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Solid Waste Management in a Context of Sustainability in the Sahuangal Community, Ecuador

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Abstract

In developing countries, where rural communities face limitations in terms of solid waste management (SWM), they often resort to practices such as prolonged storage and open burning. Proper planning helps reduce environmental, health, and economic impacts and moves towards more sustainable waste management. This study analyses SWM in the rural community of Sahuangal (Ecuador) and proposes a pilot management plan based on community participation. A three-phase methodology was applied: (i) preliminary analysis, surveys, and Strengths, Weaknesses, Opportunities and Threats (SWOT-TOWS) analysis; (ii) infrastructure design for the pilot plan, integrating the physical characterisation of waste for infrastructure sizing; (iii) economic- and financial evaluation and multicriteria prioritisation using the Analytic Hierarchy Process (AHP). The survey results indicate that 75.86% of households reported a predominance of organic waste, whereas the pilot-level characterisation conducted in a typical household identified an organic fraction of 69.81%. The SWM pilot plan is cost-effective and, by relying on small-scale infrastructure built with local materials and community labour, incorporates social and environmental sustainability criteria. The combination of SWOT-TOWS analysis with AHP emphasised community participation, the viability of composting, and the recovery of recyclables as the predominant criteria, suggesting that the plan can be adapted to other rural communities with similar conditions.

Keywords: circular economy; rural areas; citizen participation; community recycling; socio-environmental impact; sustainable development

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1. Introduction

Over time, human beings, as part of a system marked by disparity, have influenced their natural environment and developed their culture [1]. This process of interaction with nature and social relations has resulted in an accumulation of actions that generate solid waste, which represents a considerable challenge for communities, whether local, regional, national, or even global [2]. Faced with this reality, various strategies have emerged to address the problem and minimise its effects.

Solid waste management (SWM) is a growing challenge associated with urban development, aimed at reducing pollution, protecting health, and improving quality of life [3]. In previous decades, when the world population was smaller, SWM was not a significant

priority [4], and final disposal practices were more effective due to the ease of access to land designated for this purpose [5].

Globally, more than 2 billion tonnes of municipal solid waste (MSW) are produced each year from domestic, commercial, industrial, and institutional activities [6,7]. A study in Bangladesh found that in developing countries, residential activity is the predominant source of MSW, often accounting for more than half of total municipal waste [8]. According to the Global Waste Management Outlook 2024, nearly one-third of MSW worldwide is managed improperly (e.g., open dumping and uncontrolled burning). By 2025, this figure is expected to exceed 1.6 billion tonnes per year [9].

This inadequate management of MSW causes health and environmental impacts, such as contamination of water [10], soil [11], and air [12], as well as alterations to ecosystems, quality of life, and local development [13]. This problem leads to the spread of infectious diseases such as malaria [14], mainly affecting vulnerable groups living near uncontrolled landfills [15]. In addition, weak institutional management and technical resources limit the effectiveness of current systems [16,17].

On the path towards sustainable development, waste management has gained relevance due to growing academic interest in new methodologies [18], the impetus provided by organisations such as the United Nations (UN) through the Sustainable Development Goals (SDGs) [19], and the adoption of national SWM policies by governments [20]. In this context, SWM is consolidating its role as a link in fulfilling SDG 12, which focuses on promoting sustainable patterns of production and consumption. Its cross-cutting scope is also reflected in its contribution to SDG 11, relating to sustainable cities and communities, as well as SDGs 6 and 13, by influencing water quality, reducing inappropriate discharges, and reducing emissions linked to poor waste management.

Proper MSW management promotes the use of waste as an energy resource (20–30% recovery in developed countries) and contributes to job creation, with an estimated potential of 6–7 million net jobs globally by 2030 [21–23]. Likewise, the organic fraction of municipal waste offers additional recovery opportunities, not only through conventional processes such as composting or anaerobic digestion, but also through biotechnological routes to obtain products of higher added value. In this regard, Marchetti et al. [24] demonstrated that industrial bread waste can be converted through acidogenic fermentation into solutions rich in organic acids with potential applications in circular value chains. Thus, strategies for separation at source and decentralised management can act as upstream tools that improve substrate quality and facilitate downstream advanced recovery processes.

Countries such as Germany, South Korea, and Denmark have translated conceptual advances into concrete practices, establishing global benchmarks in waste management aligned with the SDGs. Germany achieved a recovery rate of 98% for municipal waste in 2022, with 67.69% recycled and 30.19% incinerated with energy recovery, according to the German Federal Statistical Office [25]. South Korea implemented mandatory sorting policies and waste volume-based fees, achieving a food recycling rate of 90% [26]. Denmark reports that 50% of MSW was recycled or prepared for reuse in 2022. On the other hand, the remaining waste was mainly managed through energy recovery, maintaining minimum landfill levels [27].

In Latin America, countries such as Colombia, Bolivia, and Brazil have made progress in SWM, although structural challenges remain. In Colombia, waste recovery increased from 8.7% in 2016 to 53.4% in 2021 after implementing the Comprehensive Solid Waste Management Plan (CSWMP) and circular economy approaches [28,29]. Bolivia, with recycling rates of 10–15%, has proposed increasing this figure to 25% through selective collection and collaboration across sectors [30,31]. In Brazil, sustainable production and consumption policies have been promoted, notably the inclusion of recycling cooperatives

that contribute to waste management [32,33]. These cases reflect a progressive transition towards more sustainable management models adapted to local contexts.

Ecuador has developed policies and regulations for SWM, highlighting the Organic Code of Territorial Organisation, Autonomy and Decentralisation (COOTAD—acronym in Spanish) [34]. This legal framework, based on Articles 136, 137, and 431, establishes municipalities' responsibility for integrated waste management and promotes inter-municipal cooperation to optimise services [35,36]. It is estimated that solid waste generation in the country is approximately 0.58 kg per inhabitant per day, underscoring the importance of improving waste collection, treatment, and final disposal systems [37,38].

Although public policies guide the institutional framework, the sustainability of SWM programmes depends largely on citizen participation, as this encourages responsible practices and strengthens social capital within communities [39,40]. At the household level, this participation reduces waste generation and raises awareness of local problems [41]. In the Ecuadorian Amazon, the 'Río Blanco' community has proposed a composting and recycling system that allows for the reuse of around 76% of domestic waste and a 24% reduction in the amount sent to landfill [42], showing that community empowerment contributes to both environmental sustainability and local socio-economic development. In Istanbul, Turkey, citizen participation in recycling has been effective through economic incentives, with the income being allocated to public spaces [43]. This evidence shows that a lack of social involvement hinders the implementation of policies and exacerbates environmental impacts [44,45].

The case study focuses on the community of Sahuangal, located in the parish of Pacto, Pichincha province, Ecuador. This community faces SWM problems, such as uncontrolled dumping, waste burning, and dumping untreated organic waste, which affect soil [46], health, and the environment [16,47]. It is essential to establish an appropriate management model that addresses these issues, promoting environmental sustainability and the well-being of the population. The study seeks to answer the research question: How can SWM in the context of sustainability contribute to the recovery and use of waste in the community of Sahuangal, Pichincha? The objective is to develop a community-based SWM pilot plan to promote guidelines that strengthen the separation, recovery, and utilisation of waste generated in the Sahuangal community. This plan integrates the diagnosis obtained through surveys and Strengths, Weaknesses, Opportunities and Threats (SWOT-TOWS) analysis, together with the technical-environmental assessment that covers the physical characterisation of solid waste and the pilot design of operational alternatives (temporary collection infrastructure and community composting), as well as an economic analysis that supports the formulation of the guidelines. Complementarily, the Analytic Hierarchy Process (AHP) method is used to prioritise the strategic actions derived from the expert analysis.

2. Materials and Methods

The study adopted a mixed-methods approach, combining qualitative and quantitative tools across three phases of development (Figure 1). In the first phase, oriented to the case study analysis, surveys were conducted with community residents to analyse their knowledge of waste separation, the frequency of waste generation, and the main difficulties in its management. Based on these results, a SWOT-TOWS analysis was conducted to identify the internal (strengths and weaknesses) and external (opportunities and threats) drivers affecting local waste management, generating a participatory diagnosis that reflects the conditions and perceptions of the population, facilitating the formulation of strategies aligned with the identified needs [48].

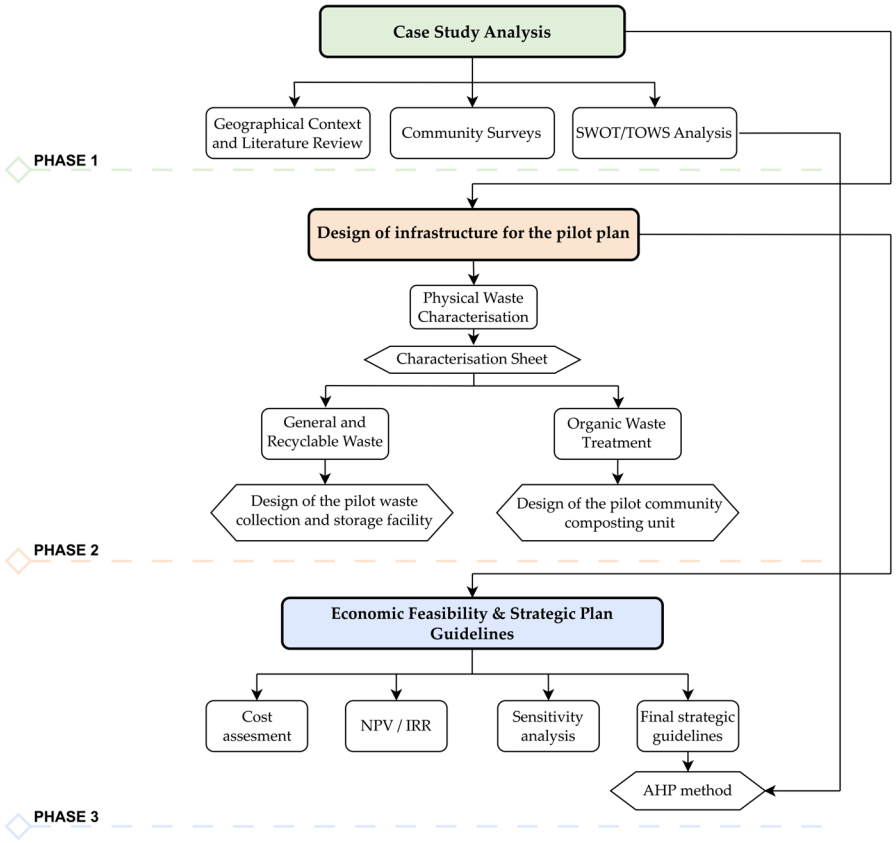

Figure 1. Phased approach for formulating the SWM pilot plan.

