Information System (SIPSN) platform. In 2023, Sragen Regency recycled only 20,204.08 tons of waste, a figure lower than that of Banyumas, Wonogiri, Semarang, and Temanggung Regencies, despite generating less waste. Furthermore, Sragen Regency's recycling rate stood at a modest 25.34%, lower than Wonogiri Regency's 38.89%, underscoring inadequate management and utilization of waste, particularly in advancing the circular economy agenda.

To mitigate waste generation and enhance waste management practices, the Sragen Regency Government enacted the 2017 Sragen Regency Regional Regulation on Environmental Protection and Management. This legislation mandates the management of various waste types to safeguard a livable environment for all residents. Of particular urgency is the management of organic waste originating from commercial and residential activities, including restaurants, offices, businesses, apartments, and dormitories, where food waste constitutes a significant portion of the organic waste stream in Sragen Regency.The regulation imposes compliance obligations on all businesses, including medium and large industries like the tofu processing sector. Tofu production waste, known for its high Total Suspended Solids (TSS), Chemical Oxygen Demand (COD), and Biological Oxygen Demand (BOD), poses ecological risks to Sragen Regency's aquatic ecosystems (Martia & Fatoni, 2020). Efforts to mitigate these impacts involve advanced processing of tofu production waste to produce economically viable products such as liquid organic fertilizer, biogas, Nata de Soya, tempe gembus, and tofu pulp chips (Cahyani et al., 2021).

Similarly, the Sugar Factory (PG) Mojo, a longstanding producer of White Crystal Sugar (GKP) and Refined Crystal Sugar (GKR) in Sragen Regency since 1883, adheres to stringent environmental regulations. PG Mojo converts sugarcane milling waste into liquid organic fertilizer prior to discharge into the downstream Bengawan Solo River. The factory also conducts regular waste analyses in collaboration with relevant authorities and holds a Liquid Waste Disposal Permit (IPCL) certification. Moreover, the inauguration of the Modern Rice Milling Plant (MRMP) in Masaran District, Sragen Regency in 2023, supported Bulog's efforts to manage Harvested Dry Grain (GKP) in collaboration with local farmers. The MRMP significantly enhances Bulog's capacity to store and utilize GKP until the next harvest cycle, thereby ensuring the sale of entire harvests. This initiative aligns with the government's strategy to achieve national food self-sufficiency by minimizing food loss, particularly GKP, in agriculturally productive regions.

The Independent Sugarcane Agroforestry Program (ATM), initiated by Perum Perhutani in 2022, has significantly contributed to reducing food loss within the sugarcane plantation sector in Sragen Regency. This program fosters collaborative partnerships between Forest Village Community Institutions (LMDH) and the sugar processing industry, aiming to ensure the purchase and processing of all sugarcane plantation products into White Crystal Sugar (GKP) and Refined Crystal Sugar (GKR). Additionally, efforts to minimize food loss by strengthening connections between producers and trade markets have been achieved through the collaboration between PT Perusahaan Perdagangan Indonesia (PPI) and the Sragen Regency Regional-Owned Business Empowerment Agency (BPUMD). This collaboration prioritizes the distribution of nine essential commodities (sembako) directly to consumers, thereby securing sales for these products.

Several other companies operating in the processing industry sector in Sragen Regency are also actively addressing food loss and waste (FLW). PT Japfa Comfeed Indonesia Tbk, for instance, provides training, socialization, funding, and infrastructure support to communities for establishing waste banks in various localities. This company has made substantial contributions to FLW

management in Sragen Regency through the establishment of two waste banks: Si Repi (Resik Nguripi) Waste Bank and Kecik (Karang Becik) Waste Bank. These initiatives aim to facilitate the management of household waste, including food waste, with the goal of reducing waste generation, promoting waste reuse, and encouraging recycling. The establishment of waste banks also empowers local communities by promoting the utilization and proper management of waste within their environment (Nisa & Saputro, 2021). This approach aligns with research highlighting the potential for waste banks to enhance community well-being (Wardany et al., 2020), increase awareness about waste management and recycling efforts, and enhance economic benefits and community welfare (Dai & Pakaya, 2019).

Moreover, waste management efforts that emphasize recycling can alleviate additional costs associated with procuring raw materials from waste resources, compared to expenses related to waste disposal fees and taxes (Budak & Ustundag, 2017; Galbreth et al., 2013). High costs associated with waste disposal fees and taxes are recognized barriers to achieving a circular economy (Bicket et al., 2014; Grafström & Aasma, 2021; Masi et al., 2017; Rizos et al., 2016; Urbinati et al., 2021).

Si Repi Waste Bank, a community-based organization, focuses specifically on managing household food waste, which is prevalent due to the high population and productivity in the Food and Beverage (F&B) sector in the area. The primary objective of Si Repi Waste Bank is to manage food waste by increasing its economic value through recycling activities. One successful initiative involves processing food waste into Liquid Organic Fertilizer (POC), which has gained traction in the market. These efforts exemplify the application of the circular economy to FLW management in Sragen Regency.

Similarly, Kecik (Karang Becik) Waste Bank also concentrates on processing household food waste. This waste bank cultivates maggots, utilizing the abundant food waste available in the local environment. Maggot cultivation results are marketed for animal feed and fish farming needs through collaborations with relevant stakeholders. In addition to maggot cultivation, Kecik Waste Bank produces liquid organic fertilizer (POC) to enhance the productivity of vegetable seeds and plants such as pumpkins, chilies, and ornamental plants, which are subsequently traded. The proceeds from these activities are accrued in the waste bank fund. The management practices of Kecik Waste Bank exemplify the circular economy concept through the processing of FLW for maggot cultivation and the production of POC raw materials.

3.2. Influence of Variables in Accelerating Food Loss and Waste (FLW) Management to Support the Implementation of Circular Economy

The findings from stakeholder interviews, observations, and documentation were translated into numerical data by referencing established variables from previous research on circular economy implementation. Variable determination involved aligning perceptions and confirming stakeholder responsibilities in managing food waste (FLW) to support circular economy initiatives in Sragen Regency. The MICMAC method was utilized to assess the influence and interdependence of these variables on accelerating FLW management efforts. However, as noted by Barati et al. (2019), while the MICMAC method identifies variables in parallel, it does not assign an overall priority value to each variable. Subsequently, the qualitative data obtained from interviews, observations, and documentation were quantified into Matrix Direct Influence (MDI) data.

These numerical values range from 0 to 3, indicating varying degrees of influence (from low to high), with the addition of "P" denoting potential future impact. It is crucial that this conversion process is conducted meticulously and comprehensively to ensure the generation of reliable and accountable data (Nopriani et al., 2022). The MDI data are detailed in Table 3. Table 3 illustrates that stakeholder relations, community scale, waste prevention, cultural factors, and location factors directly influence outcomes with moderate to strong intensity. The elevated MDI values indicate significant correlations identified through MICMAC analysis, which assesses the degree of influence or dependence of each variable (factor). Additionally, the "P" value denotes potential future impact; for instance, the cultural factor influences financial factors, while the location factor affects infrastructure and facilities.

