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Circular Economy Implementation in Community-Based Plastic Waste Management: A Case Study of Waste Bank Amal Haqiqi Garut, Indonesia

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ABSTRACT: Waste banks represented a pivotal form of community-based waste management with the potential to operationalize circular economy principles by integrating social, environmental, economic, and technical dimensions. However, empirical verification through systematic performance measurement was essential to validate their effectiveness. This study aimed to analyze the implementation of a circular economy system in plastic waste management at Bank Sampah Amal Haqiqi, located in Bayongbong, Garut. The research first utilized Material Flow Analysis (MFA) to quantify the flow and transformation of plastic waste. Subsequently, the Analytical Hierarchy Process (AHP) was employed to evaluate management performance based on 11 stakeholder perspectives across four criteria: social, environmental, economic, and technical aspects. The AHP results were validated using a Consistency Ratio (CR) of ≤ 0.10. The MFA revealed a plastic waste recycling rate of 76%, with a residue rate of 3.7%. The AHP weighting identified the social criterion as the highest priority (0.33), followed by the technical criterion (0.30). These findings highlighted that management success was predominantly driven by human factors and operational infrastructure. The implementation of a circular economy at Bank Sampah Amal Haqiqi was significant but remained highly dependent on community engagement and technical support. To ensure sustainability, management strategies should have prioritized strengthening social participation and upgrading technical facilities to further reduce residue levels.

KEYWORDS: Circular economy; plastic waste; material flow analysis; analytical hierarchy process

1. Introduction

Plastic waste had become one of the most critical environmental challenges of the modern era due to its rapid increase in generation and its persistent nature in the environment [1]. As a material that degraded extremely slowly, plastic accumulated in terrestrial and aquatic ecosystems, leading to long-term ecological damage, degradation of environmental quality, and increased risks to human health and economic sustainability [2]. These challenges were particularly pronounced in developing countries, where population growth, urbanization, and changing consumption patterns were not adequately matched by effective and sustainable waste management systems [3].

Indonesia was among the largest contributors to plastic waste globally, ranking as the second-largest plastic waste–generating country worldwide [4]. National estimates indicated that approximately 6.8 million tons of plastic waste were produced annually, with more than 60% remaining inadequately managed or unrecycled [5]. The prevailing waste management system remained largely linear, emphasizing collection and final disposal rather than material recovery and resource circulation [6]. Consequently, large quantities of plastic waste continued to accumulate in landfills and open dumping sites, exacerbating soil, water, and air pollution while placing increasing pressure on environmental carrying capacity [7].

In response to these challenges, the circular economy had emerged as a promising alternative framework for sustainable waste management [8]. The circular economy shifted the conventional "take–make–dispose" model toward a system that prioritized waste reduction, reuse, recycling, and the continuous circulation of materials within economic processes [9]. By treating waste as a potential resource rather than an end product, this approach aimed to minimize environmental impacts while generating social and economic value [10]. Within this framework, community-based initiatives played a crucial role, particularly in contexts where centralized waste management systems faced structural and capacity limitations.

One of the most prominent community-based approaches in Indonesia was the waste bank (bank sampah) system. Waste banks encouraged household-level waste segregation and material recovery by providing economic incentives in exchange for sorted recyclable materials [11]. Beyond reducing the volume of waste sent to landfills, waste banks also functioned as social instruments that promoted environmental awareness, community participation, and local economic empowerment [12]. Despite their rapid growth in number, however, the overall contribution of waste banks to plastic waste reduction remained relatively limited, especially in regions with high waste generation rates such as West Java [13].

West Java Province faced significant challenges in plastic waste management due to its large population, rapid urbanization, and high consumption of single-use plastic products. These pressures were particularly evident at the local level, including in Garut Regency, where waste management systems continued to rely heavily on open dumping practices and where household plastic waste constituted a major share of total waste generation. In such contexts, the effectiveness of community-based circular economy initiatives became increasingly important, as they could offer practical and scalable solutions to complement formal waste management systems.

Against this backdrop, Waste Bank Amal Haqiqi (BSAH), located in Bayongbong, Garut, represented a relevant case of a community-driven initiative that sought to apply circular economy principles in plastic waste management. Since its establishment, BSAH had implemented systems of waste collection, segregation, and recycling that actively involved 335 local residents and aimed to reduce plastic waste leakage into the environment. However, the extent to which these practices effectively reflected circular economy principles across environmental, social, technical, and economic dimensions had not yet been systematically evaluated. The circular economy concept applied at BSAH is illustrated in Figure 1.