The second phase involved designing infrastructure for the pilot plan, including characterising solid waste generated in the community using a physical solid waste characterisation data sheet. Pilot collection infrastructures were designed for recyclable and non-recyclable waste, as well as a community compost bin for organic waste. All proposals were adapted to the community's operational capacity and available local resources. In the third phase, an economic and financial assessment was carried out. The costs of implementing and maintaining the proposed infrastructure were analysed, together with the potential income from the sale of recyclables and compost [49]. The results were integrated with the SWOT-TOWS analysis. This exercise was complemented by the application of the AHP method, which enabled the weighting and prioritisation of strategic factors through expert judgement, thereby reinforcing objectivity in the formulation of the SWM pilot plan guidelines [50]. The results of each phase were integrated into a community management proposal focused on environmental sustainability and waste harvesting in the community.

2.1. Phase I: Analysis of Case Study

2.1.1. Geographical Context and Literature Review

The Sahuangal community is located at the Andean region of Ecuador (Figure 2), with an estimated altitude of 600–800 m above sea level [51] and population of 708 inhabitants [52]. The local climate is tropical megathermic humid, characterised by high rainfall (>2000 mm per year) and average temperatures between 20 °C and 22 °C, as observed in the climate typology of the lowest areas of the Metropolitan District of Quito (DMQ, acronym in Spanish) [53]. The study site is part of the Andean Chocó, recognised by UNESCO as a Biosphere Reserve for its high biodiversity and its vulnerability to anthropogenic pressures [54,55], underscoring the need to implement more sustainable management practices that reduce environmental impacts on this ecosystem.

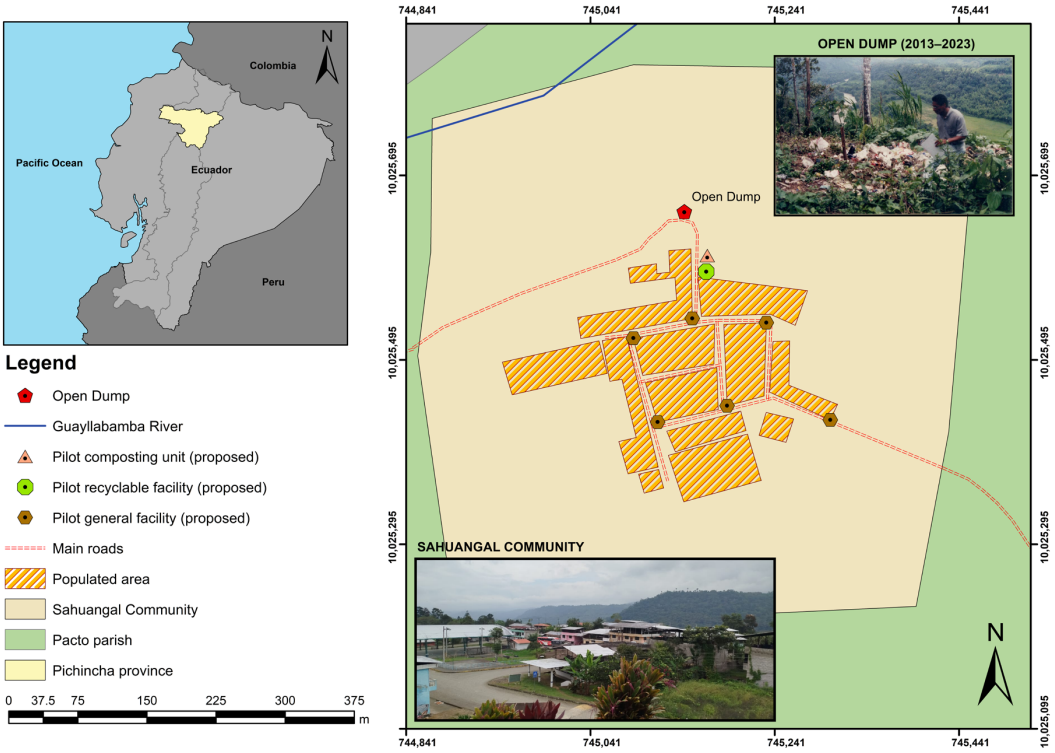

Figure 2. Geographical location of the Sahuangal community, Pacto parish, Pichincha province.

This section also included a literature of community experiences with SWM in rural areas of Ecuador. In San Andrés parish, Chimborazo province, agricultural waste generated by local producers was characterised, concluding that it had the appropriate physical and chemical conditions for composting, validating its potential as a source of organic fertiliser at the community level [56]. Furthermore, in agricultural communities in the Chimborazo province, composting was evaluated as a strategy for horticultural waste management, demonstrating its technical feasibility and contribution to local cooperatives' self-sufficiency in agricultural inputs [57]. In rural communities on the Ecuadorian coast, local models for source-separated waste collection and the recovery of recyclable materials were implemented, improving waste recovery and strengthening coordination among community actors and local institutions [58]. The population of this case study faces persistent challenges with SWM, despite an established collection system coordinated with the municipality that operates every 15 days. One of the main problems is the prolonged accumulation of waste in homes, especially during the rainy season, when landslides block access roads and disrupt services.

2.1.2. Calculation of Representative Sample for Surveys

Surveys were conducted on a representative sample of the inhabitants of the Sahuangal community. The survey information was collected in person at the selected households. The instrument consisted of 27 questions, divided into 11 closed-ended multiple-choice questions, 10 dichotomous questions (yes/no), 3 questions with a numerical rating scale, and 3 open-ended questions (Table S1 in Supplementary Materials). These simplified response formats were accompanied by simple language and practical examples to facilitate understanding. The survey was organised into six sections: (i) Respondent consent; (ii) General information; (iii) Physical characterisation of solid waste; (iv) Current SWM practices; (v) Perception of SWM; and (vi) Circular economy criteria in SWM.

To calculate the representative sample for the survey, the total population was defined as the number of households (N = 115) [52]. This sample selection is justified given that

the SWM is conducted at the household level, a methodological approach that is used in other community contexts. In rural research, households have been used as the basis for calculating sample size, as they represent an appropriate unit for collecting information on community practices and household services [59]. A representative sample was calculated using stratified probability sampling [60] and the formula for finite populations (Equation (1)), recommended for small-population studies [61].

$$n = \frac{z^2 \times p \times q \times N}{\varepsilon^2 \times (N-1) + z^2 \times p \times q} \quad (1)$$

$$n = 58$$

where

z = 1.28 (z-value associated with 80% confidence);
p = 0.5 (probability of success);
q = 0.5 (probability of failure);
N = 115 (total population − total dwellings);
ε = 0.06 (margin of error).

The resulting representative sample (n = 58) was limited to the central area of the community (urban center), encompassing 62 dwellings, excluding unoccupied dwellings. There were no refusals to participate, nor was it necessary to apply adjustments for non-response. The sample size was calculated with an 80% confidence level (z = 1.28). Similar studies used this confidence level due to field or resource limitations [62]. In the present case study, the criteria adopted for selecting the confidence level are detailed below: (i) Accessibility restrictions to peripheral dwellings; (ii) The pilot nature of the study (no previous studies on SWM have been recorded); and (iii) Presence of vacant dwellings associated with migration processes to urban areas.

Given that the survey was conducted in person, the validation process was carried out considering three aspects: (i) prior explanation of the study context and types of questions, (ii) clarification of doubts at the time of the survey, and (iii) accompaniment of respondents to avoid incomplete or inconsistent responses. Likert scales were not used because, in populations with limited literacy, they can cause comprehension difficulties and reduce the ability to discriminate between response categories adequately, increasing measurement error [63].

2.1.3. Analysis of Internal and External Factors

A SWOT-TOWS matrix was developed, a qualitative tool that enables the identification of internal and external factors to establish strategic guidelines [64]. This matrix was constructed based on a systematic analysis of the results of the household survey, which collected: (i) sociodemographic information; (ii) local SWM practices; (iii) level of knowledge about organic and inorganic waste; (iv) perception and willingness to separate waste at source; and (v) circular economy practices. Internal factors (strengths and weaknesses) were derived from the practices, knowledge, and limitations reported by households. External factors (opportunities and threats) were identified by considering community willingness, expectations for improvement, territorial conditions, and institutional factors identified during the information-gathering process.

2.2. Phase II: Infrastructure Design for the Pilot Plan

The assessment was based on criteria of operational feasibility, environmental sustainability, and suitability for the community context, prioritising the optimisation of SWM over the construction of large-scale infrastructure. Among other aspects, the following considerations were considered: (i) the availability, type, and volume of solid waste identified

in the physical characterisation; (ii) ease of construction and maintenance; (iii) the use of local materials and community labour to reduce costs; (iv) safety and public health considerations in waste handling and storage; and (v) environmental compatibility, prioritising low-impact practices such as composting and separation at source. The established aspects were translated into pilot waste storage and composting infrastructures adapted to the case study's geographical, social, and economic conditions (Figure 3), with technical designs developed in AutoCAD 2025 (Version 58.0.0) [65].