Table 3. Identification of Matrx Direct Influence (MDI) Values

		1: SR	2: CS	3: ERI	4: FF	5: WP	6: SP	7: CF	8: FWR	9: FWTC	10: IF	11: EQ	12: LF	13: AW	14: KT	15: CA
1	Stakeholder Relations (Institutional)	0	3	3	3	3	3	3	3	3	3	3	3	3	3	3
2	Community Scale (Institutional)	3	0	3	3	3	3	3	3	3	3	3	3	3	3	3
3	Effectiveness of Regulation Implementation (Environment)	1	2	0	3	2	3	2	3	3	2	3	1	3	3	3
4	Financial Factors (Economy)	1	1	2	0	0	2	0	1	1	0	0	3	0	1	0
5	Waste Prevention (Institutional)	3	3	3	2	0	3	3	3	3	2	3	2	3	3	3
6	Scale of Production (Economic)	1	1	2	2	2	0	1	2	2	2	3	2	1	1	2
7	Cultural Factors (Social)	3	3	3	P	3	3	0	3	3	3	3	3	3	3	3
8	Food Waste Recycling (Economic)	1	2	3	2	2	3	2	0	3	2	3	2	3	1	3
9	Food Waste Treatment Cost (Economic)	1	1	2	2	1	2	2	2	0	0	1	1	2	0	2
10	Infrastructure and Facilities (Facilities)	1	1	2	2	0	1	1	1	2	0	2	1	1	1	1
11	Environmental Quality (Environment)	1	1	2	2	0	2	2	2	2	0	0	1	2	0	1
12	Location Factor (Environment)	3	3	3	3	3	3	3	3	3	P	3	0	3	3	3
13	Awareness (Social)	1	2	3	2	2	3	2	3	2	2	3	2	0	3	3
14	Knowledge and Training (Social)	0	2	1	0	0	1	1	1	2	1	1	1	2	0	1
15	Community Attitude (Social)	1	1	2	0	1	1	1	2	1	0	2	1	2	1	0

Source: Author's calculation based on research data, processed (2024)

These findings align with field observations highlighting that adequate financial resources can bolster community engagement in optimizing FLW management. Access to various benefits acts as a catalyst for heightened community participation in the program, influencing cultural norms by emphasizing the importance of food waste management and the economic value of recycling food waste. The MDI data facilitate the mapping of variables into four distinct quadrants, as illustrated in Figure 2. Concurrently, the mapping analysis results for each variable are depicted in Figure 3.

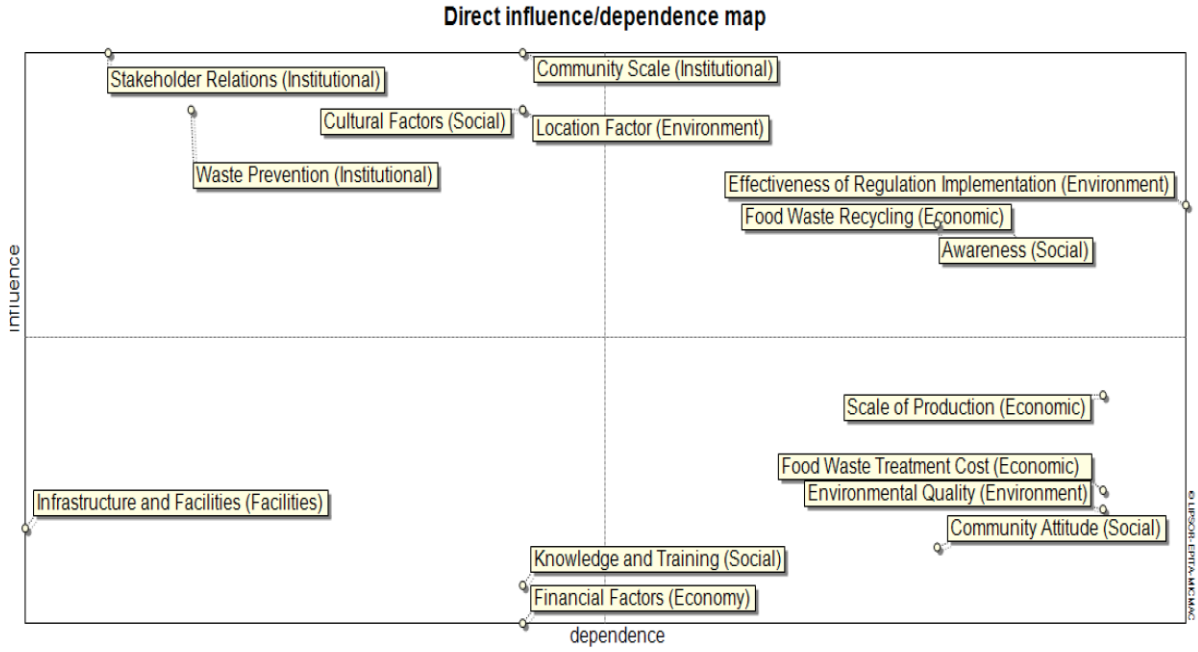


Figure 2. Direct Variable Influence and Dependency Quadrant
Source: MICMAC analysis, processed (2024)

Figure 2 illustrates the mapping of variables into the input, stake, output, and excluded quadrants. Quadrant I highlights fundamental variables (inputs) crucial for accelerating food loss and waste (FLW) management to support the circular economy in Sragen Regency. These variables are categorized based on their degree of influence, with stakeholder relations, waste prevention, community scale, location factors, and cultural factors exerting the greatest impact. Stakeholder relations, in particular, play a significant role due to stakeholders' pivotal involvement in shaping regulations and the regulatory environment, which are essential for enhancing FLW management. Legislative frameworks, waste management directives, and governmental support standards are pivotal in influencing institutional stakeholders (Atasu et al., 2013; den Hollander et al., 2017; Khor et al., 2016; Niero et al., 2017; Singh & Ordoñez, 2016; Zeng et al., 2017). Optimizing synergy among stakeholders represents a critical influence that spans across other quadrants, emphasizing the importance of collaborative efforts among academic institutions, businesses, communities, government bodies, media, and NGOs to accelerate FLW management and support circular economy initiatives in Sragen Regency. This approach aligns with the relative importance of each factor (influence and dependency) in achieving set objectives, consistent with theoretical frameworks proposed by Mitchell et al. (1997) and Freeman (1984), emphasizing the foundational role of stakeholder synergy in entity management.

Quadrant II of the MICMAC mapping includes variables of high importance with significant sensitivity and instability (relay variables), necessitating strategic attention to policy formulation (Elmsalmi & Hachicha, 2013). These stake variables encompass awareness, regulatory effectiveness, and recycling initiatives. Awareness, as highlighted by Lawrence et al. (2020), is pivotal in accelerating FLW management, underlining the critical role of internal motivation factors in advancing environmental education. The awareness variable critically evaluates the efficacy of regulatory implementations and recycling initiatives related to food waste. These variables are integrated with cultural factors (habits) in Quadrant I, where they exhibit varying degrees of importance and mutual interdependence. The influence of cultural habits on individual awareness towards specific goals is significant, underscoring the need to implement measures that reshape societal and individual habits concerning food management, consumption, and disposal. These efforts are essential in fostering new behaviors that promote awareness of sustainable practices in everyday life. Furthermore, effective regulatory implementations aimed at reducing upstream food waste generation, coupled with recycling initiatives that economically circulate waste downstream, are crucial strategies to manage food waste effectively and support the circular economy.

