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A Socio-Environmental Model for Recovering Expanded Polystyrene Waste as a Building Material in Colombia

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ABSTRACT: Expanded polystyrene (EPS) is a voluminous, low-density waste that is rarely recovered in Colombia, although its use as a lightweight aggregate is well documented. This study designed and validated a socio-environmental management model for transforming post-consumer EPS into a building material in Sogamoso (Boyacá, Colombia). A qualitative, exploratory action-research design was used. The diagnosis combined documentary analysis with four semi-structured interviews and two open-ended questionnaires answered by six actors from the public-institutional, waste-management and construction sectors; a demonstrative block with EPS occupying 25% of the mould volume was produced in ten trials, and the model was validated with representatives of the same sectors. Three independent sources agreed that EPS is not collected because it is paid by weight and has no buyer; no local entity knows its volume, and it hinders compaction in collection trucks. The barrier operates at two points: the waste has no buyer, and a new product must overcome the preference for clay brick. The model evolved through three versions; the cooperative proposed in the second, the only component not derived from the actors, was the only one rejected. The final model combines volume-based payment to waste pickers, a special-waste collection channel within the municipal waste plan, a private transformation company and voluntary public training. The block (about 900 g; ≈952 kg/m³) demonstrates production feasibility only; mechanical, acoustic, durability and fire performance must be verified against applicable standards before any construction use. Recovering EPS in intermediate cities appears to be mainly a governance and market problem.

1. INTRODUCTION

Expanded polystyrene (EPS) is a cellular polymer composed of roughly 98% air. Its low weight, impact absorption and insulating capacity explain its widespread use in packaging and construction, but the same properties make it a problematic waste: it is barely biodegradable, occupies a large volume relative to its mass and increases transport and landfill costs (Espinoza-Merchán et al., 2020). Because recyclable materials are usually traded by weight, EPS generates almost no income for those who recover waste, and it tends to be excluded from recycling chains (Alemán Camacho et al., 2021; Lapa Ramos, 2020).

In Colombia, 2,987,271 t of waste were reported as recovered in 2024, equivalent to 19.69% of the waste generated; plastics accounted for 40.08% of that total, but EPS does not even appear as a reporting category (Superintendencia de Servicios Públicos Domiciliarios, 2025). According to industry figures reported in the press, only about 200 t of post-consumer EPS are recycled each year by 21 companies (Asmar Soto, 2021). National policy, in turn, increasingly points towards circularity: Law

2232 of 2022 sets a gradual reduction of single-use plastics (Congreso de la República de Colombia, 2022), the national solid waste policy prioritises recovery over disposal and the inclusion of waste pickers (Consejo Nacional de Política Económica y Social, 2016), and the Zero Waste Programme regulated in 2025 seeks to increase the recovery of ordinary and special waste and to reduce the vulnerability of waste pickers (Ministerio de Vivienda, Ciudad y Territorio, 2025).

The technical feasibility of EPS as a construction material is well documented. Crushed EPS has been used to replace part of the fine or coarse aggregate in concretes, mortars and blocks (Lapa Ramos, 2020; Macías Alcívar and Jarre Castro, 2022; Oblitas-Torres et al., 2024; Villalta-Góngora et al., 2023; Çelikten et al., 2023), and coated EPS particles have been used to produce artificial lightweight aggregates (Kadhim et al., 2023). These studies agree that density and compressive strength decrease as the EPS content increases, so moderate replacements and non-structural uses are recommended. Mechanical recycling, based on separation, washing and grinding, does not alter the chemical composition of the polymer (Ragaert et al., 2017), and a waste pickers' cooperative in Argentina has shown that EPS can be transformed outside large industry (Schmukler, 2025).

The social dimension, however, remains the weakest part of the circular economy. Analyses of its definitions show that social equity appears in only a minority of them (Kirchherr et al., 2017; Kirchherr et al., 2023). Waste pickers are already at the heart of circular systems in the Global South, although their work is rarely recognised or paid as a service (Gutberlet and Carenzo, 2020; Dias, 2016), and their inclusion in technology-transfer initiatives cannot be merely nominal (Carenzo and Schamber, 2021). Circular-economy research has also been criticised for its focus on conceptual and technological solutions, and action-oriented approaches have been called for, particularly in waste management (Dominko et al., 2023).

