FRONTEIRAS

OPEN ACCESS

Article

Reverse Logistics in the Amazon: A Territorialized Conceptual Model and Guidelines for Regional Public Policies

Maria José Feitoza de Souza[1] [iD]**, Franciele Bender Maritan[2]** [iD]**, Jhennifer Lauanne Tavares da Cruz Silva[3]** [iD]**, Rodrigo Duarte Soliani[4]** [iD]

[1] Specialist in Business Logistics. Federal Institute of Acre. ORCID: 0009-0002-7494-9609. Email: maria-ac1@hotmail.com

[2] Master's Degree in Intellectual Property and Technology Transfer. Professor at the Federal Institute of Acre. ORCID: 0009-0000-7220-4318. Email: francieli.maritan@ifac.edu.br

[3] Doctoral student in the Biodiversity and Biotechnology. Professor at the Federal University of Acre. ORCID: 0009-0008-3719-1062. Email: jhennifer.silva@ufac.br

[4] PhD in Environmental Technology. Professor at the Federal Institute of Acre. ORCID: 0000-0003-3354-6838. Email: rodrigo.soliani@ifac.edu.br

RESUMO

A implementação da logística reversa (LR) em regiões amazônicas é condicionada por fatores territoriais e institucionais que diferem significativamente de outros contextos, o que desafia a viabilidade das estratégias de economia circular. Apesar dos avanços conceituais recentes, ainda são limitados os modelos analíticos capazes de incorporar essas especificidades territoriais aos arranjos de LR. Este artigo analisa como fatores institucionais e territoriais da Amazônia Sul-Ocidental condicionam a implementação da LR e propõe um modelo conceitual territorializado para apoiar políticas públicas em contextos periféricos. O estudo adota uma abordagem qualitativa e exploratória, combinando uma revisão sistemática da literatura (33 artigos) com a análise documental de instrumentos legais e relatórios de gestão do estado do Acre, no período de 2020 a 2024. Os resultados indicam que a implementação da LR é limitada por fragilidades na governança, restrições de infraestrutura, baixa rastreabilidade dos fluxos, dependência de recursos externos e inclusão produtiva restrita de catadores. Com base nesse diagnóstico, o artigo apresenta um modelo conceitual estruturado em três níveis analíticos, acompanhado por um conjunto de indicadores de desempenho e diretrizes de implementação. O framework proposto oferece suporte analítico e operacional para o desenho, o monitoramento e o fortalecimento de políticas de logística reversa e economia circular em territórios amazônicos.

Palavras-chave: Amazônia; economia circular; logística reversa; políticas públicas; governança ambiental.

ABSTRACT

The implementation of reverse logistics (RL) in Amazonian regions is shaped by territorial and institutional conditions that differ markedly from other contexts, challenging the feasibility of circular economy strategies. Despite growing conceptual advances, analytical models that incorporate these territorial specificities into RL arrangements remain limited. This article examines how institutional and territorial factors in the Southwestern Amazon condition the implementation of RL and proposes a territorialized conceptual model to support public policies in peripheral contexts. The study adopts a qualitative and exploratory approach, combining a systematic literature review (33 articles) with documentary analysis of legal instruments and management reports from the state of Acre (2020–2024). The results indicate that RL implementation is constrained by fragile governance, infrastructure limitations, low flow traceability, dependence on external funding, and restricted productive inclusion of waste pickers. Based on this diagnosis, the article presents a conceptual model structured into three analytical levels, along with a set of key performance indicators and implementation guidelines. The proposed framework offers analytical and operational support for designing, monitoring, and strengthening RL and circular economy policies in Amazonian territories.

Keywords: Amazon; circular economy; reverse logistics; public policies; environmental governance.

Introduction

In recent decades, the intensification of economic globalization, accelerated urban growth, and the climate crisis have generated transformations that reshape local economies, reorganize production chains, and widen socio-spatial inequalities (Espey et al., 2023). These processes show that traditional development models no longer respond adequately to contemporary pressures, creating the need for strategies capable of integrating economic, social, and environmental dimensions (Rahman et al., 2023). In this context, sustainability is no longer treated as a topic restricted to environmental concerns and has become a guiding principle for international research agendas and public policy (Sedovs & Volkova, 2024).

The strengthening of this movement has been driven by international frameworks that establish shared strategic directions. The Sustainable Development Goals (SDGs) set integrated targets across the social, economic, and environmental dimensions (UN, 2015a), while the Paris Agreement established commitments aimed at climate change mitigation and the transition to low-carbon models (UN, 2015b). Together, these instruments consolidated sustainability as a structuring guideline for development policies and strategies.

Among the mechanisms mobilized to achieve these goals, the circular economy (CE) stands out for proposing extended product life cycles and the reintegration of waste into production processes (Fernando et al., 2023). Within this paradigm, reverse logistics (RL) functions as an instrument that promotes efficient resource use, reduces environmental impacts, and enables waste recovery. Despite this potential, its adoption remains uneven across countries and regions, reflecting historical and institutional asymmetries and highlighting the need for analytical models that consider territories with limited coordination capacity and infrastructure (Le, 2023; Kirchherr et al., 2023).

In Brazil, the National Solid Waste Policy (PNRS, Law 12.305/2010) recognized RL as a structuring axis of integrated waste management and established shared responsibility over product life cycles (Brasil, 2010). Its implementation, however, varies significantly across states, particularly those facing fiscal constraints, low administrative capacity, and strong dependence on external transfers (Santiago et al., 2023). Acre, located in the Southwestern Amazon, exemplifies this situation by combining environmental and geopolitical relevance with structural limitations that hinder the execution of CE-related policies (Acre, 2012; 2023; 2024). Infrastructure gaps, low waste separation, and the socioeconomic vulnerability of actors such as waste pickers reinforce this scenario (MPAC, 2020).

These challenges are observed in several regions of developing countries, where RL faces barriers such as the absence of long-term planning, low visibility of recycling flows, and fragile institutional governance arrangements (Sonar et al., 2024). Mallick et al. (2023) emphasize that such obstacles reduce traceability and undermine cooperation among actors in the chain. In the Amazonian context, these barriers intensify due to long distances, high logistical costs, supply chains marked by informality, and the lack of economic instruments to stimulate material circulation (Teixeira et al., 2024). Together, these factors indicate that RL must be understood as a territorial process, conditioned by local capacities and contexts that vary substantially across regions.

Based on this context, this study seeks to answer the following question: How do territorial and institutional characteristics of the Southwestern Amazon influence the implementation of RL? Although important advances have been made in the fields of CE and RL, analytical formulations that address Amazonian territories, marked by low institutional density and limited operational conditions, remain scarce. The absence of tailored models hampers the understanding of the factors that shape the feasibility of material return strategies.

In light of this theoretical gap and the challenges observed in RL implementation in the region, this article examines the experience of Acre and, drawing on a systematic literature review (SLR) and documentary analysis, proposes a territorialized conceptual model to support the structuring of RL in peripheral contexts. The model

is organized into three levels and six dimensions and brings together guidelines and indicators related to institutional coordination, results-oriented financing, infrastructure, and productive inclusion.

CE and the operational dynamics of RL

In recent decades, sustainability has moved beyond the normative domain and has increasingly informed operational decisions in public policies and business strategies (Picard & Manfredi, 2023). Within this context, the CE has emerged as a structuring approach grounded in the idea that production cycles can be redesigned based on extending product lifespans, maintaining value over time, and reducing dependence on the continuous extraction of natural resources. This shift breaks with the linear take–make–dispose model (Dennison et al., 2024) and supports productive systems that reintegrate materials into economic cycles.

Within this arrangement, RL functions as the operational backbone of circular chains by enabling the return of materials to productive systems (De Giovanni, 2022; Mishra et al., 2023). This function involves specific stages (collection, consolidation, transportation, sorting, and processing) that allow for direct reuse, recycling, remanufacturing, or environmentally appropriate final disposal (Rodríguez et al., 2024). RL is, therefore, both a technical mechanism that organizes material circulation and an element that articulates environmental, economic, and social interests (Soliani, 2021).

The structuring of these flows depends on the joint action of governments, firms, cooperatives, and waste pickers, who perform complementary yet unequal roles (Zisopoulos et al., 2023). In the case of organic waste, RL involves processes requiring differentiated organization, such as source separation, dedicated selective collection, and technologies capable of transforming the organic fraction into new productive inputs through composting or anaerobic digestion (Teixeira et al., 2024). This diversity of flows demonstrates that RL operates under heterogeneous territorial conditions, demanding governance arrangements capable of managing variations in infrastructure and institutional capacity.

Although RL is a structuring component of CE, its implementation faces obstacles that limit its consolidation. These include low flow traceability, high logistical costs, the absence of integrated planning, and weak coordination mechanisms between productive sectors and public agencies (Sonar et al., 2024; Mallick et al., 2023). In developing countries, these barriers are intensified by infrastructure shortages, the predominance of informal recycling chains, and difficulties in inducing consistent disposal behaviors (Araújo et al., 2024). These limitations are not evenly distributed across territories and tend to worsen in regions marked by structural inequalities.