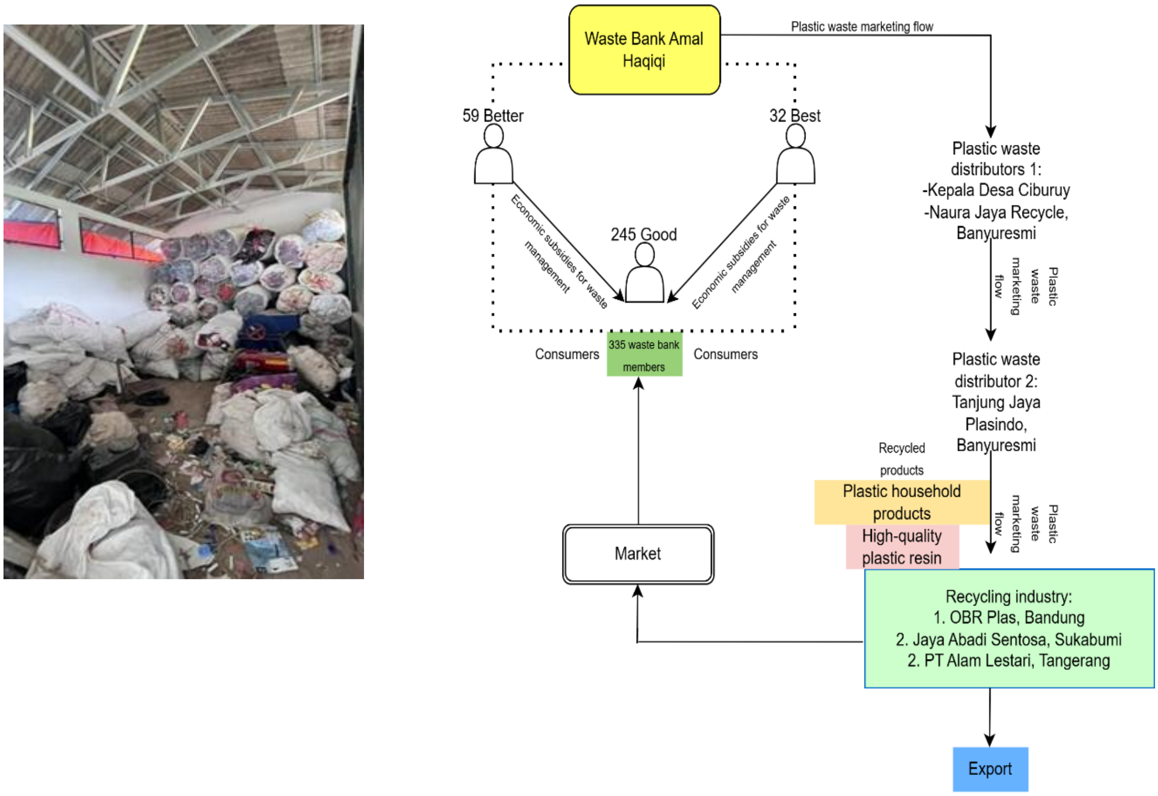

Figure 1. Circular economy concept applied at waste Bank Amal Haqiqi.

Therefore, this study aimed to assess the implementation of circular economy principles in plastic waste management at the community level through a case study of Waste Bank Amal Haqiqi. By applying a multidimensional evaluation framework, this research sought to provide empirical insights into the performance, strengths, and limitations of waste bank–based circular economy practices. The findings were expected to contribute to the academic discourse on circular economy implementation in developing country contexts and to inform policy and practice for strengthening community-based plastic waste management systems.

Despite the growing body of literature on circular economy applications in the waste management sector, studies focusing on the implementation of circular economy principles at the waste bank scale remained limited. Existing studies had mainly emphasized policy analysis [14], SWOT-based assessments [13], and innovation-oriented strategies for sustainable waste management. This gap highlighted the need for a more comprehensive assessment of how circular economy principles were operationalized and performed at the community level. Accordingly, this study addressed the existing limitations by systematically analyzing the implementation of circular economy practices in plastic waste management at a waste bank, thereby offering a more holistic understanding of community-based circularity. The results were expected to strengthen the academic foundation of community-based waste management and to serve as a reference for improving the effectiveness of circular economy strategies at the grassroots level.

2. Materials and Methods

2.1. Research area and period.

The fieldwork for this study was conducted over a one month period in October–November 2025 at Waste Bank Amal Haqiqi. The geographical location of the study area is shown in Figure 2.