Sogamoso (Boyacá) illustrates these tensions. The regional landfill located in the municipality receives waste from 43 municipalities and had been blocked by the neighbouring community since November 2022, so municipal waste is currently transported to another landfill in Tunja. No study had addressed EPS management in the region, and no initiative to recover it existed. An action-research process was undertaken to design and validate, together with local actors, a socio-environmental management model for the collection, processing and transformation of EPS into a material for non-structural masonry. The study therefore addresses the following question: how should a socio-environmental management model for the recovery of EPS be designed so that it is technically, economically and socially viable in an intermediate city?

2. MATERIALS AND METHODS

2.1 Research Design and Setting

The study followed a qualitative approach with an exploratory scope and an action-research design (Hernández-Sampieri and Mendoza Torres, 2018). Of the action-research cycle, the stages of diagnosis, planning and reflection were completed, while implementation was left for a later phase. A similar design has been used to redesign material flows under circular-economy principles in organisations (Leclerc and Badami, 2022). The fieldwork took place in Sogamoso, an intermediate city in the department of Boyacá, Colombia. The management model was built iteratively in three versions: version 1 derived from documentary analysis, version 2 from the diagnosis with local actors, and version 3 from the validation.

2.2 Participants

Participants were selected by purposive sampling so that each actor intervening in the EPS chain was represented: those who regulate and plan waste management, those who collect it, those who recover materials on the street and those who could use the transformed material (Table 1). The sample size follows the logic of qualitative research, in which the criterion is the presence of the relevant perspectives rather than statistical representativeness; each perspective was therefore collected from a single informant. For the validation, five participants were the same as in the diagnosis; the waste picker interviewed initially could not be located, because no name or contact data were recorded at his request, so validation was carried out with another person whose livelihood depends on recycling.

Table 1. Participants and data collection techniques

Sector	Participant	Diagnosis	Validation
Public-institutional	Mayor of Sogamoso	Written questionnaire	In-person session with prototype
Public-institutional	Official of the regional environmental authority (Corpoboyacá)	In-person interview	Recorded conversation and in-person session with prototype
Waste management	Planning Department of the waste collection company	Written questionnaire	In-person session with prototype
Waste management	Driver of a collection truck	In-person interview	In-person session with prototype
Waste management	Waste picker	In-person interview	In-person session with prototype (different person)
Construction	Architect and builder	Virtual interview	Recorded conversation and in-person session with prototype

2.3 Data Collection

Three techniques were used. First, semi-structured interviews were conducted with four actors using sector-specific guides organised by the analytical categories; they were audio-recorded with the participants' authorisation and transcribed verbatim. Second, because an interview could not be scheduled with the mayor and the collection company, the same guide was adapted into an open-ended written questionnaire, which preserved the open character of the questions but did not allow follow-up questions. Third, documentary analysis covered planning instruments, applicable regulations and technical and social studies on EPS transformation and waste-picker inclusion. Validation was carried out in two moments: a recorded second conversation about version 2 with the environmental authority and the architect, and individual in-person sessions with representatives of the six sectors, in which the model and the prototype were presented and open feedback was collected. These sessions were documented through photographs and a written synthesis by the researcher.

2.4 Demonstrative Prototype

A demonstrative block was produced to allow actors to discuss the model around a tangible object, not to characterise the material technically. Its purpose was therefore to show that the material could be produced with simple means, not to verify its suitability for construction (Section 3.3). EPS from household-appliance packaging was washed and ground with a drill fitted with a long spiral bit until particles of about 3 mm were obtained, close to the size used by Lapa Ramos (2020). The formulation started from the replacements reported in the literature (Macías Alcívar and Jarre Castro, 2022). Ten trials were carried out: five cement-to-sand ratios (1:1, 1.5:1, 2:1, 3:1 and 1:2, by volume), each prepared by dry and by wet mixing, with hydrated lime kept constant at 1/4 part and EPS at 25% of the mould volume. Blocks of 15 × 9 × 7 cm were cast in wooden moulds, demoulded after 24 h and weighed at 7 days. Apparent density was estimated from the mass at 7 days and the nominal mould volume (945 cm^3); oven-dry density was not determined, and no laboratory tests were performed.