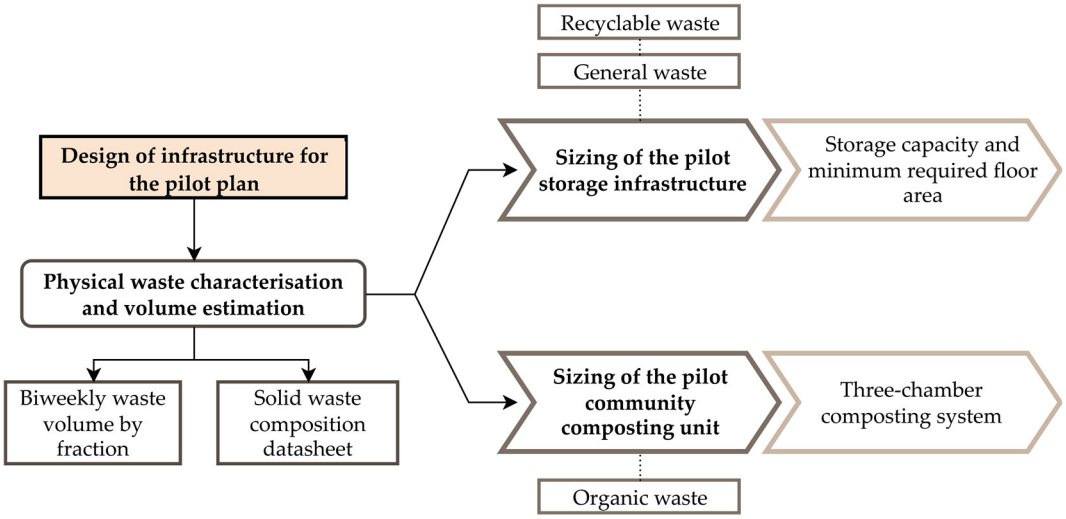

Figure 3. Diagram of the technical design and pilot process for community collection and composting infrastructure.

2.2.1. Physical Characterisation of Solid Waste

At this stage, a data sheet was developed to determine the types and sub-types of waste generated by the typical household in the community, quantifying their proportion by weight and their temporal variation over two weeks (Table S2 in Supplementary Materials). The data sheet was designed in accordance with ASTM D5231-92 [66], which establishes the procedure for determining the composition of MSW through sampling and manual segregation. To complement the characterisation data sheet, bulk density values reported in the scientific literature for waste fractions with similar characteristics were consulted to estimate the equivalent volume of each component. The data were primarily drawn from the Environmental Protection Agency (EPA) report, Volume-to-Weight Conversion Factors [67,68], which is widely used in MSW [69].

2.2.2. Pilot Proposal for Storage Infrastructure

The pilot proposal was based on international standards adapted to the rural context, recognising that the community of Sahuangal lacks formal infrastructure for temporary waste storage before collection. The sizing was based on the physical characterisation of solid waste, enabling estimation of the relative proportions of general, recyclable, and organic waste, in accordance with local disposal practices and the biweekly collection system. To estimate the volume of waste to be stored, the Space Guidelines for Recycling, Organics, and Refuse Services for Designers of Multifamily & Commercial Buildings [70], were used, considering the proportions of each solid waste fraction and calculating the required number of standard containers for general and recyclable waste fractions. In calculating the total physical volume required for the collection infrastructure, the standardised container dimensions (footprint and height) were considered, as specified in the Solid Waste Storage Technical Design Guidelines [71].

2.2.3. Pilot Proposal for a Community Compost Unit

The design of the community composting unit was based on adapting the technical and construction methodologies described in three reference documents. The Farmer's Composting Manual [72] was used to identify the composting process stages and the management criteria required to ensure stability, adequate ventilation, and leachate control. The Guide to Community Composting [73] provided guidelines on the minimum capacity of modules per container to ensure the initiation of the biological process and proper operation in three-chamber systems. Finally, the Manual for Composter Construction [74] served as a practical guide for defining the characteristics of the pilot infrastructure, including the use of local materials (wood and wire mesh). International evidence indicates that community composting schemes can reduce operational costs and emissions while demonstrating high social acceptability, thereby providing empirical insights into design and operational parameters [75].

2.3. Phase 3: Economic and Financial Assessment and Formulation of Strategic Guidelines

The assessment was based on a circular economy model that valorises organic and recyclable waste as local resources, thereby reducing final disposal costs and generating sustainable economic benefits. Findings from the preceding phases, together with the incorporation of the AHP method, informed the formulation of the guidelines.

2.3.1. Cost Assessment, Financial Indicators and Sensitivity Analysis

Direct costs associated with the construction and outfitting of the pilot infrastructure (two community composting units, each comprising three chambers, and a recyclable waste collection point) were estimated, using locally available bamboo and timber to reduce acquisition and transport costs relative to metal structures. These cost estimates were then used to develop cash flow projections over the analysis horizon, incorporating potential revenues from the economic valorisation of glass, plastic, and aluminium, alongside revenues from the sale of compost produced. Financial feasibility was evaluated using Net Present Value (NPV) and the Internal Rate of Return (IRR), which indicate whether future benefits offset the initial investment and provide an estimate of project profitability [76,77]. In addition, a sensitivity analysis was conducted, considering revenue reductions from 0% to −20% (for compost and recyclable materials) and total cost increases from 0% to +50% (construction, maintenance, transport, and labour). These analyses identified the ranges within which the NPV remained positive, and the IRR exceeded the social discount rate, thereby assessing the project's economic robustness under adverse scenarios [78].

2.3.2. Strategic Guidelines (SWOT-TOWS and AHP Methods)

Findings from the preceding phases were integrated to consolidate the strategic guidelines for the SWM pilot plan, aligning these with strategic planning frameworks applied to community-based management systems, in which sustainability is evaluated in social, environmental, and economic terms [79,80]. The AHP method was used to assign weights to the strategic factors identified through the SWOT-TOWS analysis and thereby prioritise the plan's lines of action. AHP is a multicriteria decision-making technique that structures a problem hierarchically into criteria and sub-criteria, deriving weights through pairwise comparisons [81]. Although it originally uses the Saaty scale (1–9) [82], this study used reduced comparison scales of 1–5 and 1–6, which retain the fundamental preference structure of the original method. This adaptation reduced the cognitive load on the experts. It improved the consistency of judgments in a community-based pilot context by adjusting the level of discrimination based on the type of criterion, as reported in recent applications of AHP in waste management [83,84]. panel of six experts was selected based on the following inclusion criteria: (i) academic training in SWM or related environmental fields;

(ii) direct participation in planning, implementation, or research processes at the local or community level; and (iii) at least 2 years of experience in SWM or related environmental areas. Compliance with the expert panel criteria is summarised in Table 1.

Table 1. Selection criteria of experts for AHP analysis.

EN *	Criteria 1	Criteria 2	Criteria 3
1	Geotechnic applied to SWM	Academia/research	7 years
2	Geodesy applied to SWM	Public sector/NGO	20 years
3	Environmental field	Academia/research	5 years
4	SWM in public health	Public sector/government	2 years
5	Sanitation applied to SWM	Academia/research	3 years
6	Land use planning and governance	Academia/research	15 years

* Note: EN: Expert number; NGO: Non-governmental organization.

Data were collected through a structured survey administered via Google Forms (Table S3 in Supplementary Materials), focusing on the relative importance of community participation, implementation barriers, the feasibility of community composting, the commercialisation of recyclable materials, and design criteria for waste storage and composting infrastructure. The judgments issued by the experts were aggregated using the arithmetic mean to construct two final pairwise comparison matrices (pilot infrastructure design and strategic criteria of the plan), from which the weights were obtained using the normalised eigenvector method. The consistency of the assessments was verified by calculating the Consistency Index (CI) and the Consistency Ratio (CR) with Equations (2) and (3), respectively. The CI was defined as a function of the matrix's maximum eigenvalue and the number of criteria [85], and was calculated using the following equation:

$$CI = \frac{\lambda_{mx} - n}{n - 1} \quad (2)$$

where:

λ_{mx}: maximum eigenvalue of the matrix;

n: number of elements/criteria compared.

Whereas the CR was obtained by comparing the CI with the Random Index (RI), enabling an assessment of whether the comparison pattern is acceptable [86]. The CR was computed as follows:

$$CR = \frac{CI}{RI} \quad (3)$$

where:

CI: obtained from Equation (2);

RI: random index reported by Saaty.

Only matrices with a CR ≤ 0.10 were accepted, consistent with classical AHP recommendations and recent methodological reviews [87,88]. Strategic guidelines were then formulated using the derived weights.

3. Results

3.1. Community Perspective Analysis in SWM

Survey data from 58 households characterised Sahuangal as an agricultural community, with farming as the primary livelihood for 68.97% of families, aligning with the predominance of organic waste (75.86%) reported by the community (mainly food scraps and crop waste). Inorganic waste is dominated by plastics, with proportions far exceeding those of glass or metals. The most widespread practice for organic waste is its use as rudimentary fertiliser (91.38%) (Figure 4b), indicating an incipient, non-mechanised form of valorisation. By contrast,

the management of recyclables is limited: seven in ten households discard them with mixed household waste (Figure 4c). Nevertheless, there is unanimous agreement on the importance of source separation (100%) and a high willingness to participate in collective programmes (93.10%). This context indicates potential to strengthen composting and the commercialisation of materials, provided that structural constraints such as the absence of separate collection systems and limited training provision are addressed (Figure 4a).