RL in Brazil and the Amazon

In the Brazilian context, the PNRS established shared responsibility for product life cycles, aligning the country with international debates on extended producer responsibility (Brasil, 2010). RL became part of this framework as both a legal and technical instrument, organizing obligations among manufacturers, retailers, consumers, and public authorities (Brasil, 2010; Oliveira et al., 2023). The operationalization of this regime relies on sectoral agreements that define specific commitments for return and reintegration structures.

Even so, many agreements concentrate efforts on the final stages of the chain, limiting themselves to collection and recycling while failing to advance strategic fronts such as ecodesign, waste reduction at the source, or product life extension (Souza et al., 2024; De Andrade & De Araujo, 2025). This restriction keeps RL tied to a compliance-oriented model rather than transforming it into a driver of structural reorganization within productive systems. There are successful cases, such as aluminum can recycling, which exceeds 98% due to stable coordination among industry, cooperatives, and consumers (Brasil, 2022), and the lubricant oil return

system, which allows for partial reintegration of the material (Gonzaga et al., 2021). These examples, however, remain exceptions and do not constitute a national pattern of circularity.

When this scenario is shifted to the Amazon, structural limitations become more pronounced. Geographic dispersion, reliance on river transport routes, high logistical costs, and institutional fragility result in fragmented RL systems that are difficult to consolidate (Brandão et al., 2023; Souza & Nascimento-e-Silva, 2024). Empirical evidence illustrates these constraints: in Castanhal (PA), low source separation hinders the recovery of the organic fraction (Teixeira et al., 2024); in Parintins (AM), circularity initiatives in the furniture sector face infrastructure limitations (Souza, 2025); in Rio Branco (AC), fewer than 40% of consumers return pesticide containers despite training campaigns (De Souza et al., 2023); and in Porto Velho (RO), the return of automotive batteries depends on external structures, undermining consistent compliance with PNRS requirements (Souza & Melo, 2020).

These cases reveal that RL does not operate uniformly across the territory. Its effectiveness depends on state capacities, coordination among actors, and the existence of infrastructure that ensures the continuous functioning of flows. In the Amazonian context, this dependence becomes even more acute due to socio-spatial inequalities, long distances, low institutional density, and material fragilities that shape the daily realities of municipalities and productive chains (Patulski et al., 2024).

In Acre, the institutionalization of RL through the State Integrated Solid Waste Management Plan (PEGIRS/AC, 2012) established relevant goals, but its implementation has been marked by persistent limitations. Reports from 2020 to 2024 highlight low selective collection coverage, financing difficulties, and strong dependence on external transfers (Acre, 2020; 2021; 2022; 2023; 2024). The revision of the PEGIRS initiated in 2024 acknowledges this gap and signals the need to strengthen institutional coordination and implementation capacity.

Together, these findings reinforce the importance of understanding RL as a territorialized process conditioned by state capacities, productive structures, and specific social dynamics. The recurring distance between planning and practice, observed in Acre and other Amazonian states, indicates that analytical models capable of integrating normative, institutional, and territorial dimensions are still lacking, underscoring the relevance of conceptual models tailored to the region's peripheral realities.

Methodology

This study adopts a qualitative approach of an exploratory and analytical nature, following Lösch et al. (2023), who emphasize the suitability of this type of investigation for deepening understanding of underdeveloped phenomena and supporting the formulation of conceptual propositions. The methodological design integrates two complementary components: (i) a SLR and (ii) documentary analysis of legal frameworks and management reports related to the PNRS and the state of Acre. This combination enabled the integration of theoretical foundations on RL and CE with institutional and territorial evidence from the Southwestern Amazon. Figure 1 summarizes the stages of the process and illustrates how each step contributes to the construction of the conceptual model.
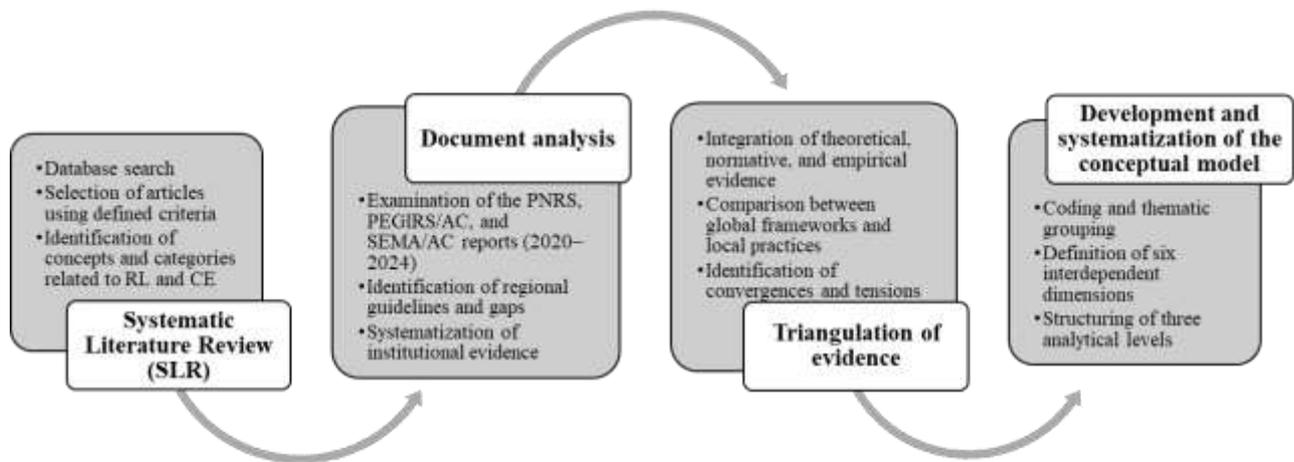
Figure 1. Methodological stages of the research. Source: Prepared by the authors (2025).

The SLR was conducted following the recommendations of Carrera-Rivera et al. (2022) to ensure transparency and reproducibility. The databases Web of Science, Scopus, SciELO, and the CAPES Journal Portal were consulted, considering publications between 2020 and 2025 in Portuguese and English. The search strategy employed descriptors combined with Boolean operators, as exemplified by the expression: ("logística reversa" OR "reverse logistics") AND ("economia circular" OR "circular economy") AND ("gestão de resíduos" OR "waste management" OR "responsabilidade estendida do produtor" OR "extended producer responsibility") AND ("Amazônia" OR "Amazon region" OR "Brasil" OR "Brazil").

Peer-reviewed and open-access articles were included if they addressed: (i) interfaces between RL and CE; (ii) governance and public policies on solid waste; and (iii) implementation experiences in developing countries, with particular attention to Brazil and the Amazon. Duplicate records, conference abstracts, texts lacking methodological detail, non-peer-reviewed articles, and studies without full access were excluded.

Data analysis

The documentary analysis encompassed three main sets of sources: the PNRS and its complementary legislation; the PEGIRS/AC and its associated technical documents; and management reports from the Acre State Secretariat for the Environment (SEMA/AC) from 2020 to 2024. These materials were examined to identify formal guidelines, implementation gaps, and regional strategies related to reverse logistics.

Data from the systematic literature review and the documentary sources were integrated through thematic content analysis, following Sampaio and Lycarião (2021). The procedure unfolded in three complementary stages: the systematization of the literature on reverse logistics and circular economy, the analysis of institutional documents with emphasis on guidelines and regional constraints, and the triangulation of theoretical, normative, and empirical evidence. This process enabled the comparison of global frameworks with local practices and supported an understanding of how international and national guidelines are reinterpreted through the institutional, territorial, and socioeconomic conditions of the Southwestern Amazon.

Within this analytical process, the unit of analysis comprised policy guidelines, programs, targets, and implementation actions explicitly reported in legal instruments and management reports. Coding followed a

deductive–inductive logic, combining categories recurrent in the literature with themes emerging from the documents. Each coded excerpt was assigned to one of the analytical dimensions according to its primary function within the reverse logistics system. This procedure allowed the identification of documentary evidence supporting each dimension, including governance gaps reported by SEMA (2020–2024), financial dependence documented in FEMAF reports, data on waste picker cooperatives (SEMA, 2021), contrasts between PEGIRS/AC targets and selective collection coverage, limitations in organic waste recovery, and misalignments between PNRS guidelines and their local implementation.

Category construction and model development

The development of the conceptual model followed the principle of explicit evidence systematization, as discussed by Jaakkola (2020). The findings from the triangulation were organized by thematic affinity, forming a preliminary set of analytical categories related to RL in Amazonian contexts. These categories were continuously compared with the literature and institutional documents to ensure conceptual coherence and avoid a merely descriptive or fragmented synthesis.