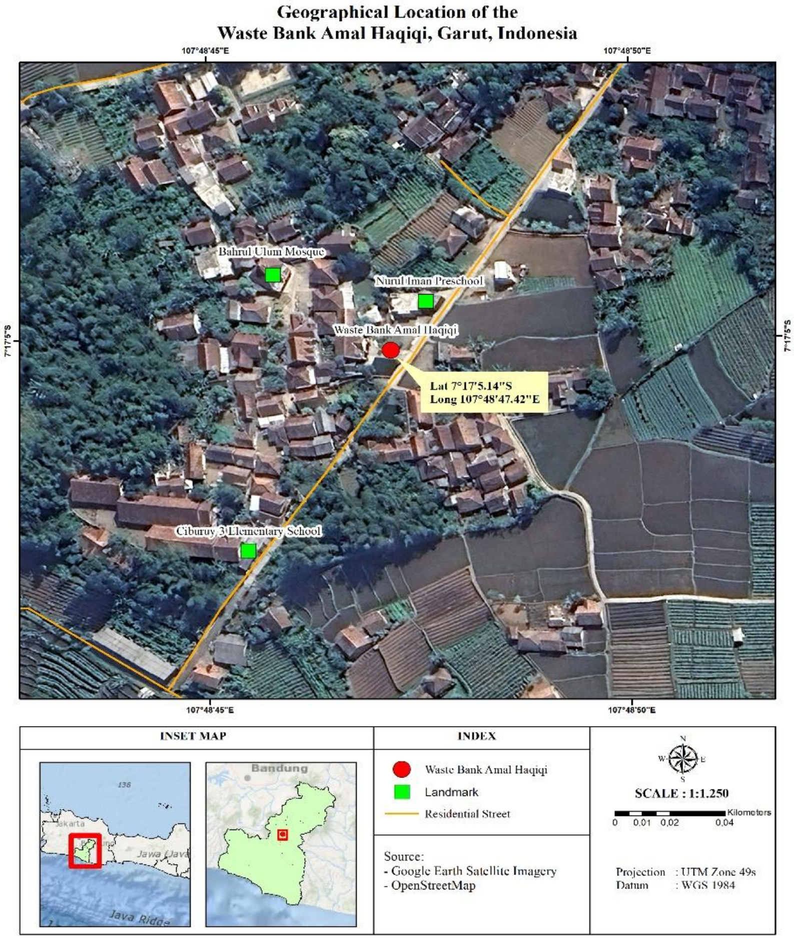

Figure 2. Location map and geographical position of waste Bank Amal Haqiqi, Ciburuy, Bayongbong, West Java.

During this period, primary data were collected through in-depth interviews, direct observations, and questionnaire distribution to key stakeholders. In addition, the study utilized secondary data derived from plastic waste transaction records covering an 11-month period (January–November). Plastic waste data were recorded on a monthly basis based on routine transaction logs, while interviews and questionnaires for the AHP were conducted once during the fieldwork period. These records were obtained from the operational database of the waste bank and were used to support the quantitative analysis of plastic waste flows. The integration of short-term primary data collection with long-term secondary data enabled a more comprehensive assessment of both operational practices and material circulation performance.

2.2. Research methods.

This study employed a mixed-method approach to evaluate the implementation of a circular economy system at Waste Bank Amal Haqiqi, Bayongbong, Garut. The qualitative phase utilized in-depth interviews to explore the waste bank's profile, operational mechanisms, waste collection and sorting processes, and community participation in waste management. Qualitative and quantitative informants were selected using purposive sampling, a non-probability sampling technique that enabled the selection of respondents based on predefined criteria relevant to the research objectives [15, 16].

The quantitative analysis consisted of MFA and the HP. MFA was applied to quantify and map plastic waste flows, including generation, reuse, recycling, and residual disposal, using primary data derived from waste weighing records, operational reports, and field observations [17]. A census approach was adopted for all plastic waste transactions recorded over an 11-month period to ensure data accuracy and representativeness. AHP was employed to identify and prioritize key factors influencing the success of circular economy implementation by evaluating environmental, social, economic, and technical aspects through pairwise comparisons [18]. Data were collected through questionnaires distributed to 11 selected stakeholders using purposive sampling based on the pentahelix framework.

2.1.1. MFA.

MFA was applied to quantify and map the flow of plastic waste managed by Waste Bank Amal Haqiqi within a defined system boundary [19]. The MFA focused on plastic waste flows from collection at the community level to downstream processing and final destinations, following the principles of mass balance analysis [17]. The system boundary included plastic waste inputs from household sources, sorting and temporary storage processes at the waste bank, and outputs in the form of recyclable materials distributed to recycling partners as well as residual waste. The analysis covered an 11-month period using secondary data obtained from waste transaction records, weighing logs, and operational reports. A census approach was applied, in which all plastic waste transactions recorded during the 11-month period were included. The quantity of each plastic type (PET, PP, HDPE, etc.) was quantified based on measured weight (kg) rather than sample units. The system boundary and key components of the MFA are presented in Table 1.

Table 1. System boundary and MFA components.

Component	Description
Input	Plastic waste collected from households (kg)
Process	Sorting and temporary storage at the waste bank
Output (Recycling)	Plastic materials sent to recycling partners/distributor (kg)
Output (Residual)	Non-recyclable or contaminated plastics (kg)

Plastic waste was classified according to material types commonly handled by the waste bank, including PET, HDPE, PP, and mixed plastics. Quantitative data were analyzed to determine the total amount of plastic waste generated, reused, recycled, and disposed of as residuals. The mass balance principle was applied to ensure data consistency, whereby total inputs were equal to the sum of all outputs and stock changes [20].

2.1.2. Recycling rate and residue rate.

The performance of circular economy implementation in plastic waste management was evaluated using material flow–based indicators, particularly the recycling rate and residue rate, which were widely applied to assess the effectiveness of material circulation within waste management systems [21]. These indicators reflected the extent to which plastic materials entering the system were successfully returned to productive use, as well as the proportion of materials that remained as residual waste. Accordingly, MFA results were used to evaluate the effectiveness of plastic waste circulation within a circular economy framework by identifying the material recycling rate and residue rate within the system [22]. The recycling rate represented the proportion of plastic waste that was recovered and directed to recycling processes [23], while the residue rate indicated the share of plastic waste that was not recovered and was ultimately disposed of or lost from the system [20]. The recycling rate and residue rate were calculated using the following equations:

$$Recycling\ Rate = \frac{M\text{recycling}}{Mtotal\_in}$$

$$Residue\ Rate = \frac{M\text{residu}}{Mtotal\_in}$$

These indicators enable a quantitative assessment of circular economy performance by linking material flow outcomes with system efficiency, thereby providing a clear measure of the effectiveness of community-based plastic waste management practices [23].