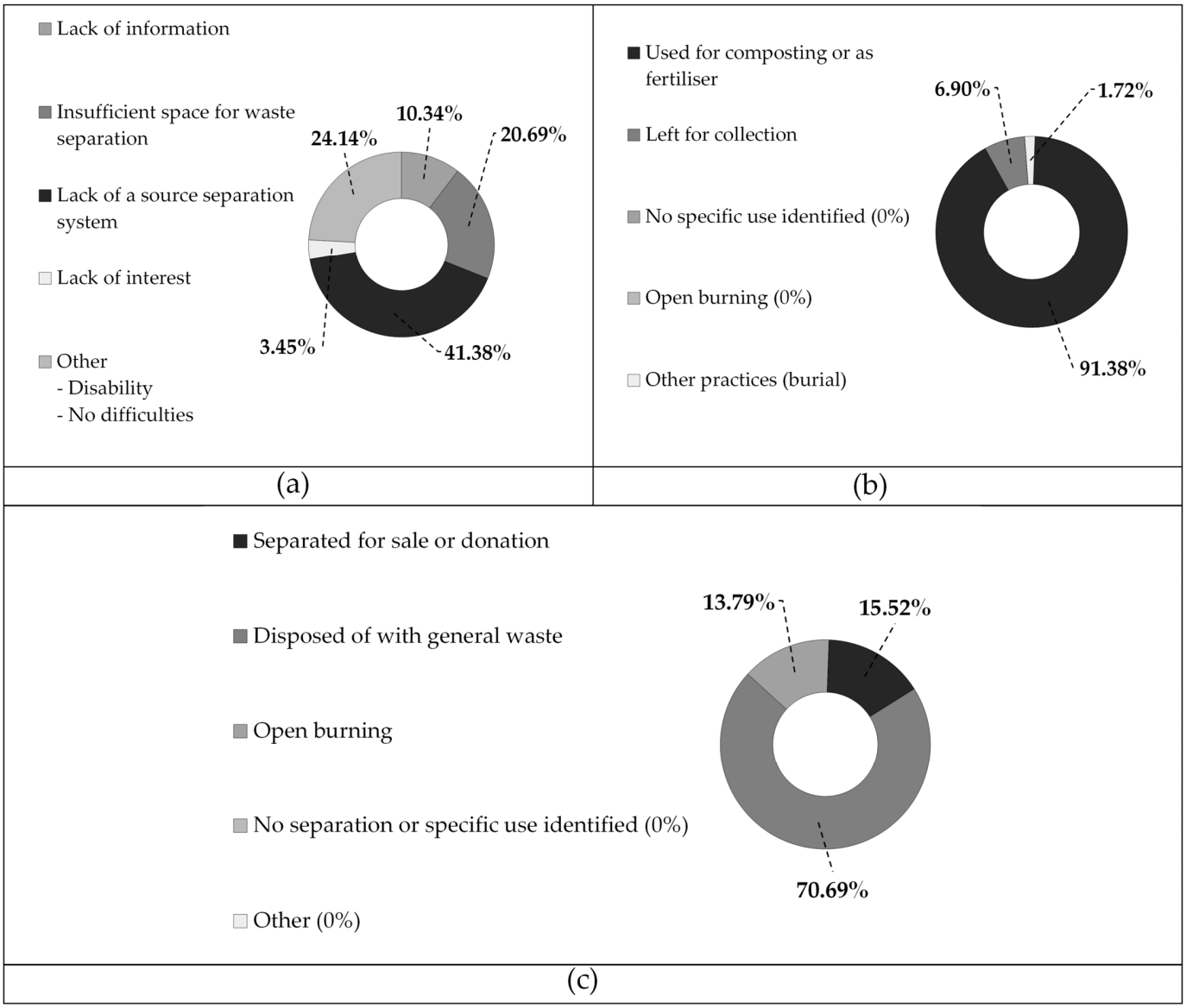

Figure 4. Community perspectives on SWM practices: (**a**) key barriers to implementing source separation; (**b**) current organic waste management practices; and (**c**) management practices for recyclable inorganic waste.

3.2. SWOT-TOWS Matrix

The survey findings were incorporated into the SWOT matrix developed from the survey results (Table 2). The implementation of community waste storage infrastructure and the treatment of organic waste constitute the most consistent strategies for advancing SWM. In the former, the community's willingness to commercialise recyclables (S5) and interest in separating plastics (O2) intersect with the weakness that most recoverable materials are mixed with residual household waste (W3), as well as the threat of waste being dispersed in public spaces by animals (T3).

Table 2. SWOT matrix based on survey results in the community.

Strengths (S)	Opportunities (O)
S1: High willingness among community members to participate in collective programmes (93.10%). S2: Widespread awareness of organic/inorganic waste separation (98.28%). S3: Rudimentary use of organic waste as fertiliser (91.38%), indicating an early adoption of resource recovery practices. S4: Population stability (31.03%), which favours the continuity of initiatives. S5: Interest in commercialising recyclables as an additional source of income (96.55%)	O1: Feasibility of community composting (75.86%). O2: Interest in separating recyclables, particularly plastics (53.45%). O3: Openness to training and control measures. O4: Potential for institutional support O5: A regional circular economy agenda providing strategic backing.
Weaknesses (W)	**Threats (T)**
W1: Low educational attainment (predominantly primary and secondary education). W2: Limited experience with recycling (89.66% reporting no prior participation). W3: High proportion of recyclables mixed with residual household waste (70.69%). W4: The absence of a separate collection system is perceived as a barrier by 41.38% of households. W5: Limited coverage of SWM training (24.14%).	T1: Disruptions to waste collection services. T2: Continued waste burning or burial (24.14%). T3: Stray dogs dispersing waste. T4: Remoteness from urban centres increases costs and reduces collection frequency. T5: Public health risks associated with prolonged waste storage.

3.3. Analysis of Solid Waste Composition

The typical household was selected considering the most common household size (3 to 4 persons per house) in the sample survey that is 62.07% of the surveyed population, therefore the typical household is representative. Additionally, many households were unable to undertake this due to constraints on space, time, and agricultural work, particularly given the absence of public lighting and the reliance on daylight hours for crop-related activities. In the typical household was developed a waste segregation and weighing over two consecutive weeks. Over the assessment period, a total of 17.18 kg of waste was recorded, corresponding to an estimated volume of 0.14 m^3, derived using reference bulk density values from Volume-to-Weight Conversion Factors [67,68]. Overall, the findings indicate substantial potential for organic waste valorisation through community composting, alongside the feasibility of implementing selective storage for recyclables (Table 3).

Table 3. Main types of waste generated in the typical household.

Components	Weight (kg)	Percentage (%)
Plastic	1.06	6.14
Food Waste	2.16	12.58
Other Organic Waste	9.83	57.23
Aluminium	0.78	4.54
Glass	3.35	19.51

Note: Percentages calculated based on the total weight of waste (17.18 kg) from the typical household.

Limitations and Pilot Nature of the Solid Waste Characterisation

The application of the waste characterisation form in the typical household constitutes a methodological limitation. Consequently, the quantitative results should be interpreted as exploratory and pilot findings, rather than as representative of the entire community. However, the selected typical household has characteristics consistent with the survey results among 58 household representatives in the urban area, particularly regarding family size and the predominance of agricultural activities as the main source of income. These conditions correspond to the majority profile of the urban area (68.97%), indicating consistency between

the unit analysed and the socioeconomic pattern identified in the sample. Although this does not allow statistical extrapolation of waste composition to the entire community, it does provide contextual consistency with the assumptions used for the pilot design.

3.4. Proposal for Community Waste Storage Infrastructure and Composting Units

In sizing this proposal, a waste ratio of 10/30/60 (garbage/recycling/organic) was adopted, which corresponds to a technical estimate derived from the physical characterisation of typical household solid waste and is used exclusively for the purposes of pilot design. The total estimated waste volume for the 58 households evaluated was 8.12 m^3, distributed in the selected ratio. International guidelines were considered to define the dimensions, number of containers, and collection frequency of the infrastructure. Standard 360 L containers were used, whose footprint (0.56 m^2) and height (1.13 m) correspond to a total volume of approximately 0.633 m^3 [71]. Based on this capacity, a requirement of 3 containers for general waste and 7 for recycling was determined. The organic fraction was excluded from the collection system because it was destined for composting. The waste containers were distributed across six decentralised stations, equivalent to an effective capacity of 0.3165 m^3 per station. Based on this volume, the dimensions of the collection modules for general waste were estimated (Figure 5a,b). At the same time, the proposed construction design, including materials, finishes, and spatial configuration, was presented (Figure 5c).

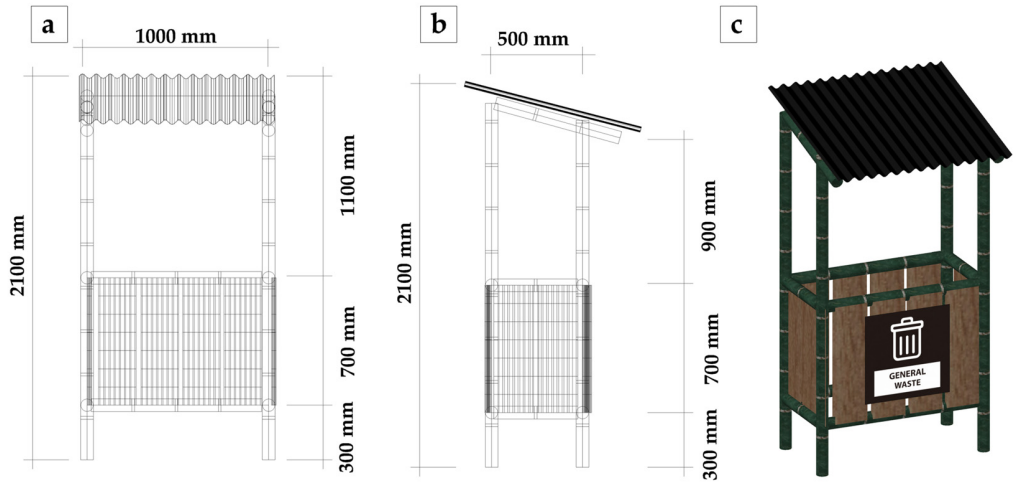

Figure 5. Design of pilot waste storage infrastructure for materials destined for collection: (**a**) front view—technical drawing; (**b**) side view—technical drawing; and (**c**) color isometric representation (render) of the final model.