2.5 Data Analysis

Transcripts and questionnaires were coded according to five categories defined a priori: current socio-environmental management of EPS, technical potential for transformation, structure of the management model, project management and stakeholder participation, and validation. Findings were triangulated across actors from different sectors and between actors and documentary evidence, distinguishing points on which sources agreed, findings provided by a single source and differences between sources. During validation, each observation was classified as a strength, an objection or a proposed adjustment, and a decision (incorporated or not, with its rationale) was recorded for each proposal. To make the rationale of each change traceable, every component of the successive versions was linked to the evidence that originated it and to the decision taken

during validation (Section 3.4). Credibility was sought through triangulation and dependability through an audit trail of transcripts, coding matrices and decision logs.

3. RESULTS AND DISCUSSION

3.1 Diagnosis: Why EPS Is Not Recovered

The documentary analysis contradicted the initial assumption that EPS could not be recycled, and led to a first, environmentally oriented version of the model in which a private company would buy EPS from waste pickers, wash and grind it, and sell the ground material for various uses. The diagnosis with local actors showed that this reading of the problem was incomplete (Table 2).

Table 2. Main findings of the diagnosis and their sources

Finding	Sources	Relationship
EPS is not collected because it is paid by weight and has no buyer	Waste picker, truck driver, environmental authority, literature	Agree
No entity knows the volume of EPS; each refers to another	Municipality, environmental authority, collection company	Agree
EPS does not compact and obstructs collection trucks	Truck driver	Single source
Generation peaks at the end and beginning of the year	Truck driver	Single source
The construction sector also generates EPS (slab fillers) and discards it	Architect	Single source
Non-structural walls are the most promising application, subject to testing	Architect, environmental authority, literature	Agree
Viability depends on securing a buyer or destination for the material	Environmental authority, collection company, waste picker	Agree
The barrier lies in the lack of a buyer or in the acceptance of the product	Environmental authority vs. architect	Complementary
Inclusion of waste pickers: formalised population vs. independent work	Municipality vs. waste picker	Differ
Each actor offers a non-financial contribution; none offers funding	All institutional actors	Agree

The strongest finding came from three independent sources. The waste picker explained it in his own words: "Lo que casi no sirve es el icopor. Uno encuentra muchísimo, pero eso prácticamente no lo compra nadie" (Styrofoam is almost useless; you find a lot of it, but practically nobody buys it). The truck driver, who observes recovery work daily, reached the same explanation ("it is sold by weight, and it does not weigh"), and the environmental authority reported that recyclers say EPS "has no after-sale". This is consistent with the literature on the low weight-to-volume ratio of EPS (Alemán Camacho et al., 2021; Lapa Ramos, 2020). The driver added an operational dimension not documented in the literature reviewed: EPS does not compact in the trucks and sometimes forces them to request support from another vehicle.

The diagnosis also revealed an information gap. The municipality reports 75 t of waste per day but has no disaggregated data on EPS; the environmental authority refers to the municipal integrated solid waste management plan (PGIRS) and the collection company; and the company provided a characterisation that records polystyrene in general, at a scale that corresponds to the sample analysed rather than to the municipal total. The volume of EPS generated in Sogamoso therefore remains unknown. At the institutional level, the environmental authority identified a possible but not yet activated route: classifying EPS as special

waste within the PGIRS, which, under national regulations, applies to waste that because of its volume or nature cannot be handled by the ordinary collection service (Ministerio de Vivienda, Ciudad y Territorio, 2015).

