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Research article

Waste Bank Funding Networks for Circular Economy in Badung Regency: A Social Network Analysis

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ABSTRACT

This study examines the structure of the waste bank funding network supporting circular economy development in Badung Regency, Indonesia. Primary data were obtained through semi-structured interviews, a focus group discussion conducted in 2026, and field observations involving stakeholders engaged in waste bank activities. Social Network Analysis (SNA) was applied to a directed adjacency matrix to assess actor positions using in-degree, out-degree, betweenness centrality, Influence Range Closeness Centrality, and eigenvector centrality, complemented by Hierarchical Cluster Analysis (HCA). The findings indicate that the Central Waste Bank occupies the most prominent structural position in the funding network, particularly through its extensive outgoing connections and intermediary role. Waste Bank Units, collectors, community groups, and other supporting actors perform complementary functions in facilitating the circulation of economic resources, whereas recycling industry actors exhibit a relatively peripheral network position. By shifting the analytical focus from communication and stakeholder coordination, which dominate much of the existing waste bank literature, to the directed structure of funding and economic-resource relationships, this study offers a distinct perspective on the institutional foundations of waste bank sustainability. The findings further suggest that institutional centrality can facilitate coordination and resource distribution but may also increase network vulnerability when alternative funding channels and market connections are limited. Accordingly, diversifying funding sources, strengthening market linkages, and improving coordination among waste bank stakeholders are essential to fostering a more resilient and inclusive circular economy system in Badung Regency.

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1. INTRODUCTION

Rapid urbanization, population growth, and increasing consumption patterns have intensified municipal solid waste management challenges in developing countries, requiring more integrated and sustainable management systems (Guerrero et al., 2013). Waste management has become a major challenge to sustainable development, particularly in regions experiencing rapid economic growth, urbanization, and tourism expansion. Increased consumer activity has led to a rise in waste volume that is not always matched by adequate management capacity. The linear economic model, which relies on a take-make-dispose pattern, is increasingly seen as incapable of meeting demands for resource efficiency and environmental sustainability, driving the emergence of the circular economy as a new paradigm for sustainable development (Geissdoerfer et al., 2017; Murray et al., 2017).

The circular economy treats waste as a resource that can be reused through processes such as repair and recycling to generate sustainable economic value. This approach not only reduces waste generation but also integrates economic, social, and environmental benefits (Kirchherr et al., 2017; Korhonen et al., 2018). In developing countries, implementing community-based circular economy initiatives is increasingly important because it can create local jobs, improve resource efficiency, and strengthen social and environmental resilience.

One circular economy instrument gaining traction in Indonesia is the waste bank. Waste banks not only reduce waste but also empower communities economically by managing materials with market value. Previous studies indicate that waste banks contribute to household economic benefits, community participation, and more integrated waste management practices within the circular economy framework (Yang et al., 2014; Asteria & Heruman, 2016; Fatmawati et al., 2024). However, waste bank sustainability depends not only on technical management capacity but also on stakeholders' ability to establish and maintain an effective, sustainable funding system. Empirical evidence from Bali further demonstrates the economic contribution of waste bank activities. Prayati (2018) found that waste savings and sales revenue significantly influenced waste bank customers' income in Denpasar. Similarly, Sekardadi & Sutrisna (2022) found that education level, family size, and participation significantly influenced waste bank members' income in Badung Regency.

Badung Regency is one of the regions facing these challenges. High levels of economic and tourism activity increase waste generation while creating a need for more sustainable waste management innovations. Various waste bank initiatives have emerged as part of local-level circular economy implementation, involving the Central Waste Bank, Waste Bank Units, waste collectors, Family Empowerment and Well-Being, the community, Eco Bali Recycle, and social media. Interactions among these actors form an economic network that reflects the movement of recyclable materials, economic resources, financial benefits, and institutional coordination that support waste bank sustainability in Badung Regency.

Studies on waste banks to date have generally focused on community participation, the effectiveness of waste reduction, and local economic empowerment (Yang et al., 2014; Asteria & Heruman, 2016). Recent studies also emphasize that stakeholder interactions and network structures strongly influence the effectiveness of urban waste management, indicating that collaboration among multiple actors is essential for sustainable waste governance (Lishan et al., 2021). Similarly, Octavianto et al. (2024) highlighted the importance of stakeholder relationships and institutional coordination in supporting regional waste management and circular economy implementation. Other research has emphasized communication networks, institutional relationships, and community collaboration in community-based waste management (Wellang et al., 2024; Wellang et al., 2025). In contrast, studies on the circular economy have largely addressed business model transformation, resource efficiency, and environmental sustainability at the macro level (Geissdoerfer et al., 2017; Kirchherr et al., 2017). Although previous research has examined financing mechanisms for solid waste management and their implications for the circular economy (Ezeudu & Bristow, 2025), the structural relationships through which funding and economic resources circulate among waste bank stakeholders remain relatively underexplored, particularly from a regional development economics perspective.