The recycling fraction was centralised in a station with an aggregate capacity of 4.43 m^3, designed for the primary separation of glass, plastic, and aluminium. With the volume defined, the dimensions of the recyclables collection infrastructure were estimated (Figure 6a,b), and its structural configuration is presented in Figure 6c. Both infrastructures (Figures 5c and 6c) prioritise small–scale solutions that consider natural ventilation, accessibility, manual collection, and the use of low-cost local materials, adapting international guidelines to the operating conditions of a rural community.

The design adopts a modular structure that is low-investment and easy to maintain, intended to process the organic waste generated by the Sahuangal community within a decentralised and replicable system (Figure 7). The minimum capacity of each module was set at 1 m^3, consistent with the minimum volume recommended as a basic condition for ensuring appropriate biological process development [73]. The design comprises three independent modules, enabling rotation across the filling, maturation, and storage phases. Figure 7 presents the layout and indicative dimensions of the model, scaled to the estimated

organic waste generation from participating households, equivalent to approximately 8.86 m^3 (about 14 containers of 360 L).

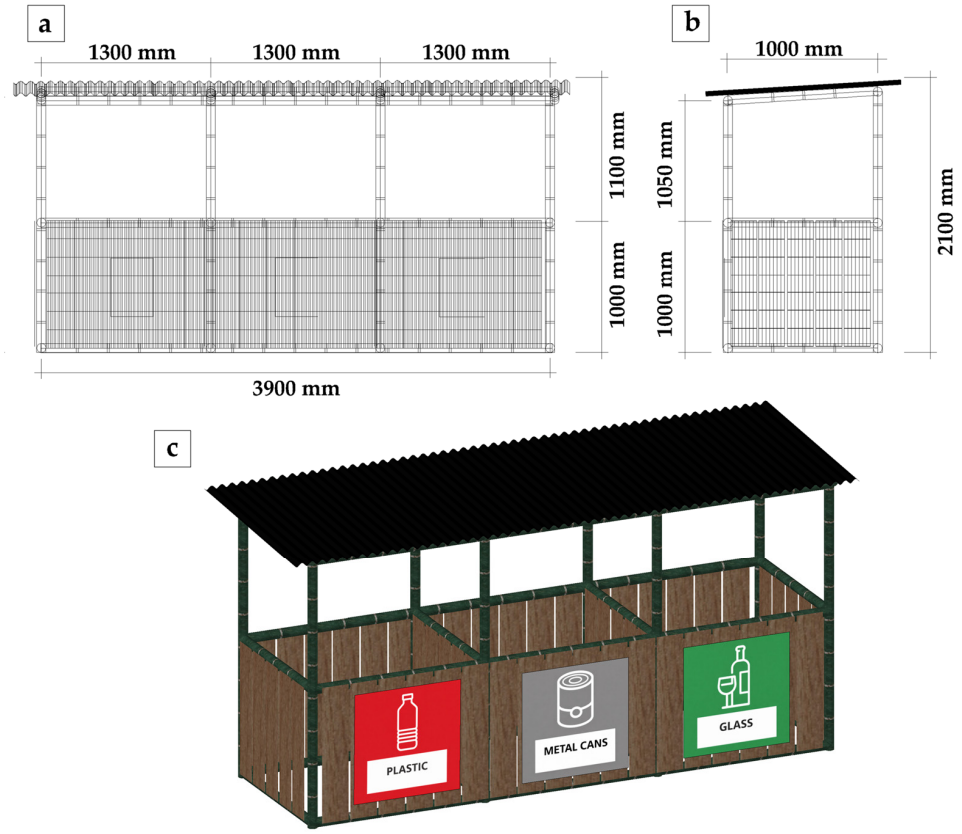

Figure 6. Design of pilot waste storage infrastructure for recyclables: (**a**) front view—technical drawing; (**b**) side view—technical drawing; and (**c**) color isometric representation (render) of the final model.

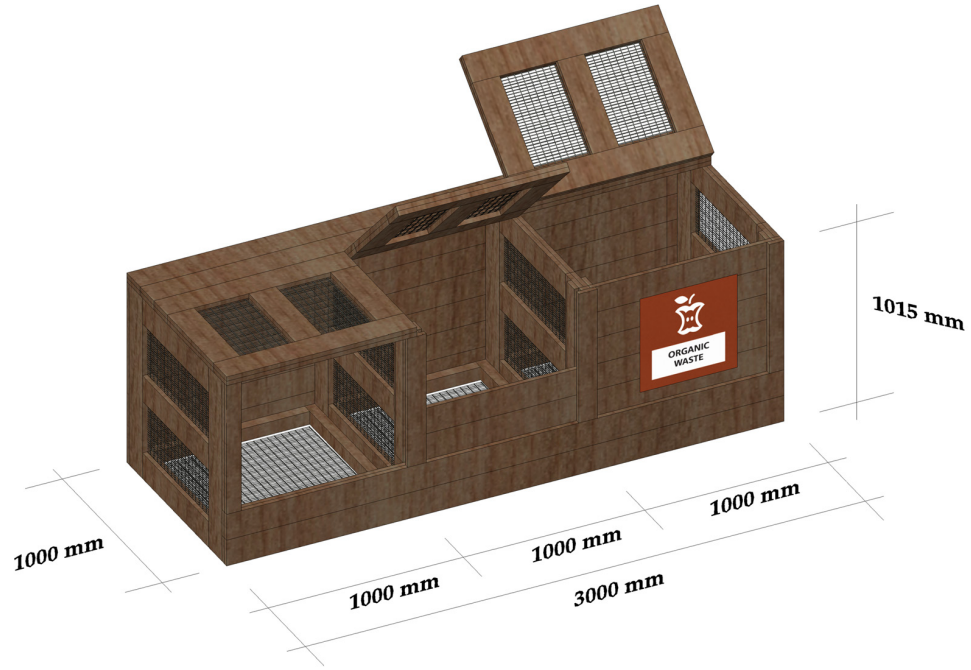

Figure 7. Design of the three-module community composting unit.

Proposed locations for these facilities within the community are shown in Figure 8, with consideration of the current waste collection vehicle route to facilitate access and system operation.

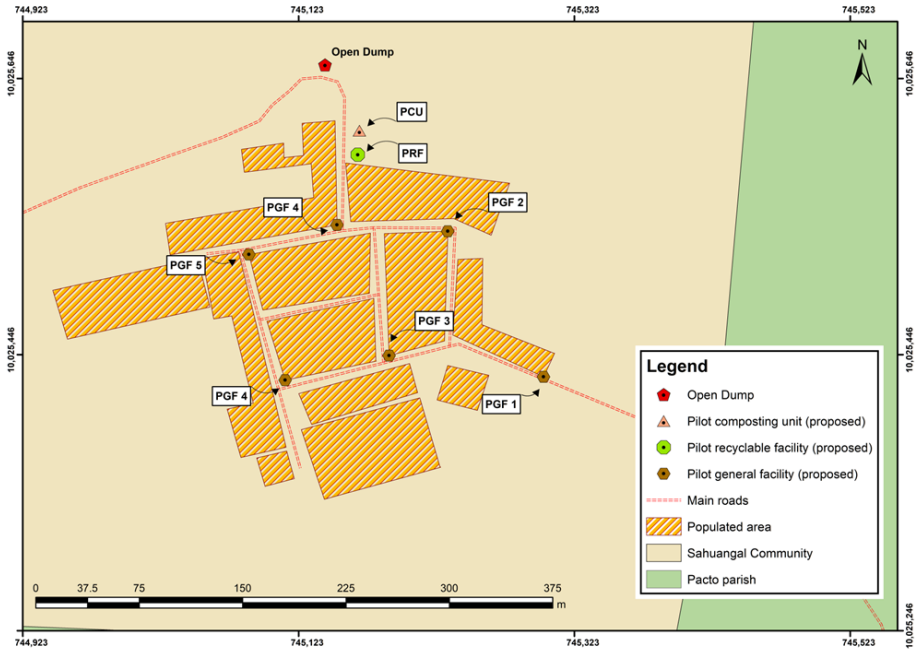

Figure 8. Spatial distribution of the proposed pilot waste storage and community composting infrastructures in Sahuangal.

3.5. Cost Assessment and Financial Indicators

The assessment was carried out over an analysis horizon (36 months), considering as initial investment the construction costs of two community composters, each with three modules, together with the collection infrastructure for recyclable materials. The recycling infrastructure will be implemented starting in month 18 to reduce the initial investment and allocate income from compost sales to the progressive financing of its construction. In the base budget, direct costs include local materials and community labour, in accordance with the prepared Unit Price Analysis (UPA). For the maintenance of the composters, 15% of the initial construction cost was considered, incorporating the maintenance and replacement costs (semiannual) necessary throughout the analysis horizon, as well as operating expenses such as tools, polyethene bags, labour for packaging, and transportation. The costs associated with the recycling infrastructure included personnel remuneration for the collection and classification of materials.