The consolidation of these categories resulted from the integration of three bodies of evidence: the theoretical foundation systematized through the SLR, the institutional documents examined, and the empirical insights produced through triangulation. This cross-analysis allowed refinement of the initial categories and their organization into six interdependent dimensions synthesizing the main conditioning factors of RL in Amazonian contexts.

Based on this structure, the conceptual model was organized into three analytical levels. The structural level encompasses institutional, governance, normative, legal, and financial aspects that shape RL coordination capacity. The operational level incorporates logistical, technological, and environmental elements that influence the execution of material return and reintegration practices. The social level addresses socioeconomic conditions and the productive inclusion of vulnerable populations, particularly waste pickers, who play a decisive role in reverse flows in the region.

The resulting model interprets RL as a territorialized process in which technical mechanisms, institutional capacities, and social dynamics interact in specific ways. By integrating these dimensions, the model offers an analytical framework tailored to the particularities of the Southwestern Amazon, enabling an understanding of how local conditions shape the feasibility and effectiveness of material return strategies.

Results and Discussion

The results presented in this section derive from the integration of three complementary sources of evidence. The systematic literature review provided the theoretical basis, identifying recurrent dimensions, drivers, and barriers associated with reverse logistics and circular economy across different contexts. The analysis of normative instruments (PNRS and PEGIRS/AC) contributed the institutional and regulatory framework guiding reverse logistics policies in Brazil. Finally, the examination of SEMA/AC management reports (2020–2024) supplied territorial and empirical evidence on implementation gaps, operational constraints, and region-specific strategies in the Southwestern Amazon. Together, these sources informed the analytical synthesis and the construction of the territorialized conceptual model presented in this study.

The SLR process resulted in a final sample constructed through successive filtering stages. The initial search identified 448 studies across the databases consulted: Web of Science (136), Scopus (178), SciELO (62), and the CAPES Journal Portal (72). Duplicate removal eliminated 84 records, yielding 364 unique publications. The application of methodological filters reduced this number as follows: publication period (–24), language (–15), full-text availability (–19), and peer-review status (–8), resulting in 141 eligible studies. Title and abstract

screening led to the selection of 71 articles for full-text reading. At this stage, studies lacking methodological detail, empirical data, or direct engagement with the topic were excluded. Ultimately, 33 studies met all criteria and composed the final sample of the review.

Figure 2 synthesizes the stages of identification, screening, and selection leading to the definition of the final sample.
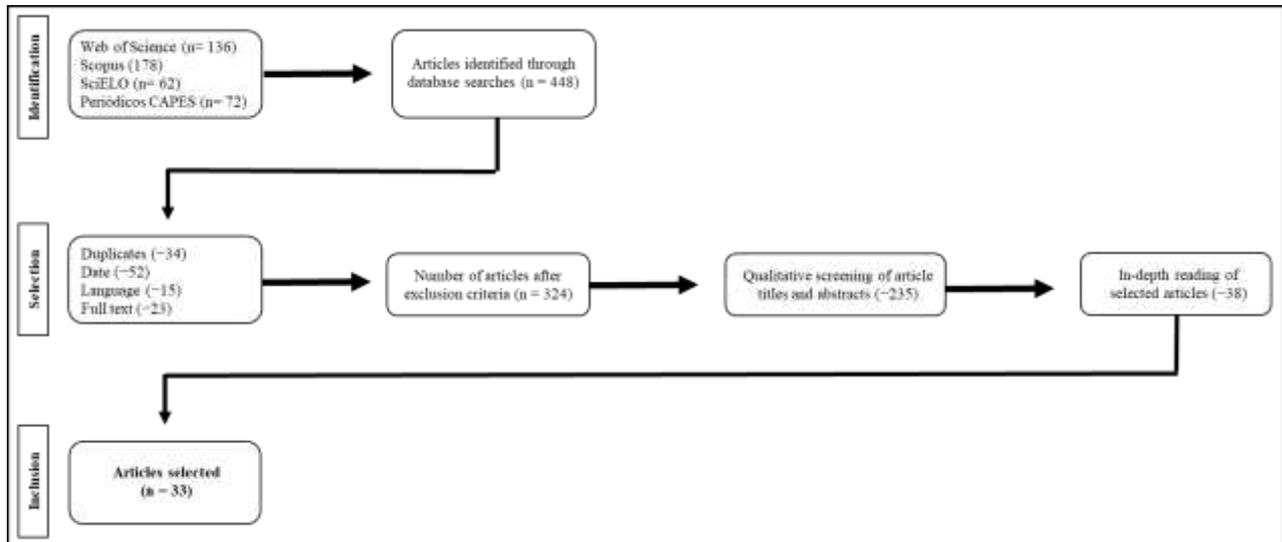

Figure 2. Article selection process for the systematic literature review. Source: Prepared by the authors (2025).

The final sample revealed a predominance of studies discussing RL in interface with CE, with emphasis on governance mechanisms, extended producer responsibility, waste picker inclusion, and integration across sustainable production chains. A balance was observed between analytical and empirical studies, including international comparisons addressing recurring challenges in developing countries. The most consistent contributions originated from Brazil and other Latin American countries, complemented by conceptual approaches developed in Europe and Asia. Together, these studies offer an integrated overview of the advances and limitations of RL, forming the foundation for the triangulation of theoretical, normative, and empirical evidence conducted in this work.

To support the integration of SLR findings with the documentary analysis, the extracted information was organized into an analytical matrix and grouped into thematic categories. Table 1 synthesizes this process by presenting, for each dimension analyzed, a diagnosis of the main barriers and gaps, and, in the implications column, the potential consequences for the design and implementation of RL at the regional scale. This constitutes an analytical synthesis that integrates theory, regulatory instruments, and empirical evidence, highlighting the limits and possibilities of RL in Acre.

The institutional and governance dimension shows that, although the PNRS and sectoral agreements constitute a relevant formal framework, their implementation progresses unevenly and exhibits low adherence to CE practices (Leal et al., 2025). In Acre, management reports point to persistent difficulties in articulating government agencies and achieving convergence among federal, state, and municipal policies, which limits the capacity to adapt national guidelines to Amazonian specificities.

In 2020, the state established the Integrated Center for Geoprocessing and Environmental Monitoring (CIGMA), bringing together the Rural Environmental Registry (CAR), Environmental Regularization Program (PRA), and hydrometeorological monitoring in an attempt to consolidate unified technical governance (Acre, 2020). In 2021, diagnostics conducted in Assis Brasil and Plácido de Castro identified local operational limitations, and in 2023, progress was made in the development of a regional project proposing sanitary landfills,

recycling plants, and composting facilities for 11 municipalities (Acre, 2021; Acre, 2023). In 2024, the revision of the PEGIRS was initiated with the aim of drafting new state waste legislation, including mechanisms for municipal technical assistance and an integrated monitoring platform (Acre, 2024). Despite these advances, these remain fragmented initiatives, insufficient to ensure continuous and coordinated governance, reinforcing the need for permanent coordination bodies and more robust mechanisms for alignment across federal, state, and municipal levels.

Table 1. Analytical synthesis of RL dimensions and challenges in Acre

Dimension	Diagnosis	Implications for RL
Institutional / Governance	Intermunicipal consortia proposed in the PEGIRS did not consolidate; coordination across government levels remains fragile; sectoral agreements advance unevenly and with low adherence to CE.	Strengthen governance mechanisms, establish permanent coordination bodies, and integrate national, state, and municipal policies.
Socioeconomic	Recycling chains marked by informality; low valuation of waste pickers; social inclusion limited to isolated initiatives; high collection costs and limited consumer engagement.	Promote productive inclusion, expand economic incentives, recognize waste pickers as environmental service providers, and intensify educational campaigns.
Environmental	Isolated advances in specific flows (e.g., lubricating oil); municipalities still rely on open dumps and controlled landfills; low source separation; limited use of the organic fraction; incipient ecodesign and industrial symbiosis.	Integrate waste-valorization strategies, expand selective collection, promote composting and biodigestion, and foster CE-oriented environmental innovation.
Technological / Operational	Insufficient infrastructure concentrated in urban areas; regional hubs outside the capital did not consolidate; difficulties in flow traceability; territorial dispersion and dependence on river routes increase transport costs.	Invest in regionalized logistics infrastructure, adopt technological solutions adapted to Amazonian conditions, and expand digital traceability of flows.
Normative / Legal	PNRS and PEGIRS provide formal guidelines, but implementation is limited; gap between normative density and practical application; need for PEGIRS revision recognized in 2024.	Ensure regulatory effectiveness, revise and update state plans, align national and local instruments, and create legal mechanisms for monitoring and transparency.
Financial	Strong dependence on external resources (World Bank, IDB, KfW, Amazon Fund); FEMAF executes annual resources but has low capacity for own mobilization; absence of consistent economic incentives and viable circular business models.	Develop innovative financing mechanisms, diversify revenue sources (environmental funds, PPPs, PES), and stimulate circular business models viable at regional scale.