Quadrant III of the MICMAC analysis identifies outcome variables crucial for accelerating food loss and waste (FLW) management. These variables are characterized by high dependence and low influence. Specifically, variables in Quadrant III include production scale, food waste processing costs, environmental quality, and community attitudes. Stakeholders' enactment of regulations and policies aimed at preventing food waste can significantly influence these variables (Rhofita & Russo, 2019; Febrianto et al., 2016; (Hasibuan, 2016; Saptenno et al., 2022). For instance, regulations such as Sragen Regency Regional Regulation Number 5 of 2017 on Environmental Protection and Management, Sragen Regent Regulation Number 72 of 2023 on Household Waste and Similar Waste Management, and other related policies exemplify the proactive role of the Sragen Regency Government in addressing substantial FLW proportions within the region (Sragen Regency Government, 2017; 2023; 2018; 2021). In Quadrant IV of the MICMAC analysis, variables are categorized as independent (excluded) variables with minimal influence and dependence on the acceleration of FLW management. These variables include infrastructure and facilities, knowledge and training, and financial factors. Financial factors are supplementary and exhibit low influence, particularly concerning infrastructure, facilities, and knowledge and training variables. The interrelationships among these variables are depicted in Figure 3, highlighting their relative positions and interactions within the FLW management framework.

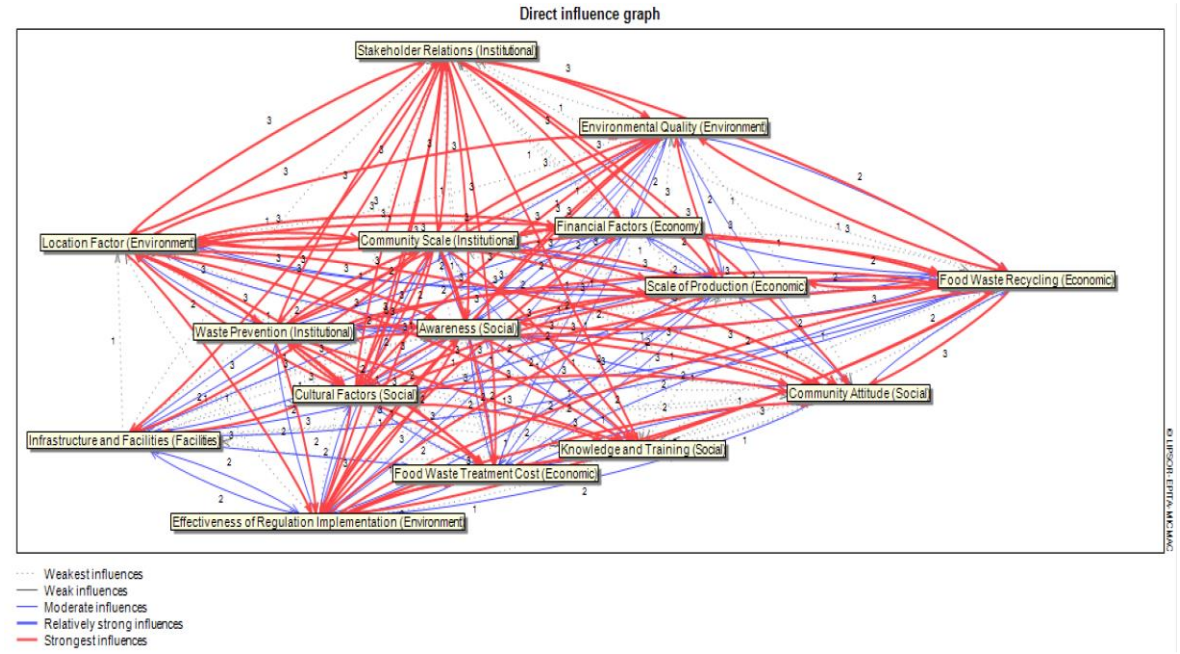


Figure 3. Direct Influence Relationship Between Variables
Source: MICMAC analysis, processed (2024)

To validate the accuracy of MDI data, a stability testing process is conducted, involving an assessment of indirect impacts on each variable (Sukwika, 2021). This testing is detailed in the Matrix Indirect Influence (MII) through the MDI transitivity process (Nopriani et al., 2022). The outcomes of the analysis of indirect effects indicate high stability of MDI data, characterized by consistent variable mappings across all quadrants. Conversely, if there were shifts in variable mappings across quadrants, data stability would be considered low. The results of the stability testing of MDI data are illustrated in Figure 4.

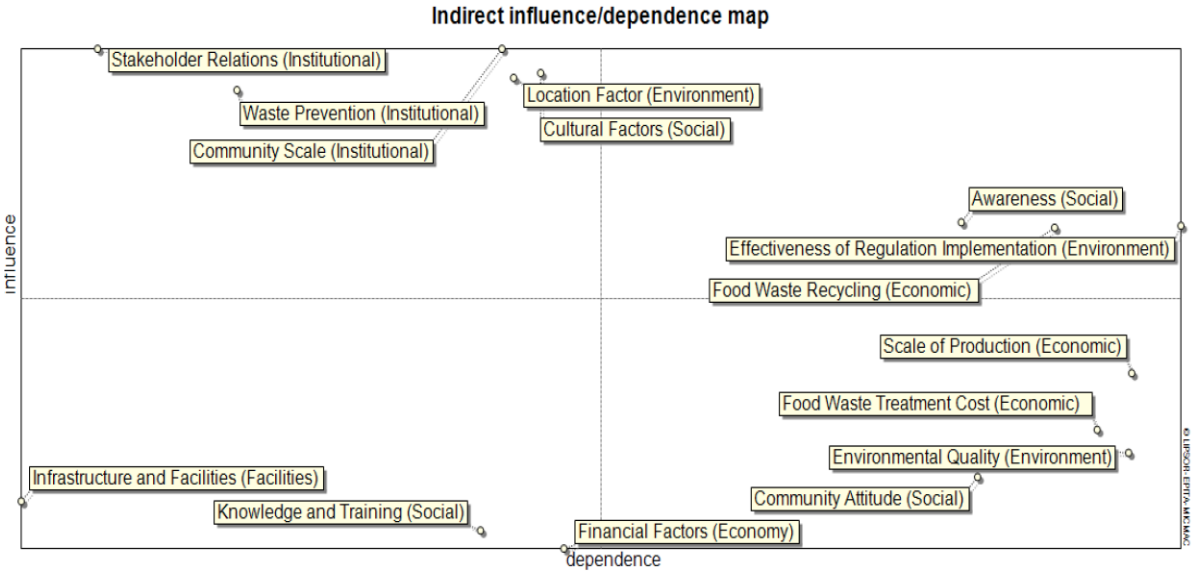


Figure 4. Quadrant of Influence and Dependency of Indirect Variables
Source: MICMAC analysis, processed (2024)

A comparison between the direct influence and dependency analysis (Figure 2) and the indirect influence and dependency analysis (Figure 4) indicates that the collected data can be classified as stable, evidenced by the absence of variable shifts across quadrants. The Matrix Indirect Influence (MII) analysis in quadrant I includes variables such as stakeholder relations (Institutional), waste

prevention (Institutional), location factors (Environmental), cultural factors (Social), and community scale (Institutional). Quadrant II comprises variables like food waste recycling (Economic), awareness (Social), and the effectiveness of regulation implementation (Environmental). Quadrant III encompasses variables related to production scale (Economic), food waste treatment costs (Economic), environmental quality (Environmental), and community attitudes (Social). In contrast, quadrant IV includes variables such as infrastructure and facilities (Facility), knowledge and training (Social), and financial factors (Economic).