These limitations reveal a research gap in how funding networks affect waste bank sustainability. Existing studies provide important insights into community participation, communication, institutional collaboration, and circular economy practices, but they have paid limited attention to the directed structure of funding and economic resource relationships among waste bank stakeholders at the local-regional level. Institutional sustainability depends not only on technical capacity in material management but also on actors' ability to access, distribute, and maintain economic resource flows. Strong local institutions and community social capital are key to sustaining common-pool resource management (Ostrom, 1990; Putnam et al., 1994). Therefore, understanding funding relationships is crucial for explaining how economic resources circulate among actors and how institutional arrangements support an inclusive and sustainable circular economy.

From an economic perspective, waste bank activities can be understood as a form of collective resource management in which households, waste banks, collectors, recycling industries, and supporting institutions interact to generate and distribute economic value from recyclable materials. The economic value generated by waste bank activities depends on continuous participation, reliable exchange relationships, and access to recycling markets. These interactions may also involve coordination costs when economic relationships are fragmented or poorly connected. An integrated network can facilitate the movement of information and economic resources by connecting actors with complementary roles. Within the circular economy framework, the circulation of recyclable materials therefore represents not only an environmental process but also an economic process through which waste is transformed into resources and potential sources of local economic value.

This study addresses this gap by analyzing the directed funding network among waste bank stakeholders in Badung Regency. Unlike previous studies that primarily examine communication, community participation, institutional collaboration, or broader resource-exchange relationships, this study centers funding and economic-resource relationships in the analysis. The novelty lies in integrating directed in-degree and out-degree centrality, betweenness centrality, Influence Range Closeness Centrality (IRCC), eigenvector centrality, and Hierarchical Cluster Analysis (HCA) to identify actors' structural roles and similarities within the funding network. By combining these network measures, the study provides an integrated explanation of how economic resources move among waste bank actors and how network concentration may support or constrain the sustainability of circular economy activities. The study therefore contributes an economic-network perspective to community-based waste bank research by linking actor positions in the funding network with the sustainability of local circular economy activities.

Based on this research gap and the identified novelty, this study aims to examine the directed funding network underlying the sustainability of waste banks in Badung Regency using a Social Network Analysis approach. Specifically, the study seeks to analyze the structure of relationships among key actors, identify actors with strategic positions in the distribution and circulation of economic resources, and examine the implications of the network structure for strengthening the sustainability of circular economy activities in Badung Regency.

2. RESEARCH METHODS

2.1 Data Collection

This study uses both primary and secondary data to analyze the funding network structure supporting the sustainability of waste banks within the circular economy framework in Badung Regency. Primary data were obtained through in-depth interviews, a Focus Group Discussion (FGD) conducted in 2026, and field observations involving stakeholders directly engaged in community-based waste bank management. Semi-structured interviews and the FGD identified funding relationship patterns, economic resource exchange mechanisms, forms of institutional cooperation, and the intensity of interactions among actors supporting the waste bank system. The FGD also validated the roles of the identified actors and the directional relationships among them. The relationships identified through interviews and the FGD were then coded into a binary directed adjacency matrix, where 1 indicates the presence of an identified directional relationship between two actors, and 0 indicates its absence. Secondary data were sourced from waste bank institutional reports, local government documents, waste management regulations, and scientific publications on the circular economy and community-based waste management. The combination of primary and secondary data was used to establish the economic and institutional relationships represented in the waste bank funding network in Badung Regency.

The study's unit of analysis comprises seven key actors: the Central Waste Bank, Waste Bank Units, Collectors, Family Empowerment and Well-Being, Community, Eco Bali Recycle, and Social Media. These actors were selected because they are directly involved in collecting, distributing, and using the economic resources generated by waste bank activities. Their interactions form a funding network that underpins circular economy implementation at the local level. To ensure the reliability

and validity of the research findings, the study used source triangulation by cross-referencing interviews, observations, FGDs, and supporting documents. This approach reduced information bias and strengthened the consistency of the relationships identified among the actors. Social media was included as a network actor because interviews and FGDs identified its role in facilitating information dissemination, promotion, public engagement, and access to potential economic relationships among waste bank stakeholders. Social media does not represent a financial institution or direct funding provider in this study. Instead, it represents a digital facilitation channel through which information and promotional activities may support economic-resource relationships among other actors. Its inclusion therefore reflects its observed relational role within the network rather than an assumption that it directly manages financial resources.

2.2 Model Specifications

This study uses Social Network Analysis (SNA) to examine the structure of the directed funding network that supports the sustainability of waste banks within the circular economy framework. The network includes seven key actors: the Central Waste Bank, Waste Bank Units, waste collectors, Family Empowerment and Well-Being, the community, Eco Bali Recycle, and social media. These actors form an economic network reflecting the distribution of economic resources, financial benefits, recyclable materials, and institutional coordination in Badung Regency. The network structure was examined using in-degree, out-degree, betweenness centrality, Influence Range Closeness Centrality (IRCC), and eigenvector centrality. We also applied Hierarchical Cluster Analysis (HCA) to identify similarities in actors' structural positions within the funding network. The measures were interpreted together to distinguish actors by direct connectivity, intermediary position, network reach, and structural influence.