Source: Prepared by the authors (2025).

The socioeconomic dimension reveals structural challenges related to the informality of recycling chains and the low valuation of waste pickers, as indicated by Izidoro and Trevizan (2025). In Acre, these workers

remain essential to the operation of reverse flows but continue to be marginalized in governance arrangements. In 2021, SEMA recorded 635 families linked to six cooperatives supported by the state government: Coopfrutos (20 families), Coaapex (35), Coopermogno (222), Coopercintra (252), Ayõpare (67), and Pushuã Shawãdawa (39) (Acre, 2021). That same year, the Reciclando Vidas project trained 42 municipal technicians and promoted environmental education initiatives in schools, which were expanded in 2022 to additional municipalities. However, these actions remain dependent on specific projects and lack structuring mechanisms for economic valorization, formalization of the chains, or sustained strengthening of productive inclusion.

The environmental dimension indicates isolated advances, such as the collection of lubricant oil containers, but highlights structural limitations in waste recovery. Persistent barriers include low source separation, limited use of the organic fraction, and the incipient adoption of CE instruments such as ecodesign, life-cycle extension, and industrial symbiosis (Mallick et al., 2024). In 2021, under the Reciclando Vidas (Recycling Lives) project, 100 waste bins were produced using timber seized by Acre Institute for the Environment (IMAC) and distributed across the 22 municipalities to reinforce environmental education efforts. Even so, reports from 2022 and 2023 show that many municipalities still rely on open dumps and controlled landfills, contrary to national eradication targets set for 2014 (Acre, 2022; 2023). These findings suggest that the environmental basis of RL in Acre remains limited by infrastructure shortages and insufficient incentives for circularity.

The technological and operational dimension reveals recurring bottlenecks in Amazonian regions characterized by territorial dispersion, low urban density, and dependence on river transport routes, which increase collection costs and restrict flow traceability (Sonar et al., 2024; Brandão et al., 2023). In Acre, selective collection remained concentrated in the capital and urban areas in 2021, with limited expansion to other municipalities (Acre, 2021). In 2023, the regional landfill project incorporated proposals for biogas plants, composting units, and recycling structures, representing an initial attempt to adapt technological solutions to local conditions, still in the planning stage and dependent on municipal implementation capacity (Acre, 2023).

The normative dimension shows that the PNRS, together with the PEGIRS/AC (Acre, 2012), provides a central guideline for integrated management, complemented by instruments such as the Ecological-Economic Zoning (ZEE) and the Multi-Year Plans, which guide government goals in four-year cycles (Acre, 2023). In 2021, a Working Group was created to revise the PEGIRS, and in 2024, the formulation of new state waste legislation began, including municipal technical support and the creation of a monitoring platform. However, this normative density contrasts with local operational limitations, revealing a persistent gap between regulation and execution.

The financial dimension presents structural weaknesses in RL financing, characterized by the absence of continuous incentives, difficulties in internalizing environmental costs, and low economic feasibility of circular models at scale (Appiah & Owusu-Bio, 2024). In Acre, these limitations are exacerbated by low public and private investment capacity, the limited economic attractiveness of recycling, and strong dependence on external transfers (SINIR, 2021). In 2023, Acre State Environmental Fund (FEMAF) submitted financial reports and consolidated an investment plan for the sector, and in 2024, it approved the Annual Investment Plan (PAI) for 2025, including the allocation of environmental fines to waste-related actions. Nevertheless, financial availability remains insufficient to structure robust collection, sorting, and recycling systems.

The integrated analysis of these six dimensions shows that RL in Acre is configured as a multidimensional process conditioned by institutional, socioeconomic, environmental, technological, normative, and financial factors. This configuration reinforces the need for territorialized and coordinated approaches capable of aligning national guidelines with local specificities and sustaining RL implementation in peripheral Amazonian regions.

Evidence from Acre

The implementation of RL in Acre must be understood in light of two interconnected frameworks. On one hand, the PNRS, which since 2010 has established national guidelines such as shared responsibility, the elimination of open dumps, and mandatory sectoral RL. On the other hand, the PEGIRS/AC, published in 2012, which sought to adapt these guidelines to the Amazonian context. The plan incorporated innovative elements, including the proposal of intermunicipal consortia for small municipalities, the creation of regional recycling hubs, and the definition of progressive selective collection targets through 2029. It also recognized specific waste management flows for riverine, Indigenous, and rural areas, demonstrating a territorial sensitivity that is uncommon in state plans from other regions of the country.

The analysis of SEMA's management reports from 2020 to 2024, however, reveals a persistent gap between planning and execution. In 2020 and 2021, the state's main environmental programs were financed predominantly by external resources from the International Bank for Reconstruction and Development (IBRD), KfW Development Bank, the Inter-American Development Bank (IDB), and the Amazon Fund, indicating low state financing capacity and a strong dependence on external transfers (Acre, 2020; 2021). During this period, selective collection remained restricted to the urban centers of Rio Branco, Cruzeiro do Sul, and Brasileia, with no expansion into smaller municipalities or isolated areas, and no progress was made in consolidating the intermunicipal consortia proposed in the PEGIRS/AC. The 2022 report reinforces this scenario, noting that in addition to the low coverage of selective collection, the state's waste management instruments required updating, as they were considered outdated in relation to operational demands and municipal needs (Acre, 2022).

The 2023 and 2024 reports make these limitations even more evident: more than 80% of municipalities in Acre continue to use open dumps or controlled landfills, in contradiction to the national eradication target established for 2014 (Acre, 2023; Acre, 2024). Selective collection remains restricted to major urban centers and does not reach riverine communities, Indigenous villages, or isolated localities, undermining the progressive targets established in the PEGIRS/AC. The social inclusion of waste pickers also remains limited and dependent on isolated initiatives, such as Terms of Conduct Adjustment, specific agreements, or environmental education campaigns, without forming a continuous state policy for socioeconomic valorization.

Despite these constraints, the reports document relevant advances, including consolidated RL initiatives for lubricant oil packaging, environmental education programs, strengthened urban cooperatives, and technical support for municipalities in organizing waste management services. In 2024, SEMA formally acknowledges the outdated nature of the PEGIRS/AC and begins its revision, accompanied by the development of new state waste legislation. Among the planned innovations is the creation of an integrated monitoring platform designed to enhance transparency and strengthen the state's capacity to track public policies.

Table 2 synthesizes the comparison between the PNRS guidelines, the orientations of the PEGIRS/AC, and the evidence observed in SEMA's management reports from 2020 to 2024.

The comparison shows that, in Acre, the implementation of RL remains constrained by institutional, operational, and financial limitations that hinder compliance with the targets established more than a decade ago. At the same time, it points to an emerging agenda: the revision of the PEGIRS/AC, the explicit acknowledgement of existing gaps, and the presence of well-structured sectoral initiatives. These elements suggest minimum conditions for advancing territorialized strategies that align normative guidelines, implementation instruments, and governance mechanisms adapted to Amazonian specificities, foundations that support the conceptual model proposed in this article.

Table 2. PNRS × PEGIRS/AC × SEMA management reports

Axis	PNRS (2010)	PEGIRS/AC (2012)	Management Reports 2020–2024
Shared responsibility	Shared responsibility among producers, consumers, and public authorities	Adaptation to intermunicipal and local arrangements	Fragile coordination; absence of consolidated intermunicipal consortia; low PNRS–municipal integration
Eradication of open dumps	National target by 2014	State deadline aligned	Persistence of open dumps and controlled landfills in several municipalities; lack of universalization of adequate disposal
Selective collection	Gradual universalization	Progressive target until 2029	Coverage restricted to urban centers; absence in remote areas and riverine communities
Sectoral RL	Mandatory (packaging, tires, lubricating oil, etc.)	Regional hubs and consortia	Isolated initiatives (e.g., lubricating oil); hubs outside the capital not consolidated
Social inclusion	Recognition of waste pickers	Support for cooperatives and inclusion of riverine/Indigenous groups	Limited and fragmented support; integration restricted to TACs and isolated programs

Source: Prepared by the authors (2025).

Territorialized conceptual model of RL in Amazonian contexts

The systematization presented in Table 1 showed that RL in Acre is structured around six interdependent dimensions. The proposed conceptual model derives from these dimensions and reorganizes them into three analytical levels, enabling an understanding of how institutional, operational, and social factors condition RL implementation in Amazonian contexts. These levels also guide the definition of the indicators presented later in the text, ensuring coherence between the conceptual foundation and the measurement parameters. In addition, the model engages with international debates in regional science by demonstrating how peripheral territories reinterpret CE guidelines based on their state capacities, socioeconomic dynamics, and particular logistical conditions.

The starting point is recognizing that RL does not function merely as a technical waste-management mechanism. In Amazonian states, its viability depends on institutional, social, and economic factors that include coordination across government levels, the valuation of vulnerable groups, overcoming infrastructure barriers, achieving flow traceability, and securing financing mechanisms capable of sustaining actions in the medium and long term. To integrate these elements, the model is organized into three interconnected analytical levels, as illustrated in Figure 3.