The analysis results lead to two conclusions: (1) The collected data demonstrates high stability; and (2) The sensitivity of each variable is classified as low. To visually illustrate the interrelationships among variables in terms of influence and indirect dependence, linkage lines are established, as depicted in Figure 5.

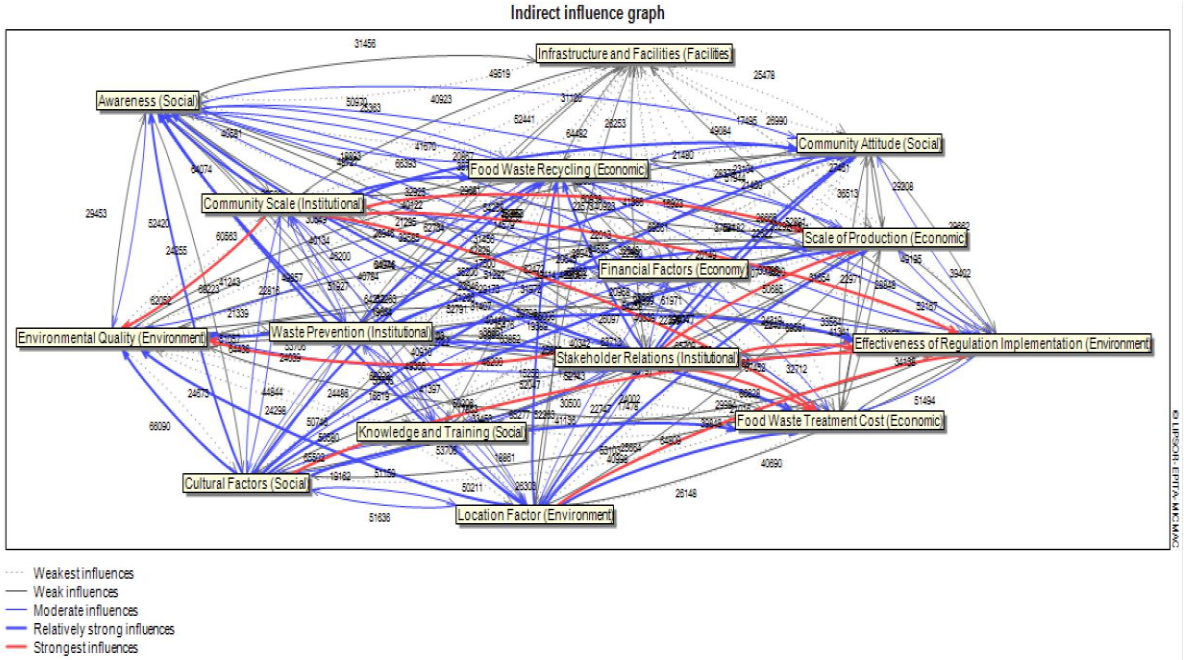


Figure 5. Indirect Influence Relationship Between Variables
Source: MICMAC analysis, processed (2024)

The MII and MPII data presented in Table 4 and Table 5 illustrate the numerical magnitude of direct and indirect influence and dependence among variables. Higher numerical values indicate the intensity of direct and indirect influence that each variable exerts on others (Sukwika, 2021). According to these data, stakeholder relations and community scale exhibit the strongest direct and indirect influence on the variable of regulatory implementation effectiveness. This underscores the pivotal role of stakeholder collaboration in both shaping and enforcing regulations and policies. Moreover, the extensive reach of community initiatives, such as waste banks, enhances the application and adherence to these regulations within the community. The scalability of community efforts also enhances the effectiveness and efficiency of training and empowerment programs aimed at managing food waste and promoting circular economy principles.

The substantial membership and scalability of community initiatives serve as indicators of the urgency and significance of efforts to improve food loss and waste (FLW) management. Additionally, the MPII analysis highlights that cultural and location factors significantly influence the effectiveness of regulatory implementation. These findings are supported by research conducted by van der Werf et al. (2019), Hebrok & Boks (2017), Ilyuk (2018), Suryana & Ariani (2018), and Luna & Suryana (2022), which similarly emphasize the role of cultural and geographic contexts in optimizing regulatory frameworks. The geographic accessibility and cultural adaptability of regulations can influence the adoption of new behaviors aligned with regulatory goals. Local communities and cultural settings may adapt more readily to new practices that align with regulatory standards,

contingent upon the financial resources available to stakeholders to support and guide these behavioral changes within regulatory frameworks.

Table 4. Matrix of Indirect Influences (MII)

	1: SR	2: CS	3: ERI	4: FF	5: WP	6: SP	7: CF	8: FWR	9: FWTC	10: IF	11: EQ	12: LF	13: Aw	14: KT	15: CA
SR	42909	52791	69561	54258	46200	68307	53706	66393	67452	40923	68223	53103	64074	52263	64482
CS	42828	52872	69561	54258	46200	68307	53706	66393	67452	40923	68223	53103	64074	52263	64482
ERI	32712	40339	53200	41341	35197	52167	40998	50685	51494	31301	52047	40690	48914	39848	49195
FF	14177	17500	22971	18130	15476	22622	17863	22013	22401	13584	22700	17478	21295	17372	21460
WP	40410	49857	65660	51292	43763	64535	50746	62734	63713	38747	64436	50206	60563	49365	60938
SP	24319	29942	39402	30795	26097	38666	30500	37591	38250	23104	38661	29984	36360	29584	36513
CF	41397	51057	67161	52722	44844	66006	52107	64212	65277	39585	66090	51159	62052	50580	62472
FWR	32648	40122	52891	41366	35200	51944	40910	50588	51286	31120	51927	40342	48727	39796	49084
FWTC	21016	25883	34138	26588	22747	33564	26303	32604	33063	20149	33453	26148	31407	25664	31654
IF	16923	20867	27461	21480	18253	26990	21266	26253	26666	16167	26946	20958	25363	20645	25478
EQ	19664	24255	31972	24946	21339	31456	24673	30549	30989	18893	31343	24486	29453	24039	29681
LF	41136	50736	66828	52143	44421	65700	51636	63852	64809	39414	65502	51135	61620	50211	61971
Aw	32925	40581	53387	41670	35500	52441	41243	50970	51853	31456	52420	40784	49280	40134	49519
KT	15256	18743	24733	19389	16519	24309	19162	23646	24002	14579	24298	18861	22816	18606	22990
CA	18280	22573	29662	23292	19821	29208	23017	28378	28848	17495	29173	22614	27429	22358	27609

Source: Author's calculation based on research data, processed (2024)

Based on the MICMAC analysis, it is evident that stakeholder relations and community scale exert the greatest influence on other variables, while knowledge and training, along with financial factors, exhibit the least influence. Following the receipt of influence, variables such as cultural factors, location factors, awareness, and community attitudes have seen an increase in their rankings. In contrast, variables like waste prevention, effectiveness of regulation implementation, and infrastructure and facilities have decreased in their influence rankings. This indicates that these latter variables are highly dependent on the influence of others to achieve the same objectives, as evidenced by their shifting ranks due to varying degrees of influence.