2.1.3. AHP.

AHP was employed to evaluate and determine priority factors for strengthening the implementation of the circular economy at Waste Bank Amal Haqiqi. This method was particularly suitable for assessing complex, multi-dimensional systems such as community-based waste banks, where environmental, social, economic, and technical aspects interacted and needed to be evaluated simultaneously [24]. AHP enabled the transformation of qualitative judgments from key stakeholders into quantitative priority weights through structured pairwise comparisons [25]. In this study, AHP was used to identify which aspects and criteria should be prioritized to improve the performance and sustainability of Waste Bank Amal Haqiqi within a circular economy framework.

Respondents were selected using purposive sampling based on the pentahelix approach, which integrated five key stakeholder groups: government, academia, business/industry, community, and media [26]. This approach was adopted to ensure that the evaluation reflected multi-stakeholder perspectives relevant to the operational, institutional, and policy dimensions of waste bank management. The pentahelix framework has been widely recognized as an effective collaborative model for supporting sustainable development initiatives through cross-sectoral engagement [27].

In AHP-based studies, the number of respondents is generally limited because the method does not aim to achieve statistical generalization but rather to elicit informed judgments from individuals with substantial expertise and direct involvement in the system being evaluated [24]. Consequently, the relevance and expertise of respondents were prioritized over sample size. The validity of the AHP results was assessed using the Consistency Ratio (CR), which evaluated the logical consistency of pairwise comparisons. A CR value of ≤ 0.10 indicated acceptable consistency and reliable judgments [24]. As long as this criterion is satisfied, a relatively small number of respondents can yield robust and credible evaluation results.

Individual judgments from 11 respondents were aggregated using the geometric mean to obtain the final priority weights. The stages of the AHP applied in this study are presented in Table 2.

Table 2. Stages of AHP.

Stage	AHP Procedure	Description
1	Problem definition	Identification of key issues and objectives related to circular economy implementation in plastic waste management
2	Hierarchy structuring	Development of a hierarchical model consisting of goal, criteria, and sub-criteria (environmental, social, economic, technical aspects)
3	Pairwise comparison	Assessment of relative importance among criteria and sub-criteria using pairwise comparisons
4	Priority weighting	Calculation of eigenvectors to determine the priority weights of each criterion with AHP calculator BPMSG. Qualitative judgments obtained through interviews were transformed into quantitative scores using Saaty's 1-9 pairwise comparison scale.
5	Consistency evaluation	Measurement of Consistency Ratio (CR ≤ 0.10) to ensure logical consistency
6	Synthesis and interpretation	Integration of weighted priorities to identify key influencing factors and strategic priorities

3. Results and Discussion

3.1. Plastic waste characterization and quantification.

During the 11-month observation period, Waste Bank Amal Haqiqi collected a total of 6,539.52 kg of plastic waste originating from households and community-based activities. Of this total, 4,967.26 kg was sorted and quantified by plastic type, 1,347.74 kg was temporarily stored in the warehouse in unsorted condition, and 241.14 kg was classified as residual waste and disposed of. The composition of plastic waste collected at Waste Bank Amal Haqiqi was dominated by polypropylene (PP), polyethylene terephthalate (PET), and high-density polyethylene (HDPE), followed by lower proportions of low-density polyethylene (LDPE), polystyrene (PS), acrylonitrile butadiene styrene (ABS), polyvinyl chloride (PVC), and mixed plastics. The dominance of PP, PET, and HDPE was commonly observed in community-based waste management systems and reflected prevailing household consumption patterns, particularly the widespread use of single-use plastic packaging [28]. The detailed polymer composition, mass, percentage contribution, and recovery pathways are presented in Table 3.

Table 3. Polymer composition, mass, percentage contribution, and recovery pathways.

Polymer Type	Mass (kg)	Percentage	Recovery Pathway
PP	1164,15 kg	17.8%	Sold to collectors (open circular)
PET	1660,47 kg	25.4%	Sold to collectors (open circular)
Polystyrene PS	140,5 kg	2.1%	Sold to collectors (open circular)
HDPE	586,02 kg	9.0%	Sold to collectors (open circular)
Bottle caps (HDPE)	16,62 kg	0.3%	Local upcycling into household accessories by Waste Bank Amal Haqiqi (close circular)
ABS	281 kg	4.3%	Sold to collectors (open circular)
PVC	119,5 kg	1.8%	Sold to collectors (open circular)
Polymethyl Methacrylate (PMMA)	30 kg	0.5%	Sold to collectors (open circular)
Low-Density Polyethylene (LDPE)	773 kg	11.8%	Sold to collectors (open circular)
Others valuable plastics	5,2 kg	0.1%	Sold to collectors (open circular)
Others non valuable plastics	196 kg	3.0%	Processed into ecobricks (downcycling)

PET and HDPE primarily originated from household beverage bottles, cooking oil containers, detergent packaging, and personal care products, while PP was commonly associated with food packaging, bottle caps, and household containers [29]. These plastic types were widely used due to their durability, lightweight properties, and low production costs, which consequently resulted in high post-consumer generation rates at the household level [30]. From a recycling market perspective, PET and HDPE were considered high-value plastics due to their relatively clean recycling streams, stable demand, and well-established recycling technologies [29].