The structural level comprises the institutional and governance, normative and legal, and financial dimensions. These dimensions establish the fundamental conditions for consolidating RL, involving stable institutional arrangements, regulatory coherence, and financial sustainability. The analysis of the 2020 and 2021 reports reveals a significant dependence on external funding for maintaining environmental programs, as documented in the previous diagnostic section (Acre, 2020; Acre, 2021). This dependence reinforces systemic vulnerability and indicates the need for regional mechanisms for resource mobilization and management, which

aligns with Appiah and Owusu-Bio's (2024) diagnosis regarding the financial fragility of circularity policies in developing countries.
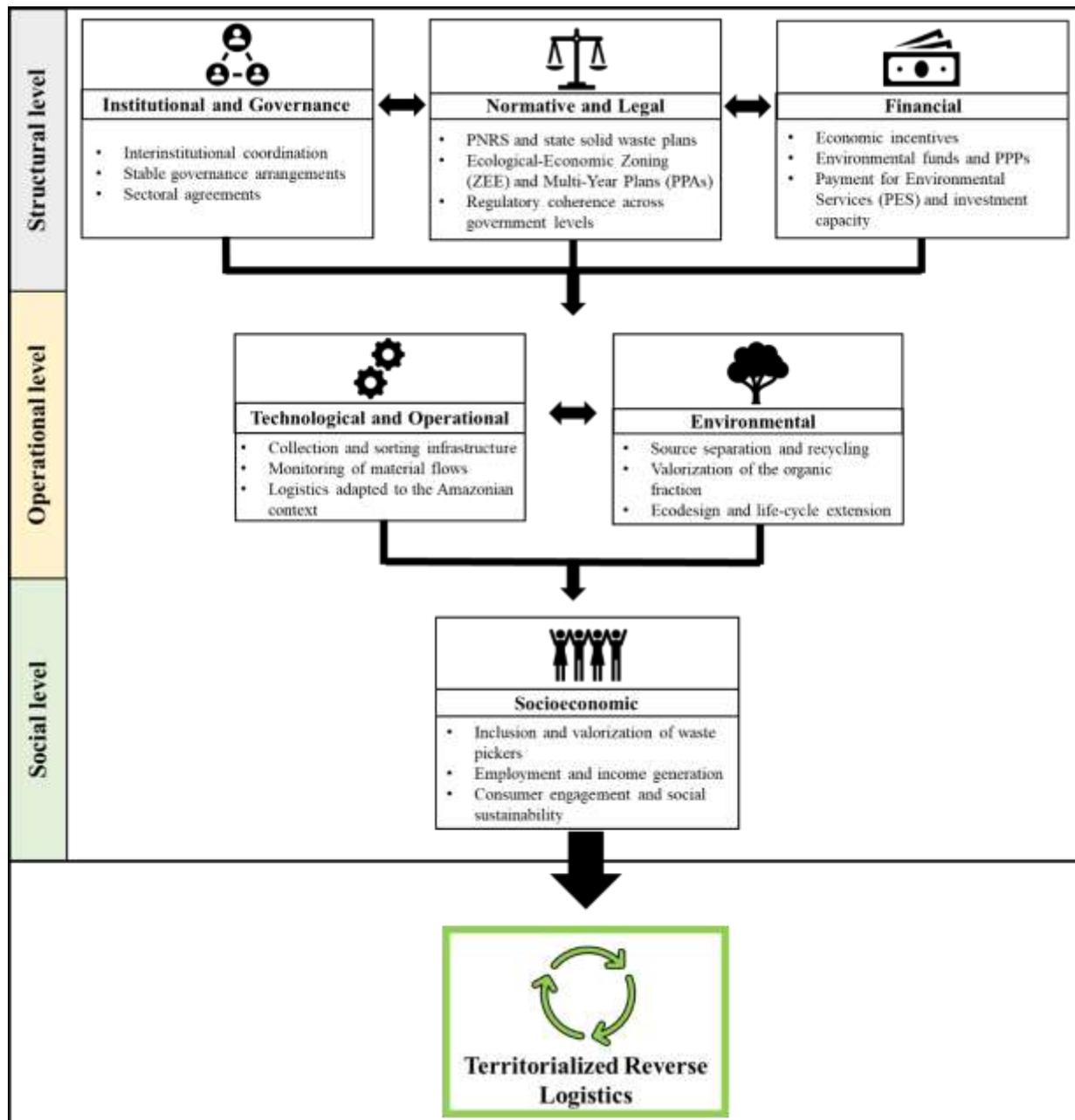

Figure 3. Territorialized conceptual model of RL in the Amazon. Source: Prepared by the authors (2025).

The operational level articulates the technological and environmental dimensions, concentrating the main implementation challenges. Central elements include logistical infrastructure, flow traceability, the efficiency of environmental practices, and the adoption of CE-related instruments such as ecodesign, industrial symbiosis, and organic waste valorization. Reports from 2022 and 2023 indicate that the previously identified structural limitations, low selective collection coverage and inadequate waste handling in the interior, remain significant barriers to RL consolidation (Acre, 2022; Acre, 2023). These documents also highlight difficulties in expanding processing and sorting facilities to the interior, largely due to territorial dispersion and reliance on costly river and road transport. These obstacles confirm that without infrastructure adapted to Amazonian conditions,

operational guidelines rarely translate into effective practices, consistent with discussions by Tadaiesky et al. (2022).

The social level corresponds to the socioeconomic dimension, responsible for conferring legitimacy to the system. This level emphasizes the inclusion of waste pickers and vulnerable populations, job and income generation, and the engagement of consumers and firms. The 2023 and 2024 reports document isolated initiatives supporting urban cooperatives, many enabled by Terms of Conduct Adjustment (TACs), and environmental education actions (Acre, 2023; Acre, 2024). However, the integration of waste pickers into RL remains limited and discontinuous, marked by the absence of stable remuneration mechanisms, formalization, or participation in decision-making processes. This scenario reinforces that without consistent social inclusion, RL tends to reproduce socioeconomic inequalities and lack territorial legitimacy, as argued by De Carvalho et al. (2021).

From an explanatory perspective, the model assumes that outcomes in territorialized reverse logistics emerge from the interaction among the three analytical levels. Structural fragilities, such as weak interinstitutional coordination and unstable financing, tend to reduce operational continuity and limit the scaling of reverse flows. Conversely, the availability of logistics infrastructure and mechanisms for flow traceability at the operational level conditions efficiency, coverage, and the effective reintegration of materials into productive chains. At the social level, the inclusion, formalization, and remuneration of waste pickers directly affect the legitimacy of reverse logistics systems and the volume of materials recovered. These interactions indicate that advances at one level are unlikely to produce sustained results in the absence of complementary progress across the others, reinforcing the need for coordinated and territorialized strategies.

The articulation among the three levels, when guided by territorialized strategies, has the potential to transform RL into a driver of regional reorganization. In Acre, integrating legal frameworks, technological innovation, financial incentives, and social inclusion can help reduce inequalities, strengthen environmental governance, and position the state within international debates on CE and sustainable development.

The distinctiveness of the proposed model lies in its ability to articulate classical RL dimensions from a territorialized perspective, incorporating Amazonian characteristics such as geographic dispersion, dependence on river transport, low institutional density, and the social vulnerability of groups such as waste pickers. At the same time, it connects these characteristics to the international debate in regional science, offering an analytical framework that not only identifies barriers but also proposes pathways for integrating institutional, socioeconomic, environmental, technological, normative, and financial factors.

Definition of indicators

Translating the conceptual model into operational instruments required defining indicators capable of consistently measuring the degree of implementation of territorialized RL. This process was guided by two complementary references. First, the six analytical dimensions of the model were considered to ensure coherence between the conceptual logic and the measurement of results. Next, the indicators were aligned with the evidence extracted from SEMA's management reports (2020–2024) and with parameters recurrent in the RL and CE literature, including national targets and international commitments such as the elimination of open dumps established in the PNRS and the SDGs.

Based on this combination of conceptual rigor and empirical adherence, a preliminary set of key performance indicators (KPIs) was developed and is presented in Table 3. The KPIs were organized according to the six dimensions of the model, allowing a direct correspondence between each analytical dimension and a specific set of monitoring metrics. This structure enables the conceptual model to move beyond a purely theoretical framework and become an effective instrument for monitoring and evaluating public policies.