Operating income derives from two main sources: first, the sale of compost, set at USD 0.25/kg, a value defined based on an analysis of market prices in several provinces of Ecuador, where a marketing range between USD 0.13 and USD 0.95/kg [89] and an average price of USD 0.36/kg were identified. In this context, the adopted value corresponds to a conservative scenario, consistent with the project's pilot nature and rural market conditions. For the sale of recyclable materials, there are no official purchase and sale values established in Ecuador; for this reason, recent empirical evidence from studies conducted in the country and in Latin American markets with comparable structures, such as Colombia, was used, where reference price ranges are reported for glass (between 0.03 and 0.05 USD/kg), PET plastic (between USD 0.30 and USD 0.45/kg), and aluminum (between USD 0.60 and USD 1.30/kg), mainly associated with informal and mixed recycling schemes [90,91]. Based on this regional background and direct consultations with local informal recyclers, conservative values of \$0.03/kg for glass, \$0.66/kg for aluminium, and \$0.40/kg for plastic (PET) were adopted, reflecting actual market conditions characterised by high transportation costs, limited collection capacity, and reduced bargaining power. A static cash flow statement was prepared, integrating sales schedules, indirect costs, cumulative cash inflows and outflows over a 36-month horizon (Table 4).

Table 4. Summary of cost and revenue projection.

Project Period (Months)	0	18 *	36
Incomes (USD)	0.00	$1875.00	$4901.18
Expenses (USD)	$656.37	$1631.24	$2401.36
Net cash flow (USD)	−$656.37	$243.76	$2499.82
Current value (USD)	−$656.37	$220.23	−$656.37

Note: Estimation based on a 36-month horizon considering the progressive implementation of composting and recycling infrastructure. * Month 18 corresponds to the construction of the recyclable waste storage structure.

The analysis yielded a positive Net Present Value (NPV) of USD 246.69, an annual Internal Rate of Return (IRR) of 193.75%, and a return on investment of 104% over the assessment period (Table 5). A 7% discount rate was adopted, consistent with recent environmental project evaluations in Latin America [89]. These results confirm the project's economic viability and its potential to enable local reinvestment, supporting the progressive implementation of the pilot infrastructures in a rural context.

Table 5. Financial evaluation indicators.

Indicator	Unit	Value
Initial investment	USD	656.37
Discount rate	%	7
Present value of updated cash flows	USD	903.06
Net Present Value (NPV)	USD	246.69
Internal Rate of Return (IRR)/annual	%	193.75
Project profitability	%	104
Profit margin	%	51

The estimated IRR in the base scenario is significantly high due to the low initial investment, the phased infrastructure implementation, and the short analysis horizon (36 months), which concentrates returns over a short period and raises the IRR. However, the literature points out that the IRR may have interpretative limitations in projects with: (i) specific cash flow structures; (ii) small scales. The consistency of this analysis should be evaluated against the NPV criterion, which is considered a more consistent measure for comparing alternatives [92–94]. Therefore, the interpretation of the financial performance of the proposed pilot plan is based mainly on the NPV and sensitivity analysis.

Business as Usual

This scenario represents current SWM practices in the community, in the absence of the proposed project. Under this scenario, recyclable materials are mixed with general waste and collected without prior separation. In contrast, the organic fraction (approximately 60% of the total waste volume) is informally reused as compost, without treatment or control of the process. Although this practice aligns with local agricultural practices, it does not enable the economic recovery of waste. It may pose environmental and health risks due to the lack of stabilisation and sanitation processes. For the post-BAU scenario (pilot proposal), with no changes in costs or sales, the cash flow shows an initial period without income during the first four months, due to delays in infrastructure implementation, the start of production, and compost marketing. However, the initial investment is recovered in month 11, with a cumulative balance of USD 62.72. In month 18, the balance rises to USD 243.76, as the accumulated income is allocated to the construction of the recyclable materials collection station. At the end of the analysis period (36 months), the accumulated balance reached USD 2499.82. This proposal enabled 90% of organic and recyclable waste to be reused, allowing compost to be used safely in agricultural activities and partially commercialised to generate economic benefits for the community.

3.6. Sensitivity Analysis

In the base scenario (0% variation), the NPV remained positive up to an approximate 20% increase in costs and a 10% reduction in revenues. In this analysis, the increase in costs includes investment, labour, transportation, and logistics costs. At the same time, the revenue reduction reflects lower demand and unfavourable prices for recyclable materials, consistent with rural market conditions. Above these thresholds, the NPV becomes negative, indicating the point at which the project becomes unprofitable. The heat map (Figure 9) shows a gradual transition from high-profitability scenarios to areas of economic loss, clearly identifying the critical viability thresholds. The values shown were calculated using the formal NPV expression presented in Equation (4) [95], with simultaneous percentage changes in income (RV) and costs (CV) over a 36-month horizon. The most unfavourable scenario showed a 50% increase in costs and a 20% reduction in prices, resulting in a negative NPV. These results confirm the economic resilience of the model, which remains viable under moderate fluctuations in key parameters, an aspect that is particularly relevant in rural contexts.

$$NPV = \sum_{t=0}^{n} \frac{[PR_t(1+RV) - PC_t(1+CV)]}{(1+i)^t} \quad (4)$$

where:

PR_t: Partial revenues in period t;
PC_t: Partial costs in period;
RV: Revenue variation (0% to −49%);
CV: Cost variation (0% to 50%);
i : Discount rate (7%);
t : Monthly cash flow period;
n : Evaluation horizon 36 months.

CV (%)	Revenues variations (%)											
	0	−2	−4	−6	−8	−10	−12	−14	−16	−18	−20	−49
0	246.69	218.10	189.50	160.91	132.32	103.72	75.13	46.54	17.94	−10.65	−39.25	−453.86
2	236.85	208.25	179.66	151.06	122.47	93.88	65.28	36.69	8.09	−20.50	−49.09	−463.71
4	227.00	198.40	169.81	141.22	112.62	84.03	55.43	26.84	−1.75	−30.35	−58.94	−473.55
6	217.15	188.56	159.96	131.37	102.78	74.18	45.59	16.99	−11.60	−40.19	−68.79	−483.40
8	207.30	178.71	150.12	121.52	92.93	64.33	35.74	7.15	−21.45	−50.04	−78.64	−493.25
10	197.46	168.86	140.27	111.67	83.08	54.49	25.89	−2.70	−31.29	−59.89	−88.48	−503.09
12	187.61	159.02	130.42	101.83	73.23	44.64	16.05	−12.55	−41.14	−69.74	−98.33	−512.94
14	177.76	149.17	120.57	91.98	63.39	34.79	6.20	−22.40	−50.99	−79.58	−108.18	−522.79
16	167.91	139.32	110.73	82.13	53.54	24.95	−3.65	−32.24	−60.84	−89.43	−118.02	−532.64
18	158.07	129.47	100.88	72.29	43.69	15.10	−13.50	−42.09	−70.68	−99.28	−127.87	−542.48
20	148.22	119.63	91.03	62.44	33.85	5.25	−23.34	−51.94	−80.53	−109.12	−137.72	−552.33
50	0.51	−28.08	−56.67	−85.27	−113.86	−142.46	−171.05	−199.64	−228.24	−256.83	−285.43	−700.04

Heatmap legend

Positive NPV values

- > 200 → High positive NPV
- 150 to 200 → Moderate–high positive NPV
- 100 to 150 → Moderate positive NPV
- 50 to 100 → Low positive NPV
- 10 to 50 → Marginal positive NPV
- 0 to 10 → Near break-even

Negative NPV values

- −0.01 to −50 → Low negative NPV
- −50 to −100 → Moderate negative NPV
- −100 to −250 → High negative NPV
- −250 to −500 → Severe negative NPV
- < −500 → Critical negative NPV

Figure 9. Sensitivity of the NPV to scenarios of percentage variation in costs and revenues. Note: CV = Costs Variations; RV = Revenues Variations. All values are expressed in USD.

3.7. Analysis of Experts Criteria with AHP Analysis

The first AHP matrix corresponds to criteria related to infrastructure design, focusing on ensuring consistency between the proposed facilities and the community's operational needs (Table S4 in Supplementary Materials). The set of criteria associated with the functionality and daily use of the infrastructure (such as storage capacity, ease of access and transport, user accessibility, maintenance requirements, and ease of operation) accounts for most of the overall weighting (Table 6). This distribution confirms that the pilot design is geared toward ensuring a system that is simple to operate, safe for users, and compatible with the community's technical and economic capabilities.

Table 6. AHP results for pilot infrastructure design criteria.

Code	Criteria	Weight (Wi)	%
D1	Storage capacity	0.110	11.03
D2	Ease of access and transport	0.116	11.64
D3	Locally available materials	0.043	4.29
D4	Construction cost	0.110	11.03
D5	Wood, bamboo and wire mesh structures	0.130	13.02
D6	Modular and flexible structure	0.082	8.17
D7	Good ventilation	0.102	10.21
D8	Accessibility for users	0.128	12.76
D9	Leachate and pest control	0.082	8.17
D10	Maintenance and ease of operation	0.097	9.70

The second AHP matrix corresponds to the strategic criteria of the SWM pilot plan, integrating information derived from the participatory diagnosis and SWOT-TOWS analysis (Table S6 in Supplementary Materials). The results indicate that the highest weightings are assigned to community participation, the viability of composting, the economic value of recyclable materials, and community acceptance with shared responsibility (Table 7). This prioritisation highlights that the sustainability of the proposed model depends fundamentally on population participation and the system's capacity to deliver tangible social, environmental, and economic benefits.