Recycled PET and HDPE were widely used as secondary raw materials for producing plastic resins and household products, making them economically attractive for waste banks and recycling industries [31]. In contrast, LDPE, PS, PVC, and mixed plastics generally had lower market value due to contamination issues, complex polymer structures, and limited recycling pathways, often resulting in their classification as residual waste or downcycled materials. The plastic waste profile observed in this study was consistent with recent findings from community-based and informal recycling systems in Asia and other developing regions. For instance, previous studies reported that PET, PP, and HDPE typically accounted for more than 60% of recyclable plastics collected in community waste banks [29]. This similarity indicated that the composition of plastic waste at Waste Bank Amal Haqiqi reflected a common pattern rather than a unique case, thereby reinforcing the representativeness of the study for evaluating circular economy implementation in community-based plastic waste management systems.

3.2. MFA of plastic waste at waste bank Amal Haqiqi.

Operationally, Waste Bank Amal Haqiqi applied a hybrid circular economy model. An open-loop circular system was predominantly implemented, in which plastic waste flows were integrated with external actors, including recycling industries, creative industry practitioners, and waste-processing partners [32]. In parallel, a closed-loop circular system was selectively applied to bottle cap commodities, enabling local upcycling within the waste bank system. This integration ensured that plastic materials were managed not only through external recovery pathways [33] but also systematically redistributed within the internal processing chain of Waste Bank Amal Haqiqi. The identified material flows consisted of plastic waste inputs from waste bank members and outputs directed either to collectors or distributors or to recycling industries. In this analysis, the classification of members into good, better, and best categories was not used as a variable in material flow calculations but instead served as institutional and managerial context. The resulting plastic waste flows were subsequently presented in a material flow diagram (Figure 3).

Based on the MFA results, the total plastic waste input to the system amounted to 6,539.52 kg during the observation period. Of this amount, 5,017.46 kg was successfully recovered through recycling and alternative utilization pathways, resulting in an overall material recovery rate of approximately 77%. This level of recovery was comparable to recycling efficiencies reported in recent community-based plastic waste management systems in developing regions [34]. Polymer-specific analysis showed that high-value plastics such as PET, PP, and HDPE exhibited higher recovery rates, as these materials were readily accepted by collectors and recycling industries. In contrast, low-value and contaminated plastics contributed disproportionately to the residual fraction (241.14 kg, 3.7%), originating mainly from mixed plastics and degraded materials that could not be further processed. Similar leakage patterns had been observed in small-scale recycling systems, where material quality and contamination remained critical constraints [35]. In addition, a stock accumulation of 1,347.74 kg was identified as temporarily stored material, reflecting operational limitations such as fluctuating market demand and storage capacity at the waste bank level. Temporary storage was a common source of uncertainty in MFA-based assessments and could affect short-term recovery performance if not managed systematically [22]. The system boundary and assumptions applied in this study followed internationally recognized MFA frameworks, which emphasized transparent boundary definition, systematic mass balancing, and consistent flow classification. This methodological approach provided a robust basis for evaluating circular economy performance and identifying opportunities for improving material recovery efficiency in community-based plastic waste management systems [36].