Because the funding network is directed, degree centrality is divided into in-degree and out-degree centrality. Out-degree centrality measures the number of relationships initiated by actor (i) toward other actors and is calculated as:

$$C_D^{out}(i) = \sum_{j=1}^{n} \alpha_{ij} \tag{1}$$

where α_{ij} represents the directed relationship actor (i) to actor (j)

$$C_D^{in}(i) = \sum_{j=1}^{n} \alpha_{ji} \tag{2}$$

where represents the directed relationship from actor (j) to actor (i)
Furthermore, betweenness centrality identifies actors who serve as connectors or mediators in the flow of economic resources among actors. This indicator is formulated as:

$$CB(i) = \sum_{j<k} \frac{g_{jk}(i)}{g_{jk}} \tag{3}$$

where g_{jk} denotes the number of shortest paths between actors j and k, while $g_{jk}(i)$ denotes the number of paths passing through an actor i. Betweenness centrality was calculated based on the shortest directed paths (geodesic paths) between pairs of actors in the network. For each pair of actors, the analysis identifies the shortest path connecting the source actor to the target actor and determines whether a particular actor lies on that path. An actor receives a higher betweenness value when it occurs more frequently on the shortest paths connecting other actors. The calculation was performed using the directed binary adjacency matrix constructed from the identified relationships. The resulting betweenness values were interpreted as structural brokerage positions rather than as direct measures of the amount or monetary value of funds passing through an actor.

Because the funding network is directed and does not necessarily provide reciprocal or complete paths among all actors, this study uses Influence Range Closeness Centrality (IRCC) to assess actors' reachability within the directed network. IRCC captures how far an actor can reach other actors through the network based on its influence range. In this study, a higher IRCC value indicates a wider outward reach, while an IRCC value of zero may occur when an actor has no outgoing path to other actors. IRCC is therefore interpreted as a complementary measure to degree and betweenness centrality, rather than a substitute for either.

In addition, Eigenvector centrality assesses each actor's structural position based on the importance of its connected actors. The measure assigns higher centrality values to actors that are connected to other actors with relatively high centrality. Eigenvector centrality is expressed as.

$$\mathrm{A_X} = \lambda \mathrm{x} \tag{4}$$

or in component form $x_i \frac{1}{\lambda} = \sum_{j=1}^{n} \alpha_{ij} x_j$, where A represents the adjacency matrix, x_i denotes the centrality score of actor i, α_{ij} represents the relationship between actors i and j, and λ is the largest eigenvalue of the adjacency matrix. In the context of this study, a higher eigenvector centrality indicates that an actor is structurally connected to other actors that are themselves relatively well connected within the network. Therefore, eigenvector centrality reflects structural influence rather than the amount of financial resources received or distributed.

To complement the centrality analysis, this study used Hierarchical Cluster Analysis (HCA) with the average linkage method to identify similarities in actors' structural positions within the funding network. The analysis groups actors by the similarity of their network relationships, allowing identification of actors with similar relational patterns. Average linkage calculates the distance between two clusters as the average of all pairwise distances between observations in the respective clusters. The resulting hierarchical structure is presented as a dendrogram, which illustrates the relative similarity and separation among the seven actors. The distance between groups is calculated using the following equation:

$$D(A,B) = \frac{1}{|A||B|} \sum_{i \in A} \sum_{j \in B} d(i,j) \tag{5}$$

The distance is calculated as the average of all pairwise distances between observations in cluster A and cluster B, expressed as $D(A,B) = \frac{1}{|A||B|} \sum_{i \in A} \sum_{j \in B} d(i,j)$, where $|A|$ and $|B|$ denote the number of actors in clusters A and B, respectively, and $d(i,j)$ represents the distance between actors i and j.

The analysis followed sequential stages. First, we coded relationships identified through interviews, the 2026 FGD, observations, and supporting documents into a binary directed adjacency matrix. Second, we calculated in-degree and out-degree centrality to identify actors with prominent receiving and initiating positions. Third, betweenness centrality was calculated using shortest directed paths to identify intermediary actors. Fourth, IRCC was calculated to assess actors' outward reach within the directed network. Fifth, eigenvector centrality was calculated to identify actors connected to structurally influential actors. Finally, HCA using average linkage was applied to identify similarities in actors' structural positions. We interpreted the results of these analyses jointly to identify core, intermediary, receiving, initiating, and peripheral positions within the waste bank funding network.

3. RESULTS AND DISCUSSION

3.1. Research Result

The waste bank funding network in Badung Regency consists of seven identified actors: the Central Waste Bank, Waste Bank Units, waste collectors, Family Empowerment and Well-Being, the community, Eco Bali Recycle, and social media. The directed network represents relationships involving the distribution of economic resources, recyclable materials, financial benefits, and

supporting information. Figure 1 presents the observed network structure.