Table 3. KPIs for territorialized RL in the Amazon

Dimension	Indicator	Unit	Expected Source	Target / Reference
Institutional / Normative	Municipalities with updated solid waste management plans integrated into the PEGIRS/AC	% of total municipalities	State reports / SEMA / IBGE / SINIR	≥ 80% by 2030
Operational	Selective collection coverage (% of urban population regularly served)	%	Municipal reports / SEMA / SNIS	≥ 50% by 2030
Operational	Annual volume of sorted recyclable waste	t/year	SNIS / SINIR / SEMA	Annual growth of 10%
Operational	Traceability of reverse flows (% of tracked waste)	%	SEMA / SINIR / digital systems	≥ 60% by 2030
Structural / Financial	Share of external resources in the waste policy budget	%	Management reports / FEMAF	< 40% by 2030
Environmental	Organic fraction recovered (composting and biodigestion)	% of total organic waste	Municipal programs / SNIS / SEMA	≥ 30% by 2030
Environmental	Municipalities without active open dumps	% of total municipalities	State reports / SNIS / IBGE	100% by 2030 (eradication)
Social	Waste pickers formalized in cooperatives	number	SEMA / TACs / local associations	Annual expansion of 15%
Social	Average monthly income of waste pickers	R$	Local surveys / IBGE / associations	≥ 2 minimum wages by 2030

Source: Prepared by the authors (2025).

The indicators presented in Table 3 serve to translate the conceptual model into verifiable parameters, ensuring coherence with the six analytical dimensions previously defined. Within the institutional and normative set, they allow for the assessment of planning capacity and the degree of regulatory alignment across federal, state, and municipal levels. In the structural and financial dimension, the indicators assess the budgetary sustainability of waste policies and the capacity for coordination among institutions, an essential aspect in contexts marked by dependence on external resources.

At the operational level, the indicators capture logistical efficiency, service coverage, and the traceability of reverse flows, elements directly associated with the day-to-day implementation of RL. The environmental dimension brings together metrics that monitor the use of the organic fraction, the reduction of improper disposal, and progress toward eliminating open dumps, parameters aligned with the PNRS targets and international circularity agendas. The social dimension encompasses indicators related to productive inclusion, formalization, and the economic valorization of waste pickers, highlighting the centrality of these actors in Amazonian reverse systems.

Taken as a whole, the KPIs function as a bridge between conceptual formulation and public management practice. They make it possible to verify whether institutional, technological, and social advances converge toward measurable circularity outcomes and simultaneously provide support for the continuous adjustment of waste policies. In this way, the indicator system strengthens the governance of territorialized RL and enhances

the capacity to guide strategic decision-making in Amazonian states, connecting normative targets, empirical evidence, and operational instruments.

Guidelines for implementing the conceptual model

analytical levels and six interdependent dimensions, as well as the set of indicators that operationalizes this structure. The following section translates this framework into implementation guidelines, aligned with the evidence observed in Acre's management reports (2020–2024) and organized according to the model's structural, operational, and social articulations. The purpose is to support public policy makers in integrating institutional arrangements, economic instruments, and technical solutions compatible with Amazonian realities.

The guidelines follow three guiding principles: territorialization of actions, coordination across government levels and private actors, and the use of results-oriented financing and monitoring mechanisms. These principles derive directly from the six interdependent dimensions of the conceptual model and are operationalized across the three levels summarized in Table 4, functioning as an extension of the indicators presented in Table 3.

Table 4. Implementation guidelines for territorialized RL

Level of analysis	Proposed guidelines	Suggested steps
Structural	Strengthen interinstitutional coordination and align national and state regulatory instruments.	(i) Create permanent governance bodies; (ii) articulate PNRS with state and municipal plans; (iii) establish stable monitoring mechanisms.
	Develop innovative financing mechanisms.	(i) Develop regional environmental funds; (ii) stimulate public–private partnerships; (iii) incorporate payment for environmental services instruments.
Operational	Invest in logistics infrastructure adapted to Amazonian conditions.	(i) Implement regional sorting centers; (ii) adapt transportation to river and road conditions; (iii) expand traceability of reverse flows.
	Promote sustainable technologies and the valorization of the organic fraction.	(i) Increase source segregation of the organic fraction (≥ 40% by 2030); (ii) Implement at least one composting or biodigestion facility per microregion by 2028; (iii) Process 50,000 tons/year of organic waste by 2035.
Social	Promote inclusion of waste pickers and vulnerable populations.	(i) Support the formalization of cooperatives; (ii) ensure fair remuneration for services provided; (iii) include waste pickers in training programs.
	Encourage participation of consumers and companies.	(i) Establish permanent educational campaigns; (ii) offer economic incentives for participation; (iii) integrate consumers and companies into RL systems.

Source: Prepared by the authors (2025).

The organization of the guidelines into levels demonstrates that the implementation of territorialized RL depends on articulated and complementary actions. At the structural level, which brings together the institutional, normative, and financial dimensions, the results indicate the need to strengthen permanent coordination mechanisms and align legal instruments across federal, state, and municipal levels. Given the structural dependence identified earlier, the financial-level guidelines require mechanisms capable of reducing the system's exposure to fluctuations in external transfers (Acre, 2020; Acre, 2021). This scenario highlights limitations in

autonomous financing capacity and reinforces the importance of developing innovative funding instruments, such as regional environmental funds and economic mechanisms designed to promote long-term stability (Silva et al., 2025).

The operational level translates structural conditions into technical actions related to the technological and environmental dimensions. This level involves installing logistics infrastructure adapted to Amazonian conditions, particularly in light of territorial dispersion, dependence on river and road routes, and low population density in rural areas. The 2022 and 2023 reports indicate persistent barriers such as low source segregation and the absence of facilities for processing the organic fraction (Acre, 2022; Acre, 2023). In response, the guidelines propose progressive targets, raising source segregation to ≥ 40% by 2030, establishing at least one composting or biodigestion facility per microregion by 2028, and achieving 50,000 tons/year of processed material by 2035—transforming operational objectives into verifiable parameters consistent with CE strategies reported in the literature.

The social level, corresponding to the socioeconomic dimension, highlights the need to integrate waste pickers and vulnerable populations into RL strategies. The 2023 and 2024 reports document isolated initiatives to support cooperatives and promote environmental education, but show that productive inclusion remains limited and lacks institutional continuity (Acre, 2023; Acre, 2024). The guidelines underscore the importance of advancing cooperative formalization, ensuring payment for services rendered, and expanding consumer and business engagement, since adherence to source segregation and material return practices is central to the functioning of reverse systems.

Taken together, the three levels demonstrate that implementing RL in Amazonian states requires consistent articulation among the six dimensions of the conceptual model, institutional, normative, financial, technological, environmental, and socioeconomic. Without such articulation, reverse systems tend to remain limited and with low capacity for expansion. When structured in a territorialized manner, these guidelines have the potential to strengthen coordination among public policies, enhance the effectiveness of waste management actions, and bring Amazonian states closer to international CE and sustainability agendas.

Diagnosis of RL in the Amazon and lessons from Acre

The triangulation of literature, regulatory frameworks, and official documents shows that the consolidation of RL in the Amazon, and specifically in Acre, is shaped by constraints that extend beyond the technical dimension. Studies indicate that, in developing countries, RL effectiveness is often limited by the absence of strategic planning, low visibility of reverse flows, and fragile coordination mechanisms (Mallick et al., 2023; Sonar et al., 2024). In Acre, these restrictions appear recurrently. The PEGIRS/AC and management reports reveal implementation gaps, low investment capacity, and strong dependence on external resources to enable structuring actions (Acre, 2012; 2020; 2021; 2022; 2023; 2024). The results include persistent difficulties in structuring intermunicipal consortia, low selective collection coverage, and continuous reliance on federal and international cooperation.

Productive inclusion of waste pickers constitutes another critical point. International research recognizes their importance for CE but also demonstrates that their integration into formal systems is uneven and limited (Zisopoulos et al., 2023). Acre's reality confirms this diagnosis: despite the presence of TACs, agreements, and isolated support projects, management reports from 2020 to 2024 indicate that waste pickers' participation in formal flows remains restricted, compromising both operational scale and the social legitimacy of RL systems. This scenario supported the analytical decision to position the social level as a structuring axis of the conceptual model, acknowledging that RL effectiveness depends on arrangements that articulate productive inclusion, institutional recognition, and stable remuneration mechanisms.

The operational dimension concentrates another set of tensions. The literature identifies insufficient infrastructure and low traceability as central barriers to circularity (Sonar et al., 2024). In Acre, these challenges are exacerbated by territorial characteristics such as geographic dispersion, low population density, and dependence on river transport, which increase transportation costs and fragment logistical flows. The 2022 and 2023 reports show that selective collection remains restricted to urban areas, failing to reach riverine communities and remote localities, and that sorting hubs outside the capital have not been consolidated (Acre, 2022; Acre, 2023). This reality reinforces the relevance of territorializing RL through regional sorting centers, consortia arrangements, and technological solutions adapted to Amazonian conditions (Brandão et al., 2023).