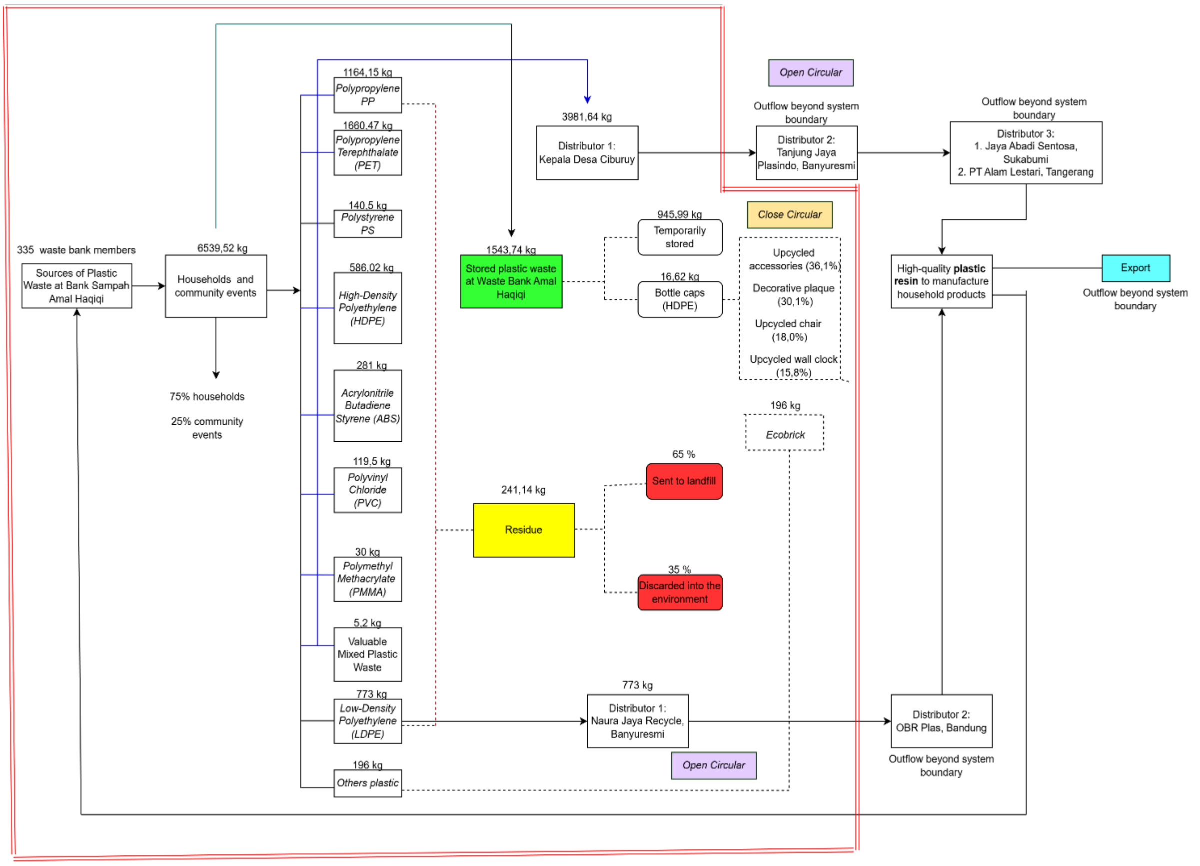

Figure 3. MFA: Plastic Waste Bank Sampah Amal Haqiqi (January-November 2025)

3.3. Evaluation of circular economy performance.

3.3.1. Recycling rate performance.

Based on the MFA, a total of 6,539.62 kg of plastic waste entered the Waste Bank Amal Haqiqi system during the January–November 2025 period. Of this amount, 4,967.26 kg was successfully directed to recycling and recovery pathways. The largest share of recovered material (3,981.64 kg) was channeled through collector-based recycling routes, involving economically valuable plastics such as polypropylene (PP), polyethylene terephthalate (PET), polystyrene (PS), high-density polyethylene (HDPE), acrylonitrile butadiene styrene (ABS), polyvinyl chloride (PVC), and polymethyl methacrylate (PMMA). In addition, 773 kg of low-density polyethylene (LDPE) was recovered through a separate collector–recycler chain.

A recycling rate of 0.76 (76%) indicated that the majority of plastic waste managed by Waste Bank Amal Haqiqi was successfully diverted from disposal and reintegrated into material recovery processes. Within the circular economy framework, this value reflected a relatively high level of material recirculation, suggesting that the system enabled plastic waste to re-enter utilization and recycling loops rather than being disposed of as residual waste.

Beyond conventional recycling channels, 196 kg of plastic waste was utilized as ecobricks through community-based alternative recovery practices, while 16.62 kg was internally processed into value-added products within the waste bank system. Similar recycling rates (60–80%) had been reported in recent studies on community-based and informal plastic waste management systems, indicating that the performance of Waste Bank Amal Haqiqi aligned with broader regional and international patterns [34]. Nevertheless, the remaining unrecovered fraction highlighted opportunities for further improving circularity through enhanced sorting efficiency, improved material quality control, and the expansion of local closed-loop recovery pathways [37]. Although the recycling rate at Waste Bank Amal Haqiqi reached approximately 76–77%, comparable to other community-based systems, previous studies showed that the overall contribution of waste banks to recyclable material management could remain limited without integrated institutional and market support, with reported contributions of around 7% in some regions of Indonesia [38].

3.3.2. Residue rate performance.

Based on the MFA conducted over an 11-month period (January–November 2025) at Waste Bank Amal Haqiqi, 241.14 kg of plastic waste was classified as residue out of a total input of 6,539.62 kg. Of this residual fraction, approximately 65% was transported to the final disposal site (TPA) due to contamination or technical limitations that prevented further recovery. The remaining 35% was either burned or disposed of in the surrounding environment as a result of limited handling capacity and time constraints. This disposal pattern reflected persistent challenges in managing residual plastic materials, where a portion of waste inevitably exited recovery pathways and posed potential environmental risks if not properly controlled [39].

The residue rate represented the proportion of plastic waste that did not re-enter material recovery or utilization cycles and served as a key indicator of system leakage and recovery limitations in circular economy–oriented waste management systems [40]. A residue rate of 0.037 (3.7%) indicated that a relatively small fraction of the plastic waste managed by Waste Bank Amal Haqiqi ultimately remained unrecovered. However, despite its low magnitude, this residual flow still represented a loss of material value and highlighted inefficiencies within the system. From a circular economy perspective, residual waste signified incomplete material loops and reflected technical, operational, and quality-related constraints in plastic waste recovery processes [41]. Consequently, further improvements in sorting accuracy, contamination control, and local treatment options were required to minimize residual flows and enhance overall system circularity [42]. Despite efforts to reduce residual plastic waste, incomplete integration between informal and formal recycling actors remained a challenge for achieving higher diversion rates. Research on municipal waste systems had highlighted that informal and formal sectors often functioned independently, thereby limiting material flow efficiency and overall recycling outcomes [43].

3.4. AHP based priority assessment for circular economy implementation.

The prioritization of plastic waste management aspects at Waste Bank Amal Haqiqi was conducted using the AHP. Data were collected through an AHP-based questionnaire administered to 11 purposively selected experts and stakeholders representing the pentahelix framework. The composition of pentahelix elements involved in this study is presented in Table

4. Integrating multi-stakeholder perspectives enabled a more holistic and applicable decision-making process, ensuring that the resulting priorities were academically sound, institutionally supported, economically feasible, and socially acceptable.