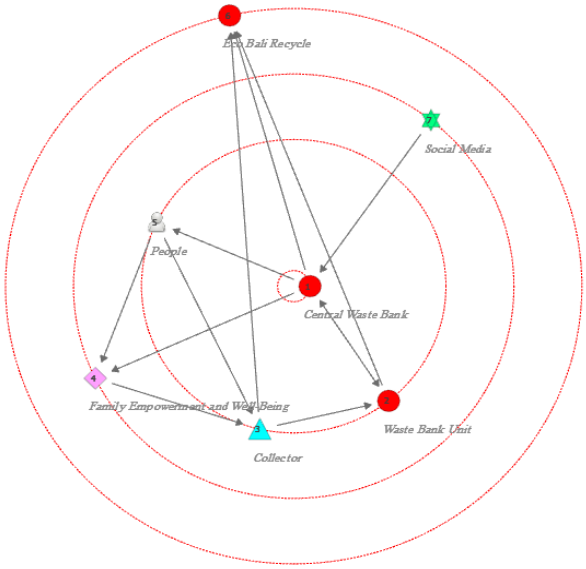


Figure 1. Funding Network Structure of the Waste Bank in Badung Regency

Figure 1 shows that the central waste bank occupies a central position in the funding network, with direct links to most of the other actors. This position indicates that the parent institution largely centralizes economic resource management, institutional coordination, and the distribution of financial benefits. Unlike some previous studies that placed the community at the center of the waste bank's economic interactions, this study's findings suggest that funding sustainability in Badung Regency depends more on the central waste bank's institutional capacity to connect the various actors involved.

Table 1. Roles of Actors in the Waste Bank Funding Network in Badung Regency

Code Actor	Actor	Role in Funding
1	Central Waste Bank	Lead coordinator and aggregator of economic resources
2	Waste Bank Unit	Manager of operations and distribution of economic benefits
3	Collector	Linking recycled material to the market
4	Family Empowerment and Well-Being	Strengthening household participation and environmental education
5	Community	Provider of materials with economic value
6	Eco Bali Recycle	End-Users of recycled materials
7	Social Media	Promotion, education, and expanding access to information

Source: Focus Group Discussion (FGD), 2026

Table 1 identifies the functional roles of the seven actors within the funding network. The Central Waste Bank serves as the main coordinator and aggregator, while Waste Bank Units manage operations and distribution. Collectors connect recyclable materials with markets, the community provides economically valuable materials, and Family Empowerment and Well-Being supports household participation and environmental education. Eco Bali Recycle functions as an end-user of recycled materials, while social media serves as a digital information and promotion channel. These roles provide the empirical basis for coding the directed relationships presented in the adjacency matrix.

Building on the identification of the seven actors and their respective functional roles within the funding network, the relationships among these actors were mapped to examine the direction of interactions within the network. The directed adjacency matrix was constructed by assigning a

binary value of 1 to indicate a directed relationship between two actors and 0 to indicate the absence of such a relationship. This coding approach systematically represents inter-actor linkages. It serves as the basis for analyzing the network structure, including the distribution of coordination, operational, and resource exchange relationships. Table 2 presents the resulting matrix.

Table 2. Directed Adjacency Matrix

Code Actor	Actor	1	2	3	4	5	6	7
1	Central Waste Bank	0	1	0	1	1	1	0
2	Waste Bank Unit	1	0	0	0	0	1	0
3	Collector	0	1	0	0	0	1	0
4	Family Empowerment and Well-Being	0	0	1	0	0	0	0
5	Community	0	0	1	1	0	0	0
6	Eco Bali Recycle	0	0	0	0	0	0	0
7	Social Media	1	0	0	0	0	0	0

Source: Results of Social Network Analysis, 2026

The table shows the direction of identified funding or economic-resource relationships from the source actor to the target actor. A value of 1 indicates a funding relationship, while a value of 0 indicates no funding relationship was identified.

Table 3. Out-Degree Centrality of Actors in the Funding Network

Actor	Degree	Normalized Degree (%)
Central Waste Bank	4	66,6
Waste Bank Unit	2	33,3
Collector	2	33,3
Family Empowerment and Well-Being	1	16,6
Community	2	33,3
Eco Bali Recycle	0	0
Social Media	1	16,6

Source: Results of Social Network Analysis, 2026

Out-degree centrality measures the number of outgoing relationships an actor initiates. The Central Waste Bank has the highest out-degree of 4, indicating four outgoing relationships to the Waste Bank Unit, Family Empowerment and Well-Being, Community, and Eco Bali Recycle. Waste Bank Units, Collectors, and the Community each have an out-degree of 2, while Family Empowerment and Well-Being and Social Media each have an out-degree of 1. Eco Bali Recycle has an out-degree of 0 because the observed network identified no outgoing relationships from this actor.

Table 4. In-Degree Centrality of Actors in the Funding Network

Actor	Degree	Normalized Degree (%)
Central Waste Bank	2	33,3
Waste Bank Unit	2	33,3
Collector	2	33,3
Family Empowerment and Well-Being	2	33,3
Community	1	16,6
Eco Bali Recycle	3	50
Social Media	0	0

Source: Results of Social Network Analysis, 2026

In-degree centrality measures the number of incoming relationships an actor receives. Eco Bali Recycle has the highest in-degree, at 3, receiving relationships from the Central Waste Bank, Waste Bank Units, and Collectors. The Central Waste Bank, Waste Bank Units, Collectors, and Family Empowerment and Well-Being each have an in-degree of 2. The Community has an in-degree of 1, while Social Media has an in-degree of 0 because no incoming relationship was identified in the

observed network. We analyzed the actors' mediating role using betweenness centrality, as shown in Table 5.