From a normative and legal standpoint, the PNRS offers a comprehensive framework, but its effectiveness depends on state and municipal instruments capable of operationalizing its guidelines. Recent studies on sectoral agreements show that, although they formally meet legal requirements, they exhibit low adherence to CE practices (Souza et al., 2024). In Acre, the gap between normative density and practical implementation is evident in management reports from 2020 to 2024: despite advances in environmental regularization, forest concessions, and bioeconomy programs, open dumps persist, selective collection barely expands, and mechanisms for financing and interinstitutional coordination remain difficult to consolidate (Acre, 2020; 2021; 2022; 2023; 2024). Instruments such as the ZEE and the PEGIRS/AC demonstrate planning capacity, but their execution depends on economic incentives, coordination across government scales, and institutional strengthening.

Considered collectively, this body of evidence indicates that RL in Amazonian states remains limited by the combination of institutional fragilities, financial constraints, operational discontinuities, and specific logistical conditions. At the same time, it underlines the need for a territorialized model capable of integrating normative, institutional, operational, and social dimensions. The conceptual model proposed in this article responds to this diagnosis by articulating six dimensions across three analytical levels, offering an integrated interpretation of RL that simultaneously recognizes constraints and opportunities. This approach converges with studies advocating arrangements that integrate environmental sustainability, social inclusion, and economic innovation as structuring elements of circularity (De Giovanni, 2022; Rodríguez et al., 2024).

In the field of regional science, Acre's experience contributes to understanding how peripheral territories reinterpret and adapt global CE guidelines. On one hand, the state presents characteristics typical of regions with low state capacity, such as dependence on external funding, informality, and limited infrastructure. On the other, it constitutes an experimental environment for policies that territorialize RL, testing forms of integration among legal frameworks, institutional capacities, technologies, and social inclusion. In this context, RL moves beyond being a mere technical instrument of waste management and becomes a process of territorial reorganization, with the potential to strengthen environmental governance, expand the bioeconomy, and bring Amazonian states closer to global sustainability and CE agendas.

Final considerations

This article examined the extent to which RL can function as a driver of territorial reorganization in Acre by articulating inequality reduction, the inclusion of vulnerable groups, and the strengthening of environmental governance. Based on a systematic literature review combined with the analysis of legal frameworks and management reports from 2020 to 2024, a territorialized conceptual model was developed, structured into three analytical levels integrating six interdependent dimensions. The analysis indicates that the effectiveness of RL in the Amazon depends on institutional coordination, stable financing mechanisms, infrastructure and technologies adapted to territorial conditions, and the productive inclusion of waste pickers, alongside the engagement of consumers and firms. The translation of this model into KPIs provides measurable parameters for policy guidance and monitoring.

The study's contributions derive directly from the empirical diagnosis and the proposed conceptual structure. First, it offers a territorialized understanding of RL oriented toward Amazonian states, shifting the focus from isolated technical instruments to institutional, economic, and social arrangements that condition implementation. Second, it reinforces the centrality of the social dimension and translates the conceptual structure into operational guidelines, supporting public managers in coordinating policies, infrastructure, and management practices in contexts marked by geographic dispersion, low operational scale, and investment constraints.

The empirical evidence reinforces this diagnosis. A strong dependence on external resources was observed, together with limited selective collection coverage outside urban centers and persistent difficulties in consolidating regional sorting infrastructure. At the same time, specific advances were identified, including improvements in sectoral flows and the initiation of the revision of the state waste management plan, with provisions to strengthen monitoring mechanisms and federative integration. These elements underpin the proposed guidelines, which emphasize institutional coordination, regulatory alignment, financial diversification, regionalized infrastructure, flow traceability, and productive inclusion. In the short and medium term, priority actions include the selection of pilot territories, the strengthening of consortial arrangements, and the expansion of organic waste management, with progressive targets for segregation, facility deployment, and processing capacity, contributing to the regional bioeconomy and territorial governance.

The study presents limitations inherent to the use of secondary sources restricted to official documents and recent literature. Although this strategy was appropriate for grounding a conceptual model, it constrains financial, operational, and social analyses based on primary data. In addition, the temporal scope and the exclusive focus on Acre limit the direct extrapolation of the findings to other Amazonian states with distinct institutional and logistical arrangements.

Future research may advance in three complementary directions: comparative analyses across Amazonian states to test the model's consistency under different governance and financing conditions; impact assessments based on the proposed indicators to evaluate operational, social, economic, and environmental outcomes; and applied studies on specific instruments, such as results-based financing, digital integration of reverse flows, incentives for ecodesign, and industrial symbiosis. Together, these avenues can strengthen the analytical and operational foundations needed to guide public policies and support the transition toward a circular economy in the Amazon.

References

Acre. (2012). *Plano Estadual de Gestão Integrada de Resíduos Sólidos*. Secretaria de Estado de Meio Ambiente, Rio Branco: SEMA.

Acre. (2020). *Relatório de Gestão 2020*. Secretaria de Estado de Meio Ambiente, Rio Branco: SEMA.

Acre. (2021). *Relatório de Gestão 2021*. Secretaria de Estado de Meio Ambiente, Rio Branco: SEMA.

Acre. (2022). *Relatório de Gestão 2022*. Secretaria de Estado de Meio Ambiente, Rio Branco: SEMA.

Acre. (2023). *Relatório de Gestão 2023*. Secretaria de Estado de Meio Ambiente, Rio Branco: SEMA.

Acre. (2024). *Relatório de Gestão 2024*. Secretaria de Estado de Meio Ambiente, Rio Branco: SEMA.

Appiah, L. O., & Owusu-Bio, M. K. (2024). Reverse logistics and financial performance in a developing country context: the moderating role of analytics capability. *Journal of Responsible Production and Consumption*, 1(1), 81–106. https://doi.org/10.1108/jrpc-11-2023-0020

Araújo, C. M., Soliani, R. D., Oliveira, D. A. de, Lima Júnior, F. B. de, Alves, S. de F. F., Nora, L. A. R. da S., Silva, M. E. da, & Siqueira, R. M. (2024). Sustainable transportation in the Brazilian agroindustrial supply chain: A literature review. *Revista de Gestão Social e Ambiental*, 18(5), e05392. https://doi.org/10.24857/rgsa.v18n5-056

Brandao, R., Edwards, D. J., Melo, A. C. S., & Macedo, A. N. (2023). Reverse supply chain practices for construction and demolition waste in the Brazilian Amazon: a multi-stakeholder view. *Journal of Material Cycles and Waste Management*, 1–17. https://doi.org/10.1007/s10163-023-01680-1

Brasil. (2010). *Lei nº 12.305, de 2 de agosto de 2010*. Institui a Política Nacional de Resíduos Sólidos; altera a Lei no 9.605, de 12 de fevereiro de 1998; e dá outras providências. Diário Oficial da União, Brasília, DF.

Brasil. (2022). *Índice de reciclagem de latas de alumínio chega a 99% e Brasil se destaca como recordista mundial*. Ministério do Meio Ambiente, Brasília, DF.

Carrera-Rivera, A., Ochoa, W., Larrinaga, F., & Lasa, G. (2022). How-to conduct a systematic literature review: A quick guide for computer science research. *MethodsX*, 9(101895), 101895. https://doi.org/10.1016/j.mex.2022.101895

De Andrade, F. N., & de Araujo, F. V. (2025). An analysis of the legal and management aspects of plastic waste in Brazil. *Sustainable Futures*, 10(101120), 101120. https://doi.org/10.1016/j.sftr.2025.101120

De Carvalho, F. dos R., Morais, H. B., Melo, A. C. S., Nunes, D. R. de L., Nagata, V. de M. N., & Braga Junior, A. E. (2021). Melhorias ao processo de logística reversa à luz da PNRS: estudo de caso em uma cooperativa de catadores. *Brazilian Journal of Development*, 7(11), 101746–101764. https://doi.org/10.34117/bjdv7n11-003

De Giovanni, P. (2022). Leveraging the circular economy with a closed-loop supply chain and a reverse omni-channel using blockchain technology and incentives. *International Journal of Operations & Production Management*, 42(7), 959–994. https://doi.org/10.1108/ijopm-07-2021-0445

De Souza, E. C. V. de A., de Lima Junior, F. B., Soliani, R. D., Oliveira, P. R. de S., de Oliveira, D. A., Siqueira, R. M., Nora, L. A. R. S., & Macêdo, J. (2023). Reverse Logistics of Pesticide Packaging: A Case Study in Rio Branco/Ac, Brazil. *Revista de Gestão Social e Ambiental - RGSA*, 17(3), e03296. https://doi.org/10.24857/rgsa.v17n3-010

Dennison, M. S., Kumar, M. B., & Jebabalan, S. K. (2024). Realization of circular economy principles in manufacturing: obstacles, advancements, and routes to achieve a sustainable industry transformation. *Discover Sustainability*, 5(1). https://doi.org/10.1007/s43621-024-00689-2