Regarding demand, the architect considered that the main obstacle for a new material is not price but acceptance in a region strongly attached to clay brick, and that installation performance matters more than cost. He offered a pilot in one of his projects, conditional on tests of strength, cracking and load-bearing capacity for wall-hung elements. Read together, the environmental authority and the architect locate the barrier at two points of the chain: at the beginning, EPS has no buyer as waste; at the end, the transformed product must overcome market preferences. Finally, every institutional actor identified a possible contribution, but none offered funding or leadership.

3.2 Version 2 and the Cooperative Proposal

With these results the model shifted from an environmental to a socio-environmental approach. Waste pickers ceased to be mere suppliers and became a population to be included through three progressive phases: paid collection at a drop-off point, voluntary training in the transformation process, and membership of a cooperative company. Sources were broadened to construction waste, the destination was narrowed to non-structural masonry blocks, and roles were assigned to the municipality, the environmental authority, the collection company and the construction sector. Each of these changes responded to a specific finding of the diagnosis (Table 2): the inclusion of waste pickers to the weight-based payment barrier, the new source to the architect's report on slab fillers, and the narrower destination to the agreement on non-structural walls.

Unlike the other changes, the cooperative was not proposed by the actors but by the researcher, based on studies that recommend cooperative formalisation of waste pickers (Barros de Deus Chuquel da Silva et al., 2025), their integration as partners rather than passive beneficiaries (Dias, 2016), partnerships between public administration and the social economy (Salazar Villano and Gutiérrez Pisso, 2025), and the Argentine cooperative that transforms EPS (Schmukler, 2025). The proposal assumed, however, an organisational base that the diagnosis had not found: the waste picker interviewed works independently, belongs to no association and competes with other pickers for material.

3.3 Demonstrative Prototype: Production Feasibility versus Construction Suitability

All dry mixes showed poor compaction and the blocks crumbled easily, so wet mixing was adopted. Among the wet mixes, the 2:1 cement-to-sand ratio gave the best result in the researcher's qualitative assessment, and unlaminated wooden moulds were replaced by laminated ones because the block adhered to the wood (Table 3). The resulting block weighed about 900 g at 7 days, which corresponds to an apparent density of about 952 kg/m³. This is lower than the lightest concrete reported by Lapa Ramos (2020), 1,087 kg/m³ with 60% of the fine aggregate replaced, although the comparison is only indicative because mixes, ages and measurement conditions differ.

Table 3. Variables tested in the prototype and decisions adopted

Variable	Alternatives tested	Result	Decision
Mixing method	Dry (5 trials) and wet (5 trials)	Dry mixes: poor compaction; blocks crumbled	Wet mixing
Cement : sand ratio (by volume)	1:1; 1.5:1; 2:1; 3:1; 1:2	2:1 gave the best qualitative result	2:1
Hydrated lime	1/4 part in all trials	Constant	1/4 part
EPS	≈3 mm particles; 25% of mould volume in all trials	Constant	25% of mould volume
Mould	Unlaminated and laminated wood	Block adhered to unlaminated wood	Laminated wood, 15 × 9 × 7 cm

The prototype therefore demonstrates only that post-consumer EPS can be cleaned, ground and incorporated into a cement–sand–lime block with simple tools and without industrial equipment; it does not demonstrate that the block is suitable for construction. Several considerations support this distinction. First, without tests, compressive strength is unknown; since lower density is consistently associated with lower strength (Lapa Ramos, 2020; Oblitas-Torres et al., 2024), the block may have a low strength. Second, the behaviour of EPS depends on the matrix in which it is incorporated (Seixas et al., 2026), so results from

other studies cannot be transferred directly. Third, closed-cell EPS is not by itself a good sound absorber, and acoustic performance depends on the whole wall system (Amran et al., 2021); the acoustic orientation suggested by the architect is therefore a hypothesis to be tested. Fourth, the density reported here was estimated at 7 days from nominal dimensions and must be redetermined under standard conditions before the unit can be classified. The high cement content may also increase cost, as reported for other EPS lightweight blocks (Villalta-Góngora et al., 2023).