Table 5. Betweenness Centrality of Actors in the Funding Network

Actor	Betweenness Centrality	Normalized (%)
Central Waste Bank	11,00	36,6
Collector	7,00	23,3
Waste Bank Unit	6,00	20,0
Family Empowerment and Well-Being	1,50	5,00
Community	1,50	5,00
Eco Bali Recycle	0,00	0,0
Social Media	0,00	0,0

Source: Results of Social Network Analysis, 2026

Betweenness centrality measures how often an actor lies on the shortest directed paths between other actors. The Central Waste Bank records the highest normalized betweenness value (36.67%), followed by Collectors (23.33%) and Waste Bank Units (20.00%). Family Empowerment and Well-Being and the Community each record 5.00%, while Eco Bali Recycle and Social Media record 0.00%. These results indicate that the Central Waste Bank occurs most frequently on the shortest directed paths among the observed actors, followed by Collectors and Waste Bank Units. We measure actors' closeness to the entire network using Influence Range Closeness Centrality (IRCC), as shown in Table 6.

Table 6. Influence Range Closeness Centrality (IRCC) of Actors in the Funding Network

Actor	IRCC	% IRCC
Central Waste Bank	0,694444	69,44%
Waste Bank Unit	0,462963	46,30%
Collector	0,416667	41,67%
Family Empowerment and Well-Being	0,347222	34,72%
Community	0,462963	46,30%
Eco Bali Recycle	0,000000	0,00%
Social Media	0,500000	50,00%

Source: Results of Social Network Analysis, 2026

The IRCC results show differences in actors' outward reach within the directed funding network. The Central Waste Bank records the highest IRCC value at 0.694444 (69.44%), followed by Social Media at 0.500000 (50.00%). Waste Bank Units and the Community each record 0.462963 (46.30%), followed by Collectors at 0.416667 (41.67%) and Family Empowerment and Well-Being at 0.347222 (34.72%). Eco Bali Recycle records an IRCC value of 0.000000. The zero value is consistent with the absence of outgoing relationships from Eco Bali Recycle in the observed adjacency matrix. In addition to connectivity levels, we analyzed actors' structural influence using eigenvector centrality, as shown in Table 7.

Table 7. Eigenvector Centrality of Actors in the Funding Network

Actor	Eigenvector Centrality
Central Waste Bank	0,63
Waste Bank Unit	0,42
Social Media	0,42
Community	0,32
Collector	0,28
Family Empowerment and Well-Being	0,19
Eco Bali Recycle	0,00

Source: Results of Social Network Analysis, 2026

The eigenvector centrality results show that the Central Waste Bank has the highest value (0.63), followed by the Waste Bank Unit (0.42), Social Media (0.42), Community (0.32), Collectors

(0.28), and Family Empowerment and Well-Being (0.19). Eco Bali Recycle records a value of 0.00. The results indicate differences in structural influence based on each actor's connections to other actors in the network. The Central Waste Bank therefore occupies the highest eigenvector position in the observed network, while Eco Bali Recycle occupies the lowest position.

To complement the centrality analysis, we conducted a Hierarchical Cluster Analysis (HCA) to identify structural proximity among actors within the funding network. Figure 2 shows the clustering results.

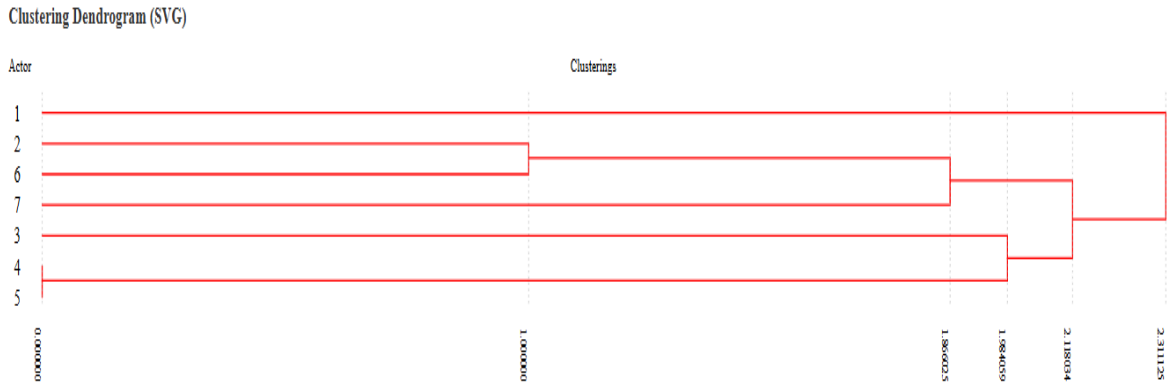


Figure 2. Dendrogram of Hierarchical Cluster Analysis of the Waste Bank Funding Network in Badung Regency

The Hierarchical Cluster Analysis (HCA) using the average linkage method identifies groups of actors with relatively similar structural positions within the funding network. As shown in Figure 2, Community and Family Empowerment and Well-Being form a relatively close cluster, indicating similar observed relational patterns. The Central Waste Bank and Waste Bank Units also form a relatively close institutional cluster. Collectors, Eco Bali Recycle, and Social Media occupy more distinct positions in the dendrogram, indicating different relational patterns from the identified clusters. The dendrogram therefore provides an additional representation of structural similarity among the seven actors.