Espey, J., Parnell, S., & Revi, A. (2023). The transformative potential of a Global Urban Agenda and its lessons in a time of crisis. *Npj Urban Sustainability*, 3(1), 15. https://doi.org/10.1038/s42949-023-00087-z

Fernando, Y., Shaharudin, M. S., & Abideen, A. Z. (2023). Circular economy-based reverse logistics: dynamic interplay between sustainable resource commitment and financial performance. *European Journal of Management and Business Economics*, 32(1), 91–112. https://doi.org/10.1108/ejmbe-08-2020-0254

Gonzaga, N. da C., Silva, R. N. da, & Andrade, L. P. de. (2021). Gerenciamento de Resíduos do Óleo Lubrificante: Uma Revisão Sistemática da Literatura. *Revista de Gestão Social e Ambiental*, 15, e02812. https://doi.org/10.24857/rgsa.v15.2812

Izidoro, L. G., & Trevizan, A. F. (2025). Waste pickers in extended producer responsibility policies: A comparative analysis of Brazil and the European Union. *Review of European, Comparative & International Environmental Law*, 34(2), 352–364. https://doi.org/10.1111/reel.70014

Jaakkola, E. (2020). Designing conceptual articles: four approaches. *AMS Review*, 10(1–2), 18–26. https://doi.org/10.1007/s13162-020-00161-0

Kirchherr, J., Yang, N.-H. N., Schulze-Spüntrup, F., Heerink, M. J., & Hartley, K. (2023). Conceptualizing the circular economy (revisited): An analysis of 221 definitions. *Resources, Conservation, and Recycling*, 194(107001), 107001. https://doi.org/10.1016/j.resconrec.2023.107001

Le, S. T. (2023). Investigating the drivers of the reverse logistics implementation in reducing waste in Vietnam. *Environmental Health Insights*, 17, 11786302231211058. https://doi.org/10.1177/11786302231211058

Leal, T. L. M. de C., Araújo, J. C. G. de, & Rodrigues, L. B. (2025). Avaliação dos acordos setoriais de logística reversa como mecanismos de promoção da economia circular. *Brazilian Journal of Production Engineering*, 11(1), 192–212. https://doi.org/10.47456/bjpe.v11i1.46051

Lösch, S., Rambo, C. A., & Ferreira, J. L. (2023). A pesquisa exploratória na abordagem qualitativa em educação. *Revista Ibero-Americana de Estudos em Educação*, e023141. https://doi.org/10.21723/riaee.v18i00.17958

Mallick, P. K., Salling, K. B., Pigosso, D. C. A., & McAloone, T. C. (2023). Closing the loop: Establishing reverse logistics for a circular economy, a systematic review. *Journal of Environmental Management*, 328(117017), 117017. https://doi.org/10.1016/j.jenvman.2022.117017

Mishra, A., Dutta, P., Jayasankar, S., Jain, P., & Mathiyazhagan, K. (2023). A review of reverse logistics and closed-loop supply chains in the perspective of circular economy. *Benchmarking: An International Journal*, 30(3), 975–1020. https://doi.org/10.1108/bij-11-2021-0669

MPAC. (2020). *Anuário da Gestão de Resíduos no Estado do Acre - 2019*. Ministério Público do Estado do Acre, Rio Branco, AC.

Oliveira, T. J. A. de, Nogueira, L. A., & Rodrigues, W. (2023). Nos limites da sustentabilidade: a responsabilidade estendida do produtor na gestão de embalagens de agroquímicos. *Ambiente & Sociedade*, 26. https://doi.org/10.1590/1809-4422asoc0076r1vu2023l3ao

Patulski, A. C. de P., Carneiro, C., & Fernandes, V. (2024). Modalities of packaging reverse logistics in Brazil, Federal Decree No. 11,413, February 13, 2023. *Engenharia Sanitaria e Ambiental*, 29(e20240034). https://doi.org/10.1590/s1413-415220240034

Picard, M. S., & Manfredi, L. C. (2023). Operationalizing a corporate sustainability transformation in a fast-moving-consumer goods company. *Estudios Gerenciales*, 464–475. https://doi.org/10.18046/j.estger.2023.169.5989

Rahman, M. A., Hossain, M. Z., & Rahaman, K. R. (2023). Climate urbanism as a new urban development paradigm: Evaluating a city's progression towards climate urbanism in the Global South. *Climate*, 11(8), 159. https://doi.org/10.3390/cli11080159

Rodríguez, E. C. A., Hernández, C. T., Aguirre-Rodríguez, E. Y., da Silva, A. F., & Marins, F. A. S. (2024). Reverse Logistics and the Circular Economy: A study before and after the implementation of the National Solid Waste Policy in Brazil. *Recycling*, 9(4), 64. https://doi.org/10.3390/recycling9040064

Sampaio, R. C., & Lycarião, D. (2021). *Análise de conteúdo categorial: manual de aplicação*. Escola Nacional de Administração Pública - Enap, Brasília.

Santiago, C. D., Marotti, A. C. B., Pugliesi, E., & Gonçalves, J. C. (2023). Política Nacional de Resíduos Sólidos: perspectivas após um decênio de sua promulgação. *Desenvolvimento e Meio Ambiente*, 62. https://doi.org/10.5380/dma.v62i0.81833

Sedovs, E., & Volkova, T. (2024). Sustainability: Is it a strategic management research fashion? *Sustainability*, 16(17), 7434. https://doi.org/10.3390/su16177434

Silva, J. C. K., Soliani, R. D., Satrapa, H. F. M., & Lobão, M. S. P. (2025). Public innovation policies in Acre: a systemic analysis of the regional ecosystem of Science, Technology and Innovation. *Revista Políticas Públicas*, 29(2), 970–990. https://doi.org/10.18764/2178-2865.v29n2.2025.53

SINIR. (2021). *Relatório Estadual de Gestão de Resíduos Sólidos*. Sistema Nacional de Informações sobre a Gestão dos Resíduos Sólidos. Ministério do Meio Ambiente e Mudança do Clima - MMA, Brasília, DF.

Soliani, R. D. (2021). Brazilian road freight transportation sector: The challenge of sustainability. *Journal of Traffic and Logistics Engineering*, 32–41. https://doi.org/10.18178/jtle.9.2.32-41

Sonar, H., Dey Sarkar, B., Joshi, P., Ghag, N., Choubey, V., & Jagtap, S. (2024). Navigating barriers to reverse logistics adoption in circular economy: An integrated approach for sustainable development. *Cleaner Logistics and Supply Chain*, 100165, 100165. https://doi.org/10.1016/j.clscn.2024.100165

Souza, A. R. D., & Melo, C. S. (2020). Logística reversa: um estudo sobre o processo de coleta de baterias em um distribuidor na cidade de Porto Velho-RO. *Diálogos: Economia e Sociedade*, v. 4., n. 2, p. 29–39.

Souza, R. de O., & Nascimento e Silva, D. (2024). A study on the difficulties of practicing reverse logistics by an association of waste pickers in the city of Manaus. *Contribuciones A Las Ciencias Sociales*, 17(12), e12782. https://doi.org/10.55905/revconv.17n.12-211

Souza, S. F. A. (2025). A implementação da logística reversa na região interiorana do Amazonas. *Revista ft*, v. 29, 144. https://doi.org/10.69849/revistaft/fa10202503151344

Souza, V. O. de, Santos, S. M., & Cabral Neto, J. P. (2024). Challenges in implementing the Sectoral Agreement for Reverse Logistics of electro-Electronic Products in Brazil. *Revista de Gestão Social e Ambiental*, 18(11), e09798. https://doi.org/10.24857/rgsa.v18n11-130

Tadaiesky, D. C., Neto, J. L. das N., Melo, A. C. S., Anholon, R., de Castro Coutinho, E., & Martins, V. W. B. (2022). Challenges to promoting resilience in supply chains observed during the COVID-19 pandemic: An exploratory study of the Amazon region using the TOPSIS technique. *Logistics*, 6(4), 78. https://doi.org/10.3390/logistics6040078

Teixeira, V. E. G., Cruz, W. S. C., Fernandes, R. M., Nunes, D. R. de L., Martins, V. W. B., & Nagata, V. de M. N. (2024). Barriers to the implementation of reverse logistics for organic solid waste in the Amazon: A study in a city in the metropolitan region of Belém. *Engenharia Sanitaria e Ambiental*, 29. https://doi.org/10.1590/s1413-415220240024

United Nations - UN. (2015a). *Sustainable Development Goals (SDGs)*. United Nations Regional Information Centre for Western Europe. Brussels, Belgium.

United Nations - UN. (2015b). *Paris Agreement*. United Nations Treaty Collection. New York, USA.

Zisopoulos, F. K., Steuer, B., Abussafy, R., Toboso-Chavero, S., Liu, Z., Tong, X., & Schraven, D. (2023). Informal recyclers as stakeholders in a circular economy. *Journal of Cleaner Production*, 415(137894), 137894. https://doi.org/10.1016/j.jclepro.2023.137894