Before the block can be recommended for practical building applications, its performance must be verified through the assessments summarised in Table 4. In Colombia, concrete units for non-structural masonry are specified by NTC 4076 and sampled and tested according to NTC 4024, the national counterpart of ASTM C140; partition walls must also meet the requirements for non-structural elements (Chapter A.9) and fire protection (Title J) of the Colombian seismic-resistant building code, NSR-10 (Ministerio de Ambiente, Vivienda y Desarrollo Territorial, 2010). Because the block contains a combustible polymer, fire resistance and smoke emission deserve particular attention, and because the architect intends to hang elements from the wall, anchorage capacity and cracking must be evaluated in addition to the compressive strength of the unit. Only once these requirements are met would the on-site pilot offered by the architect be justified.

Table 4. Status of the demonstrative block and assessments required before construction use

Performance aspect	Status in this study	Required assessment	Indicative standards
Dimensions and density	Nominal dimensions; ≈900 g at 7 days (≈952 kg/m³ apparent)	Dimensional tolerances; oven-dry density	NTC 4024 / ASTM C140
Compressive strength	Not tested	Strength at 28 days on an adequate number of units; comparison with minimum values for non-structural units	NTC 4024 / ASTM C140; NTC 4076 / ASTM C129
Water absorption	Not tested	Absorption and moisture content	NTC 4024 / ASTM C140; NTC 4076
Dimensional stability and durability	Not tested	Linear drying shrinkage; wetting–drying cycles; long-term behaviour	ASTM C426; procedure for cycles to be defined
Wall behaviour and anchorage	Not tested; requested by the architect	Cracking; load capacity of anchors for wall-hung elements; seismic requirements for partitions	NSR-10, Chapter A.9
Acoustic performance	Hypothesis only	Airborne sound insulation of the wall system in the laboratory	ISO 10140-2; ISO 717-1
Fire performance	Not tested	Fire resistance of the wall system; reaction to fire and smoke emission	NSR-10, Title J; ASTM E119 or ISO 834-1
Thermal performance (complementary)	Not tested	Thermal conductivity	ISO 8302 / ASTM C177
Economic and environmental feasibility	Not assessed	Unit cost compared with clay brick; life-cycle assessment of collection, grinding and cement use	ISO 14040; ISO 14044

Note: Standards are indicative and are cited by designation; the editions in force at the time of testing should be applied, and the final test programme should be defined with an accredited laboratory.

3.4 Validation and Final Model

The prototype was well received by five of the six actors. The mayor saw a possible use in municipal projects once the product is functional, and the architect described it as valuable and usable on site but insisted on testing before any certification. The waste picker showed no interest in the prototype or the model as a whole. Some expectations, such as building houses or replacing dry-wall systems, exceed what an untested non-structural block can support and were recorded as expectations rather than possibilities.

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Validation questioned the central component of version 2. Four actors considered the cooperative unviable, arguing that the labour inclusion of this population involves a deeper social process than a transformation company can assume; the truck driver proposed that resocialisation and training should precede any form of employment. The environmental authority did not object, and the waste picker was only interested in selling EPS at a collection point, which coincides with the preference of the waste picker interviewed during the diagnosis. These perceptions reflect the experience of each actor and should not be read as a characterisation of a diverse population. The recorded conversations added three conditions of viability: the special-waste route requires a municipal administrative act or an update of the PGIRS; a written purchase commitment should be secured before scaling up; and collection, storage and transformation capacities must be aligned. Table 5 summarises how the model changed, and **Figure 1** shows the final version.