Table 4. Pentahelix elements of waste bank Amal Haqiqi.

Pentahelix Stakeholders	Number of Respondents	Specific Details
Business Partners	3	Business Partners Bank Sampah (Deka Kebon)
Academics	2	Researcher and Waste Plastic Expert (Consultant Bank Sampah Amal Haqiqi)
Government	1	Environmental Agency (Dinas Lingkungan Hidup Kabupaten Garut)
Community	4	Waste Bank Members and Non Members/ Local Residents
Media	1	Journalists/Information Officers (Media Rumah Amal Salman Garut)

3.4.1. AHP Criteria and Sub-criteria Weighting AHP.

The AHP results indicated that the prioritization of plastic waste management at Waste Bank Amal Haqiqi was influenced by four main criteria: social, technical, environmental, and economic, each weighted according to its relative importance. These criteria reflected the circular economy framework, emphasizing a multidimensional approach in which system success depended not only on economic feasibility and environmental impact reduction but also on operational readiness and community participation [44]. Based on the calculated weights and consistency tests, the social criterion held the highest priority (0.33), followed by the technical (0.30), environmental (0.27), and economic (0.10) criteria as shown in Figure 4.

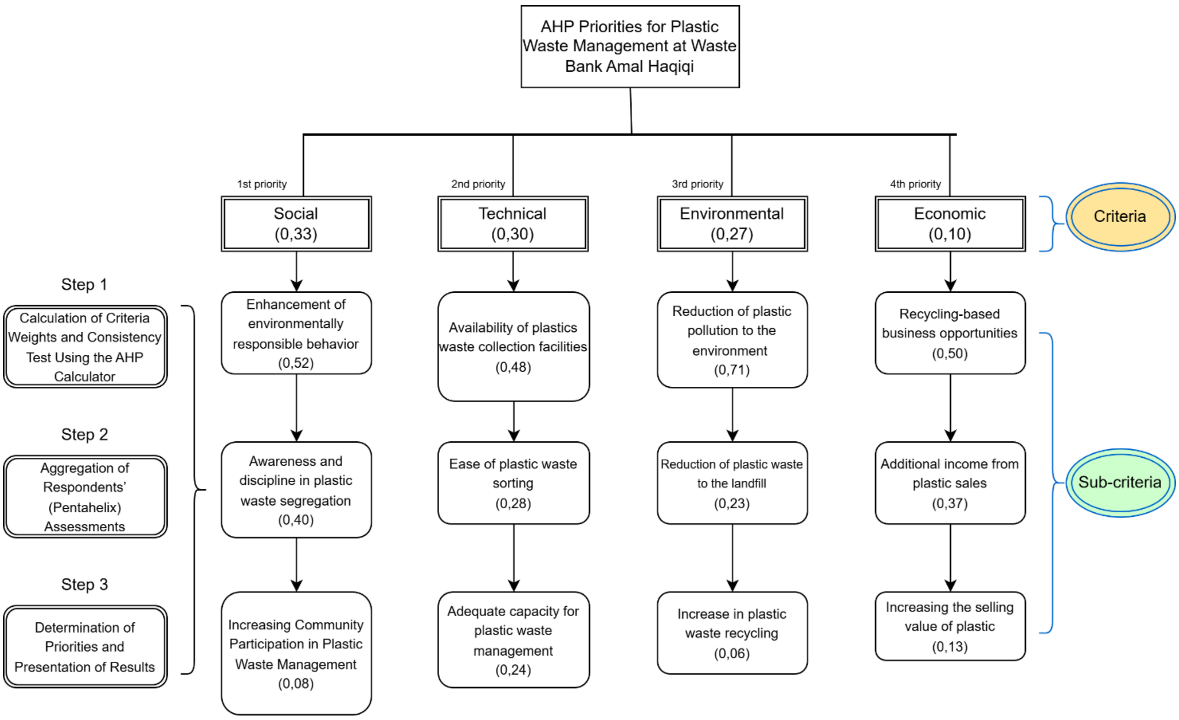

Figure 4. Presents AHP Hierarchical Structure and The Relative Weights of Criteria and Sub-criteria Used in This Study.

Within the social dimension, the sub-criterion of promoting pro-environmental behavior scored the highest (0.52), followed by awareness and discipline in sorting plastic waste (0.40) and increased community participation (0.08). This finding highlighted that long-term behavioral change, both at the individual and collective levels, was a key factor in successful plastic waste management, consistent with studies emphasizing the critical role of pro-environmental behavior and active community engagement in source-separated waste management systems [45]. For the technical dimension, infrastructure readiness and operational capacity were prioritized, with the availability of plastic waste collection facilities (0.48) receiving the highest weight, followed by ease of sorting (0.28) and adequate management capacity (0.24). These results underscored that community participation alone was insufficient without supporting technical facilities, aligning with the literature that highlighted the importance of integrating user behavior with technical system readiness, particularly at community and urban scales [46].

In the environmental dimension, reducing plastic pollution in the environment was the top priority (0.71), followed by minimizing plastic waste sent to landfills (0.23) and increasing recycling rates (0.06). The high weight assigned to pollution reduction indicated that immediate environmental impacts strongly influenced decision-making, while the relatively lower emphasis on recycling reflected local constraints related to technical capacity and recycling markets. This pattern was consistent with waste management hierarchies that prioritized prevention and environmental impact mitigation [47].