Table 5. Matrix of Potential Indirect Influences (MPII)

	1: SR	2: CS	3: ERI	4: FF	5: WP	6: SP	7: CF	8: FWR	9: FWTC	10: IF	11: EQ	12: LF	13: Aw	14: KT	15: CA
SR	43674	53655	70929	61089	46659	69513	54399	67383	68649	47133	69213	54336	64857	53127	65265
CS	43593	53736	70929	61089	46659	69513	54399	67383	68649	47133	69213	54336	64857	53127	65265
ERI	33222	40897	54133	46453	35428	52941	41418	51300	52295	35834	52695	41530	49376	40409	49660
FF	14492	17869	23538	20428	15701	23168	18163	22463	22881	15798	23084	18021	21649	17732	21805
WP	41097	50625	66893	57697	44147	65600	51352	63601	64790	44537	65324	51313	61241	50136	61619
SP	24739	30413	40167	34560	26325	39344	30857	38131	38895	26641	39171	30704	36765	30052	36915
CF	43593	53655	70929	61089	46659	69513	54480	67383	68649	47133	69213	54336	64857	53127	65265
FWR	33200	40740	53887	46481	35506	52814	41390	51290	52144	35833	52623	41254	49267	40414	49624
FWTC	21388	26303	34795	30011	22978	34131	26654	33081	33657	23152	33963	26712	31800	26087	32050
IF	17211	21188	27983	24132	18406	27440	21515	26616	27116	18597	27312	21432	25642	20966	25757
EQ	20024	24663	32605	28162	21570	32005	25018	31014	31565	21728	31841	25026	29840	24450	30071
LF	43593	53655	70929	61089	46659	69513	54399	67383	68649	47133	69213	54417	64857	53127	65265
Aw	33480	41202	54389	46857	35806	53314	41726	51675	52717	36187	53122	41699	49823	40755	50062
KT	15520	19040	25207	21774	16672	24729	19393	23985	24410	16805	24628	19299	23077	18903	23251
CA	18574	22900	30196	26109	19974	29676	23260	28747	29298	20156	29527	23118	27702	22685	27882

Source: Author's calculation based on research data, processed (2024)

Conversely, variables such as effectiveness of regulation implementation and production scale have become the most dependent variables, while infrastructure and facilities, stakeholder relations, and waste prevention exhibit the lowest degree of dependence. After receiving influence, environmental quality, public attitudes, financial factors, cultural factors, and location factors have all seen an increase in their dependence rankings. On the other hand, variables like environmental treatment costs, awareness, and community scale have experienced a decline in their dependence rankings due to receiving similar influences. This shift in rankings illustrates the varying degrees of dependence that each variable has on the influence exerted by others within the system.

3.3. *Stakeholder Synergy in Accelerating Food Loss and Waste (FLW) Management to Support the Implementation of Circular Economy in Sragen Regency*

The application of MICMAC in variable analysis necessitates complementing it with MACTOR analysis to determine the influence and interdependence of stakeholders (actors) who function as regulators, implementers, and evaluators of FLW management acceleration, aimed at facilitating the implementation of a circular economy in Sragen Regency. Stakeholders play a pivotal role as primary catalysts for policy formulation that impacts key program variables (Omran et al., 2014). Understanding the dynamics, interests, interactions, and initiatives of stakeholders is critical within the context of sustainable development (Bryant & Bousbaine, 2014). Data collected from interviews with relevant stakeholders will be quantified into numerical values using the MDI, ranging from 0 to 4 (indicating low to high influence). A higher MDI value signifies greater influence of one actor over others, and vice versa. Detailed MDI and MDII values can be found in Table 6 and Table 7.

Table 6. Matrix of Direct Influences (MDI)

MDI	UNNES	BA	RWB	KWB	EA	JMS	FWE
Universitas Negeri Semarang	0	2	3	3	2	0	2
Business Actors (Tofu Industry & Sugar Factory)	3	0	2	2	2	0	3
Si Repi (Resik Nguripi) Waste Bank	3	4	0	4	4	4	4
Kecik (Karang Becik) Waste Bank	3	4	4	0	4	4	4
Environment Agency (DLH)	4	4	4	4	0	4	4
PT Joglosemar Media Sejahtera	0	0	1	1	0	0	3
Family Welfare Empowerment (PKK)	3	4	2	2	2	0	0

Source: Author's calculation based on research data, processed (2024)

The Environmental Agency (DLH) emerges as the most influential stakeholder in the efforts to manage food loss and waste (FLW) and support the implementation of a circular economy in Sragen Regency, as evidenced by the MDII Matrix's Li column. This aligns with DLH's role as a government entity tasked with overseeing waste and environmental management, including the integrated collection, transportation, processing, and disposal of waste in a systematic manner (Sofianto et al., 2024). The responsibilities of DLH, outlined in the 2016 Regent Regulation of Sragen Regency on the Duties and Functions and Work Procedures of the Environmental Agency, include providing necessary facilities and infrastructure to facilitate collaborative efforts among stakeholders (Saputra et al., 2022).

Table 7. Matrix of Direct and Indirect Influences (MDII)

MDII	UNNES	BA	RWB	KWB	EA	JMS	FWE	Li
Universitas Negeri Semarang	12	12	12	12	12	8	12	68
Business Actors (Tofu Industry & Sugar Factory)	12	11	11	11	10	6	11	61
Si Repi (Resik Nguripi) Waste Bank	16	18	16	16	14	12	20	96
Kecik (Karang Becik) Waste Bank	16	18	16	16	14	12	20	96
Environment Agency (DLH)	16	18	16	16	14	12	20	98
PT Joglosemar Media Sejahtera	5	5	4	4	4	2	5	27
Family Welfare Empowerment (PKK)	12	12	11	11	10	6	11	62
Net dependance	77	83	70	70	64	56	88	508

Source: Author's calculation based on research data, processed (2024)

DLH also ensures the effectiveness and optimization of environmental and waste management regulations set by local government, such as Sragen Regent Regulation Number 72 of 2023 concerning the Management of Household Waste and Waste Similar to Household Waste. This regulation emphasizes waste reduction, recycling, and reuse. DLH's presence facilitates achieving regulatory objectives through activities such as collaborating with independent waste management NGOs, private sector entities, and producers, enhancing public awareness through training and empowerment programs, improving workforce competency in waste management to support circular economy practices, initiating stakeholder partnerships, and supporting the development and implementation of effective incentive systems to minimize household waste (FLW).

These findings from the MICMAC analysis affirm that stakeholder relationships and waste prevention are pivotal variables for accelerating FLW management. DLH's implementation and enforcement of government policies contribute significantly to enhancing stakeholder synergy and FLW prevention efforts. Conversely, PT Joglosemar Media Sejahtera (media) exhibits the lowest influence among stakeholders, primarily responsible for disseminating and commercializing information related to FLW management acceleration efforts. However, the role of media remains crucial in raising public awareness and fostering behavioral changes supportive of circular economy practices.