3.2. Discussion

The research findings indicate that waste banks' sustainability in Badung Regency is supported by a relatively centralized, differentiated funding network involving institutional, community, market, and supporting actors. The Central Waste Bank occupies a prominent structural position, particularly in direct outgoing relationships, intermediary roles, network reach, and overall prominence. This indicates that the funding mechanism is organized through a network in which the Central Waste Bank connects several actors with different economic and institutional functions rather than operating through individual waste banks in isolation (Freeman, 1978; Borgatti, 2018). This interpretation aligns with the broader use of Social Network Analysis in circular economy research, where network structures identify differentiated stakeholder positions and relationships that support resource circulation and circularity (Liao et al., 2023). These findings support the view that the configuration and quality of relationships among actors matter for the institutional sustainability of circular economy activities at the local level (Geissdoerfer et al., 2017; Kirchherr et al., 2017).

The distinction between out-degree and in-degree provides a more detailed explanation of the direction of economic-resource relationships within the network. The Central Waste Bank records the highest out-degree, indicating that it initiates relationships with several actors, including Waste Bank Units, Family Empowerment and Well-Being, the Community, and Eco Bali Recycle. This position suggests that the Central Waste Bank functions as an important initiator and coordinator of economic-resource relationships. In contrast, Eco Bali Recycle records the highest in-degree, indicating that it receives relationships from several actors in the observed network. This position is consistent with its role as a downstream user of recyclable materials within the circular economy

value chain. The difference between these two measures shows that actors with strong outgoing relationships are not necessarily the same as actors receiving the most relationships. Therefore, separating in-degree and out-degree more accurately reflects the directionality of the funding network than treating degree centrality as a single measure.

The betweenness centrality results further explain the network structure by identifying actors that occupy intermediary positions along the shortest directed paths connecting other actors. The Central Waste Bank records the highest betweenness centrality, followed by Collectors and Waste Bank Units. This finding indicates that the Central Waste Bank occupies an important structural bridging position because a relatively large number of shortest paths between actors pass through it. However, this result should be interpreted as evidence of a structurally important intermediary position rather than direct evidence that the largest amount of financial resources physically passes through the Central Waste Bank. The intermediary position is consistent with the institutional coordination function identified in previous studies of community-based waste management (Ostrom, 1990; Pretty, 2003). Previous waste bank research has also identified similar intermediary positions, in which actors with relatively high betweenness centrality functioned as bridges connecting other participants within the network (Wellang et al., 2024). Recent research on circularity hubs likewise demonstrates that actors may occupy differentiated roles within resource-exchange networks, including central, intermediary, and peripheral positions (Tleuken et al., 2026).

From an economic perspective, the intermediary position of the Central Waste Bank should not automatically be interpreted as centralization that limits other actors' participation. Instead, it indicates that the institution occupies a structurally important position for connecting different parts of the network. The Central Waste Bank aggregates relationships among operational units, community actors, and recycling-market actors, thereby facilitating the circulation of economic resources within the network. This interpretation is consistent with previous studies emphasizing the importance of strong local institutions, collaborative governance, and stakeholder coordination in supporting sustainable community-based resource management (Ostrom, 1990; Pretty, 2003; Zuhdi et al., 2026). Nevertheless, this heavy reliance on a central intermediary also highlights the importance of maintaining alternative connections among actors so network connectivity does not depend too heavily on a single institutional bridge.

The IRCC results offer an additional perspective on the funding network by examining the extent to which actors can reach others through the directed network. Unlike degree centrality, which focuses on direct relationships, and betweenness centrality, which identifies intermediary positions, IRCC captures actors' reach within their influence range. The Central Waste Bank records the highest IRCC value, indicating the widest observed network reach, while Social Media also records a relatively high IRCC despite having fewer direct connections. This difference shows that network reach is not necessarily distributed the same way as direct connectivity or brokerage. Therefore, an actor with a relatively high IRCC does not necessarily have the highest degree or betweenness centrality. This distinction matters because relationships among actors are directional and may not allow every actor to reach all others through the same pathways. IRCC is therefore relevant as a complementary measure of actor position rather than a substitute for direct connectivity or intermediary capacity (Tleuken et al., 2026).

The eigenvector centrality results further show that an actor's structural prominence is not determined solely by the number of its direct relationships. The Central Waste Bank records the highest eigenvector centrality, indicating that its prominent position is linked to connections with actors that also occupy relatively meaningful positions within the network. Waste Bank Units and Community also occupy comparatively stronger positions, whereas actors with lower eigenvector values are positioned more peripherally within the overall network. These findings reinforce the importance of interpreting actor centrality in relation to the wider structure of relationships rather than through the number of direct connections alone (Freeman, 1978; Borgatti, 2018). This interpretation aligns with the use of SNA in circular economy research, where stakeholder positions are understood through relationships with other actors and their location within the wider network structure (Liao et al., 2023).