Table 7. AHP weighing strategic criteria for the SWM pilot plan.

Code	Criteria	Weight (Wi)	%
L1	Community participation	0.156	15.63
L2	Barriers to implementation: lack of information and training by local authorities	0.071	7.05
L3	Feasibility of community composting	0.163	16.28
L4	Economic value of recyclables	0.163	16.28
L5	Comprehensive management strategies: community education and awareness, organic waste recovery (composting), marketing of recyclables	0.095	9.50
L6	System configuration and accessibility: decentralised community composting model and collection station accessible from all areas	0.054	5.43
L7	Community acceptance and shared responsibility: education on organic waste management, active participation and direct benefits (use of compost)	0.163	16.28
L8	Effectiveness of incentives for waste separation: economic benefits, training and awareness-raising, minor penalties for incorrect waste separation	0.136	13.56

The consistency of the panel's judgments was confirmed by consistency ratios below the established threshold in both matrices (Tables S5 and S7 in Supplementary Materials). The strategies considered in the economic analysis were established following a sequential process. In the first stage, the participatory diagnosis and survey results enabled the identification of relevant social conditions, local practices, and operational constraints. Subsequently, SWOT-TOWS analysis was used to structure this evidence into contextually

viable strategies. On this basis, the AHP method was used as an ex post validation and prioritisation tool to justify the choice of strategies that had been evaluated economically objectively. The following criteria were considered in this process: (i) alignment with community practices and capacities; (ii) technical feasibility of implementation in a rural context; (iii) small-scale infrastructure and operational requirements; (iv) potential for generating economic benefits; and (v) contribution to the social and operational sustainability of the system. A joint reading of both matrices (Tables 6 and 7) suggests that the most appropriate strategy for Sahuangal is a community-based SWM model, focused on three main areas (Figure 10): (i) strengthening local organisation and co-responsibility around composting and recycling; (ii) consolidating small-scale, accessible, and easy-to-operate infrastructure; and (iii) promoting the economic value of recovered materials and incentives for separation at source to ensure the sustainability of the system.

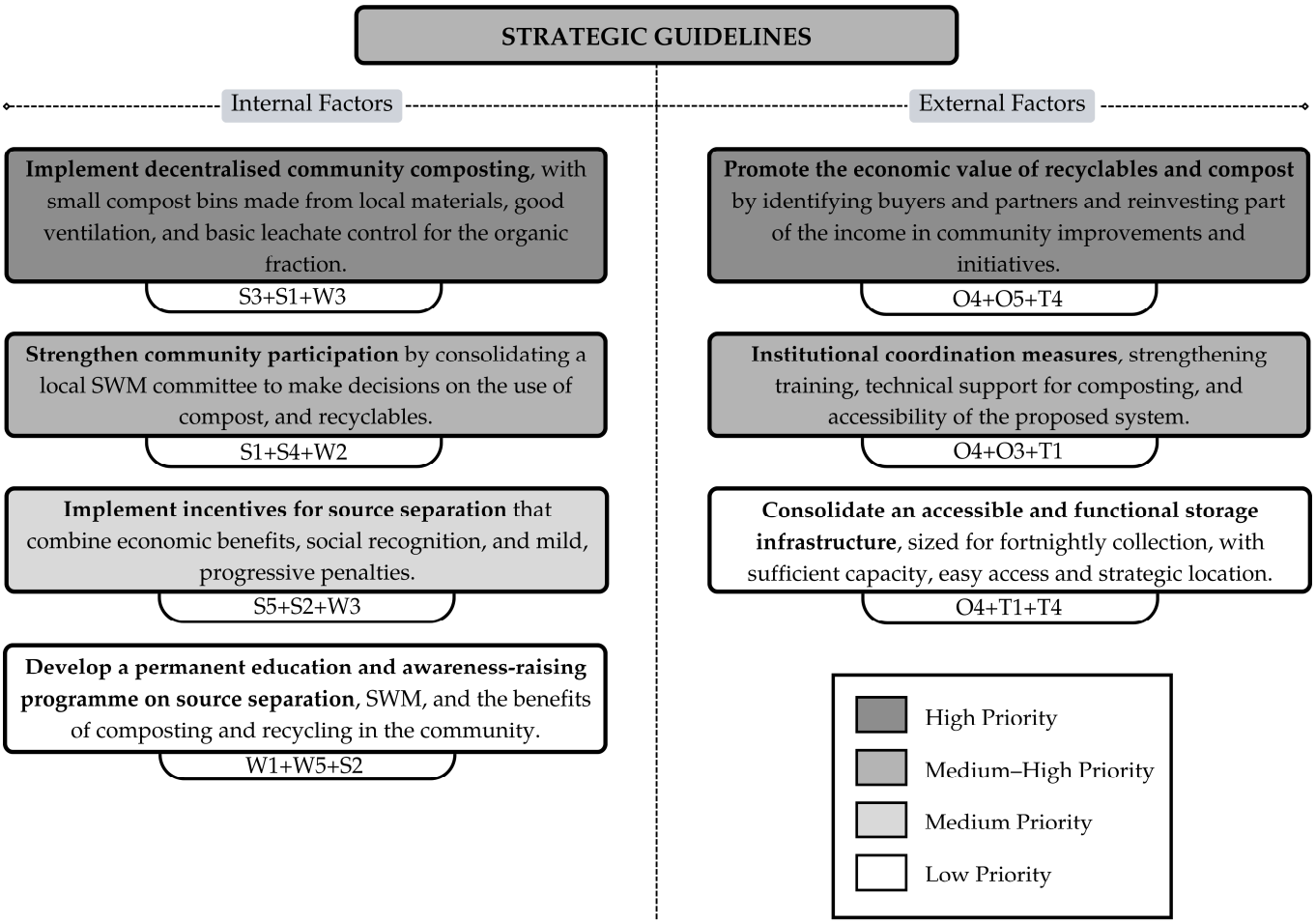

Figure 10. Proposed strategic guidelines for SWM in the community Sahuangal, according to internal (strengths and weaknesses) and external (opportunities and threat) factors.

4. Discussion

A pilot plan for SWM sustainability was formulated in the rural community of Sahuangal, Ecuador, bringing together elements from the municipal government, community organisations, and academia. Although COOTAD assigns municipalities responsibility for integrated waste management, in practice, intervention has been limited. Therefore, this study incorporated community initiatives in rural areas (Table S1 in Supplementary Materials), technical knowledge (pilot plan design and economic and financial analysis), an understanding of the territorial context (SWOT-TOWS method), and expert opinion (AHP analysis) within a comprehensive approach. The SWM pilot proposal suggests

that, in remote and ecologically sensitive communities, coordination among the government/municipalities, environmental authorities, and local organisations should consider not only collection services but also support for small-scale infrastructure, the joint definition of rules for use and maintenance, and the implementation of information and alert mechanisms. The model developed in the case study does not seek to replace municipal obligations, but rather to complement them with community management tailored to the specific characteristics of a difficult-to-access community and to serve as a reference for other rural communities facing similar challenges. For example, the community composting system in Río Blanco (Ecuador) [42] and the initiatives led by women and young people in the villages of La Yunga and Río Hondo (Cauca, Colombia) [96]. These experiences show that the link between local organisation and waste recovery can generate environmental, economic, and social benefits.

The deficient SWM process in Sahuangal is due to a context with strong territorial conditioning, summarised in three interrelated aspects: (i) geographical location (within the Chocó Andino Biosphere Reserve), (ii) history of inadequate final disposal practices, and (iii) operational limitations of the current collection system. The community is located 120 km from the province's main urban area, and access involves a stretch of difficult roads, which limits the arrival and regular operation of waste collection services [97]. Historically, SWM in the community has been handled by an uncontrolled dumpsite where all types of waste were deposited until 2013 [98]. Between 2013 and 2023 (Figure 11), a 'controlled' dumpsite associated with the arrival of a monthly collection truck was used, but its coverage was insufficient and led to the reproduction of informal dumpsite conditions [99]. Since 2023, there has been a fortnightly collection service managed by the competent authorities [52]. Nevertheless, disruptions due to landslides during the rainy season or extended public holidays prolong storage periods. In response, households adopted autonomous practices of separating organic and inorganic waste to mitigate odours and public health risks.