Table 5. Evolution of the management model across its three versions

Element	Version 1	Version 2	Version 3 (final)
Origin	Documentary analysis	Diagnosis with actors	Validation with prototype
Approach	Environmental	Socio-environmental	Socio-environmental
Company	Private	Cooperative	Private
Role of waste pickers	Suppliers	Future cooperative members	Suppliers paid by volume, with a voluntary training and inclusion path
Collection	Purchase from waste pickers	Paid drop-off point and separate collection	Two channels: waste pickers and special-waste route with public drop-off points
Product and destination	Ground EPS for various uses	Block for non-structural walls	Block for non-structural walls, subject to testing; municipal projects and builders
Role of public entities	None	Regulatory framework, drop-off sites, dissemination, joint collection campaigns	Special-collection plan, drop-off points, training, dissemination and use of the product

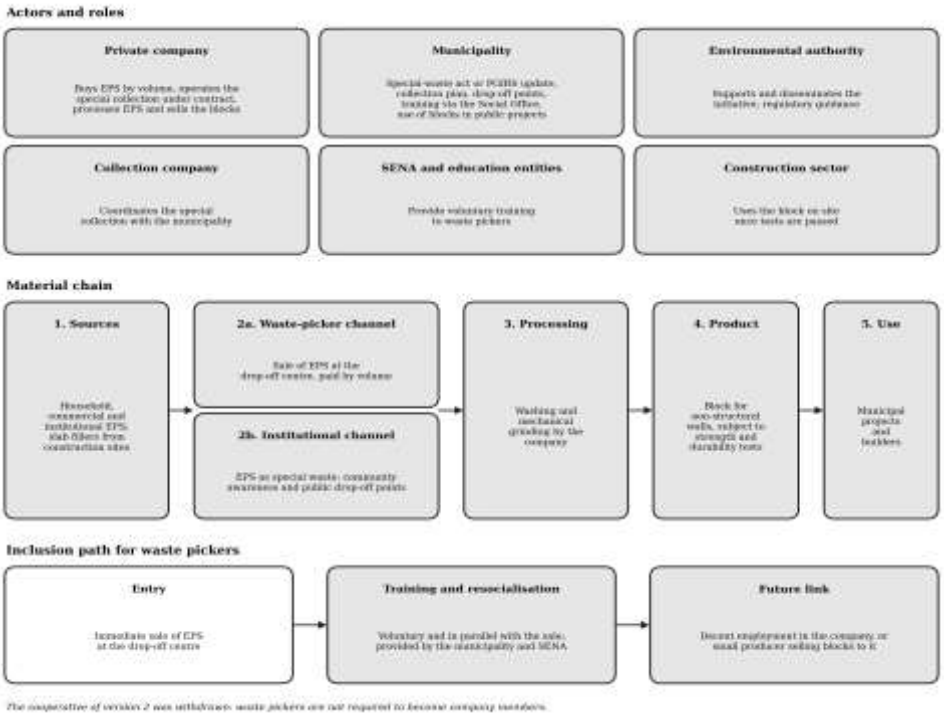


Figure 1. Final (version 3) socio-environmental management model for EPS recovery in Sogamoso.

The final model has four components: two collection channels (purchase from waste pickers at a drop-off centre, paid by volume rather than by weight, and an institutional channel based on classifying EPS as special waste, with community awareness and public drop-off points); a private company that processes the material through the mechanical route; a block for non-structural walls whose use is conditional on the assessments listed in Table 4; and a voluntary inclusion path in which the sale of the material is the entry point, training is provided by public entities, and future employment or small-producer roles remain open.

Table 6 links each component to the stakeholder evidence that originated it and to the decision taken during validation. Every component retained in the final version has at least one source in the diagnosis and was endorsed or adjusted by the actors; the only component removed was the one that lacked such a source.

Table 6. Traceability of the model components to stakeholder evidence and validation decisions