The PKK (Family Empowerment and Welfare NGO) is highlighted as having the highest dependency among stakeholders. PKK's mission focuses on community development to enhance family welfare (Aini & Ginting, 2023), assuming roles in implementing and evaluating government policies directed by DLH in FLW management. Understanding PKK's dependency on other stakeholders is crucial for assessing its involvement in policy implementation and regulatory compliance. Similarly, business actors demonstrate significant dependency on DLH, particularly regarding the optimization of local regulations impacting business operations in FLW management and related trade activities.

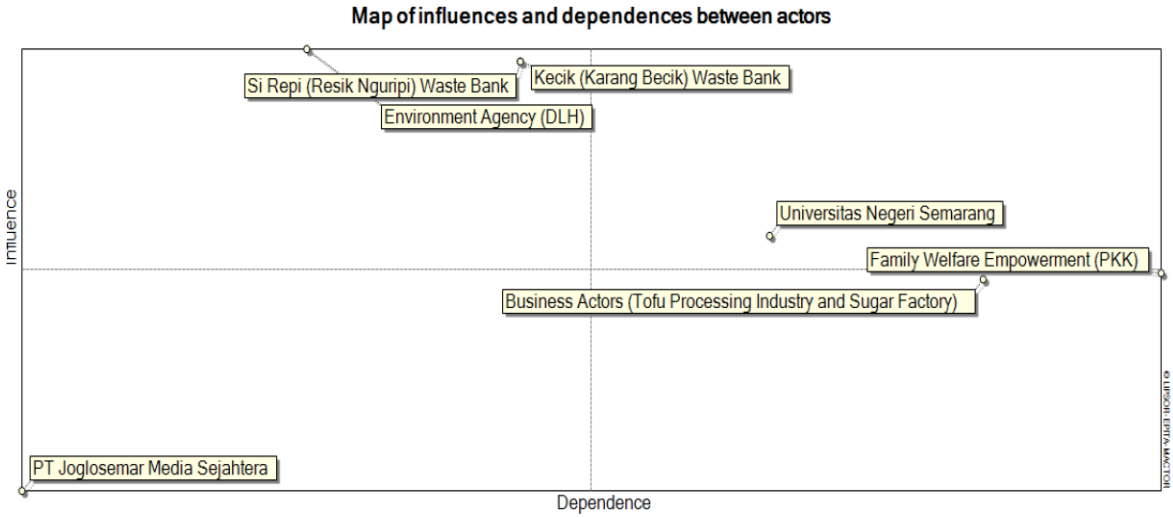


Figure 6 MACTOR Analysis Stakeholder Mapping
Source: MACTOR analysis, processed (2024)

Figure 6 illustrates the influence and dependency of stakeholders in accelerating FLW management to support the implementation of a circular economy in Sragen Regency. The figure maps stakeholders with the highest influence, notably the Environmental Agency (government), and the Kecik Waste Bank and Si Repi Waste Bank, which are community organizations of equal influence. The high influence of the Department of Environment and Forestry (DLH) stems from its critical role and responsibility in waste management, achieved through the implementation and optimization of local government policies and regulations that affect all stakeholders in each quadrant. Meanwhile, waste banks at the community level play a crucial role in reducing waste generation in specific areas (Selomo et al., 2017). Social engineering underpins waste bank activities, educating the public about environmental protection through waste sorting. Waste banks serve as

collection points for businesses dealing with non-tradable products (Fauziah et al., 2021). Their establishment is a direct implementation of Law Number 18/2018 concerning Waste Management. Kecik Waste Bank and Si Repi Waste Bank mitigate the impact of FLW by processing food waste into Liquid Organic Fertilizer (POC) and as primary raw material in maggot cultivation. The DLH supports these efforts by providing education, training, empowerment, equipment, and plant seeds to each waste bank.

In Quadrant II, Semarang State University (academicians) evaluates government policies and regulations through research and community service activities. Academic research identifies challenges and obstacles, facilitating appropriate and targeted solutions. The necessity of academic evaluation of regulations is underscored by their occasional incompatibility in certain areas due to factors such as low community competence, poor culture, low public awareness, irregular consumption and management patterns, and inadequate equipment.

Quadrant III includes the PKK (NGOs) and businesses as stakeholders dependent on others. The PKK and business actors, as implementers and evaluators of FLW management policies set by regulators (government/DLH), are significantly impacted by these policies. The PKK requires education through training and empowerment to fulfill its role in improving community welfare. FLW management policies influence the activities of the PKK by encouraging the reduction of food waste generation and optimizing recycling efforts. Similarly, these policies impact business actors by requiring them to process food waste in alignment with FLW reduction efforts, affecting production costs and food waste treatment processes. The acceleration of FLW management in support of a circular economy significantly impacts the PKK and business actors.

In contrast, PT Joglosemar Media Sejahtera, situated in Quadrant IV, has limited influence and dependency on FLW management acceleration efforts. However, as an independent actor, it influences PKK actors and business people. The MACTOR analysis displays the maximum level of stakeholder influence (direct or indirect) through the Matrix of Maxima Direct and Indirect Influences (MMDII). The MMDII analysis results include: (1) The maximum level of stakeholder influence by adding rows (IMAXi), and (2) The maximum level of stakeholder influence by adding columns (DMAXi) (Nopriani et al., 2022). The MMDII maintains the degree of influence not found in the MDII analysis. The MMDII analysis results are presented in Table 8.

Table 8 MMDII Matrix Between Stakeholders

No	MMDII	UNNES	BA	RWB	KWB	EA	JMS	FEW	IMAXi
1	Universitas Negeri Semarang	0	3	3	3	3	3	3	18
2	Business Actors (Tofu Processing Industry and Sugar Factory)	3	0	3	3	2	2	3	16
3	Si Repi (Resik Nguripi) Waste Bank	4	4	0	4	4	4	4	24
4	Kecik (Karang Becik) Waste Bank	4	4	4	0	4	4	4	24
5	Environment Agency (DLH)	4	4	4	4	0	4	4	24
6	PT Joglosemar Media Sejahtera	3	3	2	2	2	0	3	15
7	Family Welfare Empowerment (PKK)	3	4	3	3	2	2	0	17
	DMAXi	21	22	19	19	17	19	21	138

Source: Author's calculation based on research data, processed (2024)

The MMDII matrix in Table 8 reveals that the IMAXi column identifies the Environmental Agency (DLH), Kecik Waste Bank, and Si Repi Waste Bank as the most influential stakeholders. This finding aligns with the functions, duties, and responsibilities of the DLH and waste banks in FLW management. The results of the convergence analysis (3CAA) further demonstrate a correlation between the interests of these three stakeholders. Field observations support this, indicating that collaboration among these stakeholders is closely linked to efforts to accelerate FLW management in Sragen Regency.