The HCA results complement the centrality analysis by identifying actors with relatively similar structural relationship patterns. The clustering of Family Empowerment and Well-Being with the Community suggests similarities in their observed relational positions, particularly regarding household participation and community engagement. Similarly, the Central Waste Bank and Waste Bank Units form a relatively close institutional cluster. However, these clusters reflect structural similarities rather than evidence that the actors perform identical functions. This distinction matters because actors may have different levels of centrality while still showing similar relationship patterns. The findings reinforce the importance of considering both individual network positions and structural similarities when interpreting stakeholder relationships in community-based waste management (Putnam et al., 1994; Ostrom, 2000). Similar network research also demonstrates that information-sharing, collaboration, and resource-exchange relationships may form different network configurations, including distinct clusters and bridging positions (De Silva & Divigalpitiya, 2026).

Together, degree, betweenness, IRCC, and eigenvector centrality therefore provide a more comprehensive interpretation of the Central Waste Bank's position. Its prominence is not limited to many direct relationships; it is also reflected in its intermediary position, network reach, and connections with other structurally relevant actors. This multidimensional interpretation is important because centrality measures capture different aspects of network position and should not be treated as interchangeable indicators of actor importance.

The findings also show that Waste Bank Units, the Community, and Collectors perform complementary functions in circulating economic resources generated through waste management activities. The Community provides economically valuable recyclable materials, while Collectors connect these materials with downstream market mechanisms. Waste Bank Units consolidate waste-management activities at the community level and connect local collection activities with broader institutional and market relationships. This pattern indicates that economic value within the waste bank system does not originate solely from external funding but is also generated through the circulation and exchange of recyclable resources involving community participation, reflecting the economic and empowerment dimensions of waste bank activities discussed in previous studies (Wilson et al., 2006; Ferronato & Torretta, 2019; Warsiyah et al., 2025). In this sense, waste banks function not only as environmental institutions but also as nodes within material and economic networks that contribute to local economic activities, consistent with the broader economic role of waste banks discussed by Afdhal (2024). Prayati (2018) supports this economic function, finding that waste savings and sales revenue significantly contributed to waste bank customers' income in Denpasar, indicating that the circulation of recyclable materials can generate direct economic benefits for participating households.

The present finding therefore extends the interpretation of waste bank networks beyond communication and participation. Previous SNA research on waste banks has primarily examined communication and stakeholder coordination (Wellang et al., 2024; Wellang et al., 2025), whereas the present study examines how economic-resource relationships are structurally distributed among actors. This distinction matters because a waste bank's sustainability depends not only on whether actors communicate or cooperate, but also on whether material and economic resources can move through the network.

Unlike some previous studies that emphasized the community as the dominant actor in community-based waste management, this study shows that funding sustainability in Badung Regency is more influenced by institutional integration mediated by the Central Waste Bank. In other words, economic relationships among actors do not occur entirely horizontally but instead form a semi-centralized pattern that enables more effective funding coordination. This finding expands the application of Social Network Analysis in the field of waste management by making funding the primary focus of the analysis, rather than merely social relationships or communication among actors (Wasserman & Faust, 1994; Borgatti, 2018)

Social media's involvement in the funding network adds a new dimension to implementing the circular economy in Badung Regency. Although Social Media has a relatively low degree and zero in-degree, its IRCC value indicates a relatively broad reach within the directed network. This suggests

that digital platforms may function as supporting communication channels rather than direct financial intermediaries. The use of digital media can strengthen the marketing of recycled products and increase public participation in waste bank activities (Bocken et al., 2016; Korhonen et al., 2018). Recent research on circular economy networks similarly emphasizes that information exchange represents a distinct relational dimension from direct resource exchange, meaning that communication-oriented actors may have a supporting rather than intermediary financial role (Tleuken et al., 2026)

Therefore, Social Media should not be interpreted as evidence that it directly generates funding for waste banks. Rather, its potential contribution lies in facilitating information dissemination, product promotion, public engagement, and access to potential stakeholders. This distinction is important because the network measures identify structural potential, while the actual financial effect of digital platforms would require additional transaction or outcome data.

Meanwhile, Eco Bali Recycle's position on the periphery of the network does not indicate a lack of economic significance for this actor. On the contrary, its role as an end-user of recycled materials makes Eco Bali Recycle an important component of the circular economy value chain. The transactional relationship between waste banks and the recycling industry highlights the need to strengthen longer-term partnerships to sustain stable material demand and equitable distribution of economic benefits. In the observed network, Eco Bali Recycle primarily occupies a receiving position, as reflected by its relatively high in-degree and zero out-degree. Developing more collaborative partnership schemes could increase waste banks' funding capacity and expand their contribution to local economic development (Murray et al., 2017; Prieto-Sandoval et al., 2018). This interpretation aligns with recent research showing that actors' positions within waste-recycling networks are shaped by access to material flows and economic value. Therefore, a peripheral network position should not automatically be interpreted as low functional importance; rather, it may reflect a specialized downstream role within the value chain.

Strengthening the connection between waste banks and recycling-market actors may therefore be more relevant than simply increasing the number of direct connections. Stable purchasing arrangements, clearer quality standards for recovered materials, and longer-term market relationships could help transform downstream relationships from predominantly transactional interactions into more stable circular-economy partnerships.