Component	Evidence that originated it	Validation outcome	Decision and rationale
Purchase of EPS from waste pickers, paid by volume	Waste picker, truck driver and environmental authority: EPS is paid by weight and has no buyer	Waste picker in the validation interested only in selling at a collection point	Retained from version 1 and modified from weight to volume, because it addresses the main barrier
Special-waste collection channel within the PGIRS	Environmental authority: route available but not activated; truck driver: EPS hinders compaction	Recorded conversations: requires a municipal act or PGIRS update	Added in version 3, with the administrative act as a condition of viability
Private transformation company	Documentary analysis (version 1); no actor offered funding or leadership	Four actors judged a cooperative unviable; no objection to a private operator	Reinstated in version 3 as the operator of processing and sales
Cooperative with waste pickers as members	Proposed by the researcher from the literature; no organisational base found in the diagnosis	Considered unviable by four actors; waste picker not interested	Removed, because it lacked support in local evidence
Block for non-structural walls	Architect, environmental authority and literature	Well received by five of six actors; architect required testing first	Retained, conditional on the assessments in Table 4
Voluntary training and inclusion path	Municipality vs. waste picker: formalised population vs. independent work	Truck driver: training and resocialisation must precede employment	Restructured: sale as entry point, training by public entities, employment optional
Purchase commitment and alignment of capacities	Environmental authority, collection company and waste picker: viability depends on a buyer	Recorded conversations: secure a written commitment before scaling up	Added as preconditions for implementation

3.5 Discussion

The central result is that, in this context, the obstacle to recovering EPS is economic and institutional rather than technical. This agrees with studies on circular-economy barriers in construction, which identify the low cost of virgin materials (Alzara et al., 2025) and the lack of economic incentives and limited demand for recycled aggregates (Arellano-Sánchez et al., 2026) as persistent constraints. The contribution of this study is to show that, for EPS, the economic barrier operates at two points: at the start of the chain, where waste paid by weight yields no income, and at its end, where a new product must win acceptance.

On the demand side, architects and engineers are key actors in the adoption of sustainable materials (Rajendra and Mohanasundaram, 2024); in this case, however, the builder prioritised demonstrated performance over certification, suggesting that in local markets practical evidence weighs more than labels. National data reinforce the point: EPS is invisible in the official recovery statistics (Superintendencia de Servicios Públicos Domiciliarios, 2025), and the absence of municipal data reproduces that invisibility locally.

Local participation shaped the model at each iteration rather than merely endorsing it at the end. The diagnosis changed the definition of the problem: the waste picker, the truck driver and the environmental authority shifted the focus from processing technology to the economics of collection, which turned weight-based purchase into volume-based payment; the driver's observation on truck compaction and the authority's reference to the special-waste category gave rise to the institutional channel; and the architect's emphasis on acceptance and performance narrowed the product to a tested non-structural block. Validation then corrected the researcher's own contribution, the cooperative, and replaced it with a gradual and voluntary inclusion path. The fact that the only component formulated without the actors was the only one rejected supports the view that defining a project with its stakeholders from the outset is decisive for meeting their expectations (Kuchta and Mrzygłocka-Chojnacka, 2020).

The rejection of the cooperative offers the clearest lesson on inclusion. The studies that support cooperative formalisation start from organisations that already exist (Barros de Deus Chuquel da Silva et al., 2025; Ibelli-Bianco et al., 2022; Schmukler, 2025), whereas the waste pickers consulted in Sogamoso work independently. The literature recommends strengthening existing organisations; version 2 assumed they could be created. The obstacles mentioned by actors (perceived complexity of the population and the absence of an entity responsible for training) match those identified in Latin American cases, such as social stigma, fragmented governance and insufficient investment in education (Castillo-Ospina et al., 2025). The final model follows the recommendation that training be part of public programmes (Ibelli-Bianco et al., 2022) and that inclusion not be merely nominal (Carenzo and Schamber, 2021). Even so, waste pickers return to the role of suppliers, with better conditions but without recognition of their work as a service (Gutberlet and Carenzo, 2020), so the social equity of the model remains limited and dependent on public institutions (Kirchherr et al., 2023).

The integration with public waste management was the change that most widened the reach of the model. The special-waste category, defined in national regulations for waste that cannot be handled by the ordinary service (Ministerio de Vivienda, Ciudad y Territorio, 2015), fits EPS because of its volume and its operational impact on collection trucks, and is consistent with the Zero Waste Programme (Ministerio de Vivienda, Ciudad y Territorio, 2025) and the national solid waste policy (Consejo Nacional de Política Económica y Social, 2016). Extended producer responsibility for packaging (Ministerio de Ambiente y Desarrollo Sostenible, 2018) also opens a possible alliance with appliance producers, whose packaging was the source of the EPS used in the prototype.