Conversely, the DMAXi row identifies business actors as the most influenced stakeholders (dependency). This is due to the impact of FLW management policies set by the government and implemented by the DLH, which affect the production costs of business activities. These findings are corroborated by Figure 7, which indicates that the DLH is the most competitive stakeholder in terms of its capacity to support accelerated FLW management. The Kecik Waste Bank and the Si Repi Waste Bank, while significant, are less competitive in this context. Overall, the data underscores the pivotal role of the DLH in FLW management, supported by waste banks, and highlights the significant dependency of business actors on the regulatory framework established by the government.

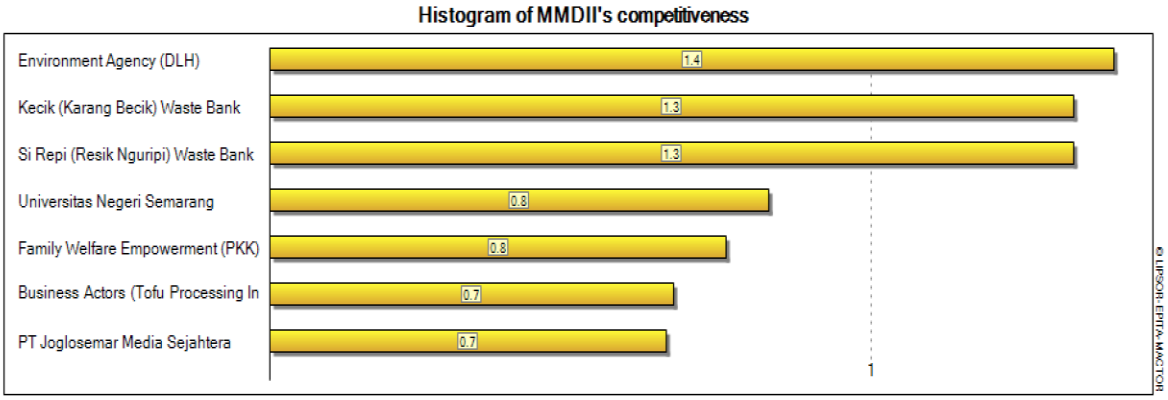


Figure 7 Histogram of Stakeholder Competitiveness Degree
Source: MACTOR analysis, processed (2024)

Based on the findings from the MICMAC analysis and the Ministry of National Development Planning (Bappenas) study on food loss and waste (FLW), five key objectives have been outlined to expedite FLW management and promote the implementation of a circular economy. These objectives are: (1) altering community behavior; (2) enhancing food system support; (3) fortifying regulations and optimizing funding; (4) leveraging FLW within the circular economy; and (5) ensuring integrated FLW data collection.

Table 9 Stakeholder Importance Matrix of Objectives (Matrix 2MAO)

2MAO	CCB	IFSS	SROF	FLWUCE	IFLWDC	Absolute Sum
Universitas Negeri Semarang	3	0	2	2	2	9
Business Actors (Tofu Industry & Sugar Factory)	0	-4	0	-2	0	6
Si Repi (Resik Nguripi) Waste Bank	4	3	3	4	3	17
Kecik (Karang Becik) Waste Bank	4	3	3	4	3	17
Environment Agency (DLH)	4	3	4	4	4	19
PT Joglosemar Media Sejahtera	2	0	0	0	2	4
Family Welfare Empowerment (PKK)	4	2	3	3	2	14
Number of Agreements	21	11	15	17	16	
Number of Disagreements	0	-4	0	-2	0	
Number of Positions	21	15	15	19	16	

Source: Author's calculation based on research data, processed (2024)

The 2MAO (Actor-Objective Matrix) data reveals the degree of stakeholder interest in the established objectives. The value in the absolute sum column reflects the level of stakeholder interest, while the number of positions row indicates the objectives most agreed upon by stakeholders. The absolute sum column indicates that the Environmental Agency (DLH) has the highest interest in accelerating FLW management efforts, whereas PT Joglosemar Media Sejahtera

shows the lowest level of interest in this initiative. The number of positions row shows that the objectives most approved by stakeholders are changes in community behavior towards FLW management and the utilization of FLW in the circular economy. These findings align with the MICMAC analysis, which indicates that community attitudes are dependent variables with a high reliance on FLW management efforts.

Table 10. Stakeholder Importance Matrix of Objectives (Matrix 3MAO)

3MAO	CCB	IFSS	SROF	FLWUCE	IFLWDC	Mobilisation
Universitas Negeri Semarang	2,5	0,0	1,7	1,7	1,7	7,5
Business Actors (Tofu Industry & Sugar Factory)	0,0	-2,7	0,0	-1,3	0,0	4,0
Si Repi (Resik Nguripi) Waste Bank	5,9	4,4	4,4	5,9	4,4	25,0
Kecik (Karang Becik) Waste Bank	5,9	4,4	4,4	5,9	4,4	25,0
Environment Agency (DLH)	6,5	4,9	6,5	6,5	6,5	30,7
PT Joglosemar Media Sejahtera	0,5	0,0	0,0	0,0	0,5	1,0
Family Welfare Empowerment (PKK)	2,7	1,3	2,0	2,0	1,3	9,4
Number of Agreements	24,0	15,0	19,0	21,9	18,8	
Number of Disagreements	0,0	-2,7	0,0	-1,3	0,0	
Number of Mobilisation	24,0	17,7	19,0	23,3	18,8	

Source: Author's calculation based on research data, processed (2024)

Furthermore, the 3MAO data supports these results by showing that DLH and the goal of changing community behavior exhibit the highest mobility values. Conversely, the number of disagreements row indicates that business actors have a negative perception of the goals related to improving food system support and utilizing FLW in the circular economy. This discordance between business actors and the objective of enhancing food system support may be due to the potential increase in the Trading and Transportation Margin (MPP). Additionally, government policies (DLH) that encourage businesses to integrate FLW into the circular economy could lead to higher production costs.