Taken together, the centrality and HCA results indicate that the waste bank funding network in Badung Regency combines a relatively centralized institutional structure with differentiated supporting roles. The Central Waste Bank stands out for its direct outward connections, intermediary position, network reach, and structural prominence. At the same time, Waste Bank Units, Collectors, Community, Family Empowerment and Well-Being, Eco Bali Recycle, and Social Media occupy different but complementary positions. The findings extend previous waste bank network studies by showing that actors' structural positions can be examined not only through communication and coordination relationships, but also through the direction and configuration of economic-resource relationships that support waste bank activities. This multidimensional perspective provides a more comprehensive understanding of how institutional, community, market, and supporting actors are connected within a local circular economy system (Wellang et al., 2024; Wellang et al., 2025; Liao et al., 2023.

The findings confirm that the success of circular economy implementation in Badung Regency depends not only on waste management technology but also on the quality and configuration of relationships among the various actors. Strengthening network connectivity, diversifying funding sources, enhancing the capacity of individual waste banks, optimizing digital platforms, and developing partnerships with the recycling industry are relevant directions for strengthening the sustainability of waste banks as instruments of inclusive and sustainable local economic development (Geissdoerfer et al., 2017; Kirchherr et al., 2017).

However, these implications should be understood as network-based directions rather than causal effects directly demonstrated by the SNA results. The analysis identifies structural positions and relationships within the observed network, while the magnitude of financial effects would require additional longitudinal or transaction-level data. This limitation also creates an opportunity

for future research to examine the value, frequency, and duration of economic exchanges among actors to complement the structural findings of the present study.

The main contribution of this study is extending the application of Social Network Analysis in community-based waste bank research from communication and stakeholder coordination to the analysis of directed funding and economic-resource relationships. Rather than treating network centrality as a single measure of actor importance, this study integrates in-degree and out-degree centrality, betweenness centrality, influence range closeness centrality, eigenvector centrality, and hierarchical cluster analysis to provide a multidimensional understanding of actor positions and structural similarities within the funding network. This approach shows that the sustainability of waste bank activities depends not only on the presence of individual actors, but also on the connectivity and complementary functions among them. In this context, the Central Waste Bank serves as an important institutional bridge, while community actors, Waste Bank Units, Collectors, recycling actors, and digital media contribute through different economic, operational, market, and information-related functions.

4. CONCLUSIONS

This study demonstrates that the waste bank funding network in Badung Regency is characterized by a differentiated and relatively centralized structure, with the Central Waste Bank occupying a prominent institutional position in coordinating economic-resource relationships among waste bank units, collectors, communities, and recycling-market actors. The findings reveal distinct structural roles across network actors. Waste Bank Units and Collectors facilitate the circulation of economic resources, while the Community and Family Empowerment and Well-Being institution supports community-based participation. Eco Bali Recycle represents the downstream market connection, whereas Social Media extends the network's information and outreach capacity. Furthermore, the hierarchical cluster analysis (HCA) identifies similarities in the relational positions of community-based and institutional actors, suggesting the presence of distinct patterns of network affiliation.

The study contributes to the literature by extending the application of Social Network Analysis beyond communication and institutional collaboration to the examination of directed funding and economic-resource relationships within community-based waste management systems. This perspective provides a more nuanced understanding of how institutional positioning and network connectivity shape the organizational foundations of waste bank sustainability. From a policy perspective, the findings underscore the importance of strengthening the coordinating capacity of the Central Waste Bank while diversifying institutional and market linkages to reduce dependence on a single coordinating connection. Local governments can facilitate this process through targeted capacity-building initiatives, transparent funding arrangements, stronger linkages with recycling industries, and digital platforms that improve information exchange and market access. These measures could contribute to a more resilient and inclusive waste bank network, thereby reinforcing its role in advancing local circular economy development.

Nevertheless, given the study's focus on the structural characteristics of the observed relationships rather than causal mechanisms or monetary transaction values, further research could employ longitudinal network data and transaction-level economic indicators to investigate how network dynamics are associated with variations in the economic performance of waste banks.

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AUTHORS' CONTRIBUTIONS

Ida Ayu Sintya Dewi contributed to the study's conceptualization, research design, data collection, methodology, formal analysis, visualization, and drafting of the initial manuscript. Ni Putu Wiwin Setyari contributed to developing the research framework and reviewing the manuscript. Ida Ayu Nyoman Saskara contributed to the theoretical framework, methodology, validation of the interpretation of findings, and review and editing of the manuscript. Ida Bagus Gede Arjana contributed to reviewing the research findings. All authors have reviewed and approved the final version of the manuscript and agree to be responsible for its content.

CONFLICT OF INTEREST

The authors declare no financial, personal, or institutional conflicts of interest that could have influenced the design, implementation, analysis, interpretation, or reporting of this research. The authors conducted the study independently, and the findings and conclusions presented in this manuscript reflect their academic assessment of the research evidence.

USE OF AI TOOLS DECLARATION

The authors used AI-assisted tools exclusively for language editing, grammatical correction, sentence refinement, and improving the manuscript's clarity and coherence. These tools supported only the presentation of the research. They did not involve data collection, data processing, Social Network Analysis (SNA) calculations, Hierarchical Cluster Analysis (HCA), or generating research findings. The authors independently conducted, reviewed, and verified all analytical procedures, interpretations, and conclusions. The authors retain full responsibility for the manuscript's accuracy, originality, and integrity.

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