Because the model was built with the actors of one municipality, its transfer to other contexts depends on at least five conditions. The first is the organisational base of waste pickers: where organisations already exist and are recognised as providers of the recovery service, the cooperative or partnership arrangement rejected in Sogamoso may be viable, as reported in other cases (Barros de Deus Chuquel da Silva et al., 2025; Castillo-Ospina et al., 2025). The second is the institutional window for classifying EPS as special waste, which depends on the timing of PGIRS updates and on the willingness of the municipal administration to issue the corresponding act. The third is the volume and seasonality of EPS generation, which determine whether processing can reach a viable scale and must be quantified locally because national statistics do not report it. The fourth is the disposal context: in Sogamoso, the blockade of the regional landfill and the transport of waste to another city increase the incentive to divert voluminous waste, an incentive that may be weaker where disposal is cheap and nearby. The fifth is the local construction culture and the presence of a committed buyer, since the preference for clay brick observed in Boyacá may differ elsewhere. Intermediate cities that share these features (independent waste pickers, unquantified EPS flows and a traditional masonry market) are the most likely candidates for adapting the model, which should in any case be validated again with local actors.

The study has limitations. Each sector was represented by a single informant, so results cannot be generalised to the populations they represent, particularly the heterogeneous population of waste pickers. Two actors answered in writing without follow-up questions, the validation sessions were not audio-recorded, and the waste picker in the validation was not the same person as in the diagnosis. The prototype was not tested in the laboratory, so its suitability for construction remains unverified, and the volume of EPS generated in the municipality is unknown, which prevents sizing the proposed operation. Finally, the economic

feasibility of the recovery system (costs of volume-based purchase, processing and cement) and its environmental implications (including emissions associated with cement and the possible release of EPS particles during grinding) were not assessed.

4. CONCLUSION

In Sogamoso, EPS is not recovered because it generates no income for those who could collect it, no entity knows its volume and no actor takes charge of its management, not because of a lack of technical knowledge. A socio-environmental model was designed through three versions in dialogue with local actors, and each component of the final version can be traced to their evidence. Its final form combines volume-based payment to waste pickers, an institutional special-waste collection channel articulated with the municipal waste plan, a private transformation company and a voluntary inclusion path supported by public entities. The demonstrative block showed that EPS can be transformed with simple means, which establishes production feasibility but not construction suitability. Future work should characterise the volume of EPS generated in the municipality; carry out a laboratory programme covering compressive strength, water absorption, drying shrinkage and durability, acoustic insulation, fire performance and compliance with NTC 4076 and NSR-10 before an on-site pilot; assess the economic feasibility and life-cycle environmental impacts of the recovery system; and study the conditions of local waste pickers with a broader sample. Transfer to other municipalities should consider the organisational base of waste pickers, the institutional window for special-waste classification, local EPS volumes, disposal conditions and market acceptance. The results suggest that, in intermediate cities, recovering EPS is primarily a problem of governance and markets, and that models built with local actors are more likely to be accepted.

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AUTHOR CONTRIBUTIONS

Javier Eduardo Sánchez López: Conceptualization, Methodology, Investigation, Formal Analysis, Writing—Original Draft.

Martha Fernández Samacá: Supervision of the methodology, Writing—Review & Editing.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ETHICS STATEMENT

Participation was voluntary. Participants received a presentation letter and gave informed consent, in written form or, in the case of waste pickers, verbally and without recording their names, in accordance with Colombian personal data protection law (Congreso de la República de Colombia, 2012). Participants are identified only by their role. Approval from an institutional ethics committee was not required for this study, as it involved non-invasive interviews and consultations with adult participants on matters related to their institutional or occupational roles, without collecting sensitive personal data.

DATA AVAILABILITY STATEMENT

Anonymised transcripts, questionnaires and coding matrices supporting the findings of this study are available from the corresponding author upon reasonable request.

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