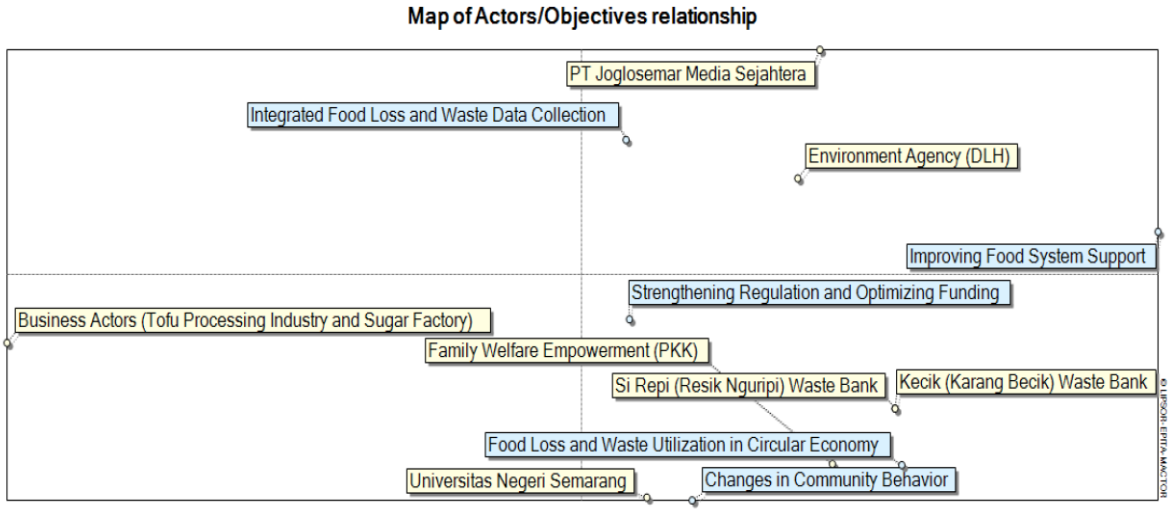
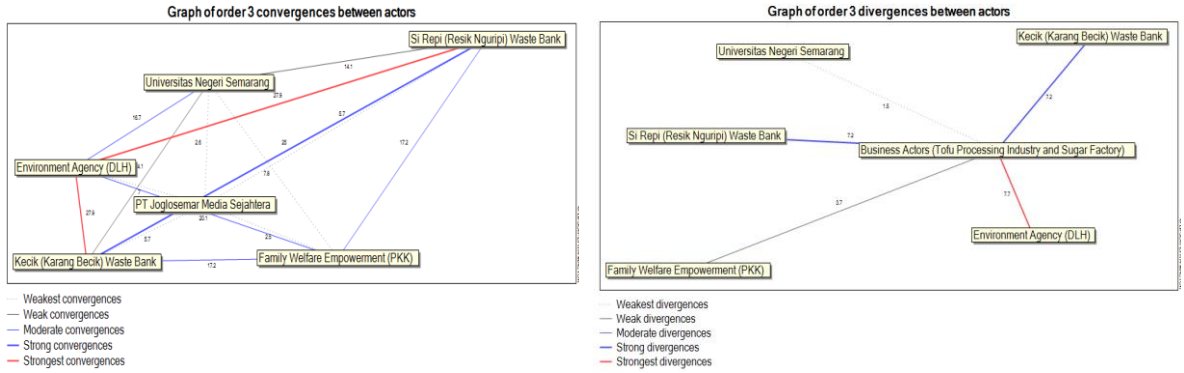


Figure 8 Degree of Influence of Each Objective Variable
Source: MACTOR analysis, processed (2024)

The impact of MPP and FLW management policies mainly affects the selling price of products traded by businesses. The interest of producers in the circular economy is influenced by various

factors, including raw material quality, market segmentation, customer behavior, product design, and distributor networks (Ghisellini et al., 2018; Larsen et al., 2018). Therefore, businesses must redesign their products, processes, and business models to align with company interests and responsibilities (Mendoza et al., 2017; Rossi et al., 2016). The relative importance and influence of each stakeholder on achieving the set goals are illustrated in Figure 8.

The collection and improvement of data pertaining to FLW, along with the enhancement of supporting food systems, represent variables that significantly influence other variables within the context of FLW management efforts aimed at supporting the implementation of a circular economy in Sragen Regency. Specifically, these influential variables (quadrant II) have the potential to impact objectives such as strengthening regulations and optimizing funding, utilizing FLW in the circular economy, and changing community behavior (quadrant III), which are dependent on the aforementioned variables.



3CAA Convergence 3DAA Divergence

Figure 9 Stakeholder Convergence and Divergence
Source: MACTOR analysis, processed (2024)

The convergence analysis depicted in Figure 9 provides insights into stakeholder interests aimed at expediting the management of food loss and waste (FLW). In this context, the collaborative efforts involving DLH, Kecik Waste Bank, and Si Repi Waste Bank foster enhanced optimization of FLW management to facilitate the implementation of a circular economy in Sragen Regency. Conversely, the divergence analysis (3DAA) highlights conflicting interests between DLH and business actors. Government policies overseen by DLH concerning FLW and household waste management influence business activities, potentially raising costs that impact product pricing. These findings underscore potential ambivalence among stakeholders, where parties may align on overarching goals but diverge on specific objectives. Addressing such divergence necessitates cultivating a collaborative environment among stakeholders, aligning their interests towards shared convergence goals and mitigating potential drivers of conflict (Fauzi, 2019).

The results of the MACTOR analysis validate Freeman's (1984) assertion on reciprocal stakeholder relationships influencing one another. The identification of the Environmental Agency (DLH), Kecik Waste Bank, and Si Repi Waste Bank as core stakeholders is rooted in their pivotal roles, influence, and responsibilities in accelerating FLW management efforts in Sragen Regency. These findings are consistent with stakeholder analysis theory proposed by Mitchell et al. (1997), which emphasizes stakeholders' power, legitimacy, and urgency in shaping policy decisions. Leveraging these attributes enables core stakeholders to effectively drive initiatives aimed at accelerating FLW management. This theoretical framework underpins collaborative efforts among stakeholders spanning academia, business, community, government, media, and NGOs within the Hexahelix model. By applying MICMAC and MACTOR methodologies, this study successfully identifies key variables and stakeholders mutually influencing the imperative to expedite FLW management, thereby facilitating the adoption of a circular economy in Sragen Regency.

4. CONCLUSIONS

This research successfully analyzed the factors and stakeholders influencing the acceleration of food loss and waste (FLW) management to support the implementation of a circular economy in Sragen Regency. Efforts to expedite FLW management have been realized through the implementation of various regulations by companies and processing industries in the region. For instance, PT Japfa Comfeed Indonesia Tbk established Kecik Waste Bank and Si Repi Waste Bank with the goal of reducing FLW to facilitate circular economy practices. These banks convert food waste into liquid organic fertilizer (POC) and raw materials for maggot cultivation, which are subsequently utilized in trade. Additionally, initiatives such as the Agroforestry Tebu Mandiri (ATM) program and the Modern Rice Milling Plant (MRMP), facilitated through government and community cooperation, aim to reduce food loss from agricultural and plantation products.

The MICMAC analysis identified stakeholder relations (institutional), waste prevention (institutional), location factors (environmental), cultural factors (social), and community scale (institutional) as core variables crucial for accelerating FLW management. In contrast, production scale (economic), food waste processing costs (economic), environmental quality (environmental), and community attitudes (social) were identified as variables exhibiting high dependence on efforts to accelerate FLW management to support the circular economy in Sragen Regency. MACTOR analysis identified the Environmental Agency (DLH), Kecik Waste Bank, and Si Repi Waste Bank as core stakeholders in accelerating FLW management. Business actors and PKK were identified as stakeholders highly dependent on these efforts. The analysis also revealed consensus among stakeholders regarding objectives such as changes in community behavior and the utilization of FLW in the circular economy. However, business actors were in disagreement regarding objectives related to improving food system support and utilizing FLW, primarily due to concerns over potential increases in production costs influenced by changes in Trading and Transportation Margins (MPP).

The findings of the MACTOR analysis underscore the interconnectedness and influence among stakeholders based on their significance. This insight can aid local governments in formulating strategic models or grand designs involving these stakeholders. The core variables identified in MICMAC serve as foundational elements for shaping missions and guiding efforts toward achieving FLW management objectives. Furthermore, MICMAC analysis highlights variables with high dependency, serving as a valuable reference for shaping regulations and policies to accelerate FLW management in Sragen Regency through the circular economy framework. Stakeholders play critical roles categorized by quadrant mapping, serving as regulators, implementers, and evaluators of policies and regulations aimed at accelerating FLW management strategies to support the circular economy in Sragen Regency.

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