Finally, the economic criterion received the lowest overall priority (0.10), with recycling-based business opportunities (0.50) ranked highest, followed by additional income from plastic sales (0.37) and increasing the selling value of plastic (0.13). This suggested that financial incentives were secondary to social and environmental objectives, reinforcing the view that waste banks primarily functioned as instruments for social and environmental change rather than purely economic entities, particularly in rural and semi-urban communities. All Consistency Ratio (CR) values obtained from each respondent were below the established tolerance threshold (≤ 0.10), indicating acceptable consistency in the pairwise comparisons. All Consistency Ratio (CR) values obtained from each respondent were below the established tolerance threshold (≤ 0.10) as shown in Table 5. This indicated that the pairwise comparison judgments provided by the respondents were consistent and methodologically acceptable [48]. Therefore, the evaluation data were considered valid and reliable for subsequent analytical stages, particularly for weighting criteria and sub-criteria using the selected AHP procedure.

Table 5. Consistency Ratio (CR) test for respondent judgments.

Responden	**Kriteria (Social, Technical, Environmental, Economic)**	**Subcriteria (Social)**	**Subcriteria (Technical)**	**Subcriteria (Environmental)**	**Subkriteria (Economic)**	**Description**
R1	0,056	0,056	0,056	0	0,056	Consistent
R2	0,056	0,056	0,056	0,056	0	Consistent
R3	0	0	0,037	0,056	0,056	Consistent
R4	0,056	0,056	0	0,039	0,039	Consistent
R5	0,084	0,084	0	0,056	0,039	Consistent
R6	0,077	0,077	0,01	0,056	0,01	Consistent
R7	0,01	0,01	0,056	0,056	0,01	Consistent
R8	0,039	0,039	0,056	0,039	0,01	Consistent
R9	0,019	0,019	0,037	0,039	0,007	Consistent
R10	0,003	0,003	0,056	0,04	0,056	Consistent
R11	0	0	0	0,074	0,037	Consistent

3.5. Implications of AHP results for pentahelix stakeholders

The dominance of the social criterion in the AHP results indicated that the success of plastic waste management at Waste Bank Amal Haqiqi was largely determined by human factors, particularly community behavior, awareness, and participation. This finding implied that effective circular economy implementation depended more on strengthening social engagement and institutional support than on technical or economic interventions alone. Previous studies had emphasized that continuous facilitation and social capacity building were key determinants of successful waste management systems in developing countries [30].

Based on the AHP results, the roles of pentahelix actors should be strategically aligned to reinforce the dominant social dimension. Government institutions functioned as facilitators rather than solely as regulators, ensuring sustained community support. Academics contributed through scientific guidance and periodic evaluation, while waste bank management played a central role in maintaining communication, trust, and service consistency to sustain participation. Communities acted as the primary agents of behavioral change, and the business sector supported long-term operational sustainability through stable partnerships [49].

This integrated approach was consistent with previous findings highlighting the importance of social interaction, institutional support, and inclusive governance in community-based waste management systems [50]. Consistent community engagement and collaboration with local government significantly influenced recycling effectiveness and waste reduction in community-based programs, emphasizing the need for enabling institutional frameworks [51]. The implications of the AHP results for pentahelix stakeholder roles are summarized in Table 6.

Table 6. Implications of AHP results for pentahelix stakeholder roles.

Pentahelix Actor	Strategic Role
Government	Continuous facilitation and support for source-level waste segregation
Academics	Knowledge provision and data-based performance evaluation
Waste Bank Management	Social mobilization and operational coordination
Community	Behavioral change and consistent participation
Business Sector	Market support for recycled plastic value chains
Media	Communication and public awareness enhancement

4. Conclusions

Integrating the findings from both MFA and the Analytic Hierarchy Process (AHP), several critical conclusions regarding plastic waste management at Waste Bank Amal Haqiqi were established. The MFA revealed a robust operational capacity with a recycling rate of 77%, demonstrating the facility's effectiveness in diverting waste into the circular economy. However, a notable residue rate of 3.7% (241.14 kg) emerged from internal processes, indicating challenges in sorting efficiency and secondary processing capacity. To address these operational gaps, the AHP evaluation identified the social criterion (0.33) as the primary strategic priority, specifically emphasizing the enhancement of environmentally friendly behavior (0.52). Technical optimization was also highlighted through the prioritization of technical aspects (0.30), with a particular focus on the availability of collection facilities (0.48). The synergy of these findings suggested that organized logistics and strengthened operational management could improve input control, thereby reducing residues generated during daily operations.Ultimately, the ideal management model for Waste Bank Amal Haqiqi required harmonizing operational management with collective community awareness through pentahelix collaboration. Future strategic policies should focus on two pillars: improving source-level sorting quality and optimizing downstream logistics. This integrative approach was expected to simultaneously elevate the recycling rate beyond 76% while minimizing internal residues, transforming the facility into a more efficient, sustainable, and economically viable system.

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Author Contribution

Nurfitriyani Purnamasari : Conceptualization, Methodology, Data Collection, Data Analysis, and Writing. Gemilang Lara Utama : Conceptualization and Supervision. Rizky Ramadhan : Conceptualization and Supervision.

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