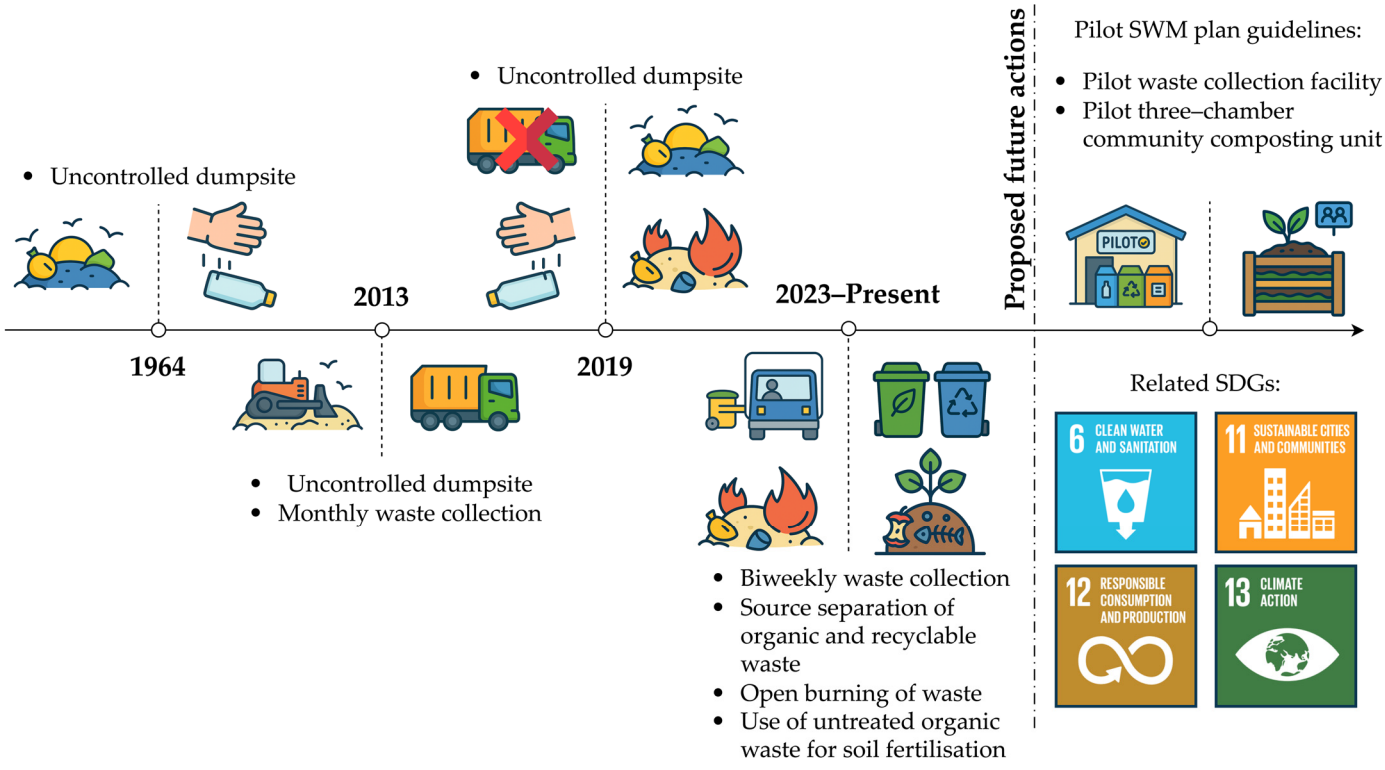

Figure 11. Timeline of SWM practices in the Sahuangal community. Icons used in this figure were generated and refined using an AI-based tool (ChatGPT, OpenAI, 2025 version).

The case study findings are comparable to experiences in contexts with limited access to municipal services and supported by previous research in Latin America [100], that highlights that communities tend to develop informal waste management practices, particularly the artisanal use of organic waste as fertiliser, which coincides with the findings of the present study. In rural contexts in Latin America and other developing regions, a high proportion of organic waste is reported, as well as a low level of formal recovery of recyclable waste due to logistical and institutional limitations [56–58]. Additionally, this study shows that the absence of shared responsibility between the two actors limits the sustainability of initiatives, as was the case with previous experiences of controlled disposal that failed to be sustained over time. In this context, community management does not replace municipal responsibility but complements it, reinforcing a model of shared governance essential to the sustainability of waste management in rural areas. Community empowerment in SWM emerges as a central axis for the sustainability of remote communities. This SWM pilot proposal identifies three areas of opportunity for intervention: (i) community management; (ii) replicability of the study; and (iii) scalability of the proposal (Table 8).

Table 8. Strategic areas of opportunity for the sustainability of the SWM pilot model in rural contexts.

#	Strategic Area	Context Identified	Operational and Implementation Implications	Source
(i)	Community management of MSW	Strong interest in participating in collective initiatives (community composting and marketing recyclables)—a social ground for promoting local empowerment processes with technical support.	Community management can transcend fulfilling an environmental obligation and become a space for learning, innovation, and income generation, with clear mechanisms for the commercialisation of recyclables and compost.	[38,101]
(ii)	Replicability of the study	The model is applicable in regions that share similar characteristics, such as active agricultural economies, basic knowledge of waste separation, and an organic fraction greater than the non-recyclable fraction.	Need to strengthen organised, low-cost schemes adapted to each territory's territorial and social conditions.	[102]
(iii)	Scalability of the proposal	Municipal support and the formation of local SWM committees are required to strengthen the link between the community and decision-makers.	Institutional support could include technical training, operational support, and the provision of small–scale infrastructure. Local SWM committees are a central element of governance, serving as a direct link between the population and the authorities.	[103]

The SWM pilot plan is directly linked to several SDGs. Separation at source, community composting, and waste recovery contribute to SDGs 12 and 11 by promoting more responsible management patterns and a better-organised rural community. The reduction in waste sent to informal landfills and open burning is related to SDGs 13 and 6 (Figure 11), as it potentially reduces emissions and pollution risks in areas within the Chocó Andino Biosphere Reserve [55]. However, the case study has several contextual limitations that condition the scope of the proposed pilot plan: (i) its location far from the urban center and access via difficult roads increases costs and leads to service interruptions during the rainy season; (ii) limited presence and intervention by public institutions, with little technical support in SWM; (iii) fragile logistics of the collection system, with biweekly collection often affected by holidays and landslides, prolonging storage in homes and maintaining the risk of inappropriate practices; and (iv) small scale of the community and low volumes of waste, reducing the possibilities of taking advantage of economies of scale for the commercialisation of recyclable materials.

5. Conclusions

The SWM pilot plan includes a community composting proposal that offers a different alternative to schemes that seek to process all organic waste at a single centralised point. In this case, the emphasis is on the infrastructure's demonstrative and educational nature. The aim is for families to observe the entire process, compare the performance of compost-fertilised soils with untreated waste, and identify a concrete incentive to adopt home composting that strengthens organic recovery in the community in the short and long term. These types of practical spaces encourage the gradual adoption of new practices, especially when the community takes an active role in daily management. This educational function is relevant in contexts where family farming carries economic and cultural weight.

The survey conducted in 58 households in the community showed that 75.86% of waste is organic matter, and 93.10% of the identified inorganic waste is plastic. The physical characterisation of solid waste conducted in a typical household identified an organic fraction of 69.81%, providing exploratory insights for infrastructure sizing. These composition figures should be interpreted with caution, given the exploratory nature of the pilot-level characterisation. The population showed strong social support for promoting changes in waste management and almost a universal awareness of the need to separate organic and inorganic waste. Most households expressed interest in selling recyclables and in participating in a community composting programme, suggesting that selling recyclables could be a realistic strategy for reducing mixed waste and generating additional income.

The AHP method allowed the priorities identified through the SWOT-TOWS analysis to be quantified. The highest weights were assigned to user accessibility and wood, bamboo, and metal mesh infrastructure (Wi $\approx$ 0.13), followed by storage capacity, construction cost, and ease of access and transport (Wi $\approx$ 0.11–0.12). In the strategic matrix, community participation, composting viability, recyclable recovery, and community co-responsibility received the highest values (Wi $\approx$ 0.16), above implementation barriers and system configuration. This analysis reinforces the fact that the success of the plan depends on both the accessibility of the infrastructure and the community's involvement.

The economic and financial assessment confirmed that the proposed model is viable: a positive NPV of USD 246.69, an annual IRR of 193.75% and a return on investment of 104% in 36 months were obtained. Profitability is linked to the use of community labour; the use of local materials in the construction, maintenance, and operation of the infrastructure; and income from the sale of recyclables and compost.

5.1. Methodological Limitations

The study recognised some limitations that should be considered when interpreting the results: (i) At the operational level, the marketing of recyclables is restricted by the low volume generated, the lack of collection centers, high transportation costs, and market uncertainty in remote rural areas. However, the presence of informal recyclers represents an emerging opportunity that can serve as an initial link and a relationship to be strengthened to improve the economic viability of the system in the medium term. (ii) The characterisation form was applied to a single household, which limits statistical representativeness and does not allow for the capture of variations between families or seasons, so the results should be interpreted as exploratory and typical of a pilot study. (iii) Secondary information on waste generation and management was scarce and not very up to date. (iv) General waste collection infrastructure was excluded from the financial analysis because it does not generate direct income. (v) Finally, the sustainability of the proposed model depends on sustained community commitment over time, the continuity of which cannot be fully guaranteed and is a critical factor for the long-term success of the system.

5.2. Identified Lines of Research

This study identifies the following topics as future lines of research: (i) comparative studies across multiple rural communities; (ii) long-term monitoring of compost quality and soil impacts; (iii) cost analysis of collection center and composting facility management models; (iv) governance models for community-municipality co-management of SWM; and (v) early warning systems and operational planning for waste collection services in rural areas that are difficult to access.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su18062811/s1, Table S1. Households survey regarding practices of physical solid waste characterisation. Table S2. Physical characterisation data sheet for solid waste in a typical household of Sahuangal Commune. Table S3. Survey of expert panel for AHP method regarding Solid waste management in Sahuangal Commune. Table S4. Criteria comparison matrix for the design of structures (collection, recycling and composting). Table S5. Criteria comparison matrix for the strategic criteria for the SWM pilot plan. Table S6. AHP consistency analysis for the criteria comparison matrix of collection, recycling and composting structure. Table S7. AHP consistency analysis for the strategic criteria for the SWM pilot plan.

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Institutional Review Board Statement: This study is waived for ethical review by UPSE University as the survey was conducted anonymously, all participants were adults, and their informed consent regarding the protection of their personal data was obtained.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The original contributions presented in this study are included in the article/Supplementary Material. Further inquiries can be directed to the corresponding author.

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Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

SWM	Solid Waste Management
MSW	Municipal Solid Waste
USW	Urban Solid Waste
SDGs	Sustainable Development Goals
SDG	Sustainable Development Goal
UN	United Nations
BAU	Business as usual
ISWA	International Solid Waste Association
SWOT	Strengths, Weaknesses, Opportunities and Threats

CI	Consistency Index
AHP	Analytic Hierarchy Process
NPV	Net Present Value
IRR	Internal Rate of Return

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