Strategies to overcome barriers to Circular Innovations in Latin America

Insights from Examples in Chile and Peru

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TU Delft

Strategies to overcome barriers to Circular Innovations in Latin America

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by

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Glossary

C-TIS (LA) Circular Technological Innovation System framework in the context of Latin America.

CAPEX Capital Expenditure.

CE Circular Economy.

CI Circular Innovation.

EPR Extended Producer Responsibility.

GDP Gross Domestic Product.

LAC Latin America and the Caribbean.

MRQ Main Research Question.

OECD Organization for Economic Co-operation and Development.

rCB recovered Carbon Black.

SDG Sustainable Development Goal.

SQ Sub-question.

TIS Technological Innovation System.

Executive Summary

Latin America faces significant environmental and socio-economic challenges due to its predominant "extract, transform, and dispose" economic model. The Circular Economy (CE) offers a crucial alternative by focusing on sustainability through rethinking and redesigning production processes to minimize waste and maximize resource efficiency. Within this framework, Circular Innovations (CIs) play a vital role in promoting sustainable practices. This research seeks to adapt the Technological Innovation Systems (TIS) framework to better identify and overcome barriers to CIs in Latin America.

The study began with a comprehensive literature review, which provided a foundation for adapting the TIS framework to both the principles of circularity and the specific context of Latin America. This adapted framework was then applied through case studies in the region, offering a practical examination of the challenges and opportunities for CE in Latin America.

The research synthesized insights from literature, case studies, and expert interviews to develop definitions of CE and CIs that are tailored to the Latin American context. The Circular Economy in Latin America is defined as the process of rethinking and redesigning production and consumption systems to minimize waste and maximize resource efficiency. This approach emphasizes waste management, recycling, and the transformation of waste into valuable resources throughout the entire lifecycle of products and services, aiming to achieve sustainability through regulatory alignment, technological innovation, and societal engagement. Circular Innovations are defined as innovations that align with these principles, focusing on waste minimization, resource efficiency, and sustainability.

The application of the adapted TIS framework revealed several significant barriers to the diffusion of CIs in Latin America. These include challenges in scaling up circular production processes efficiently, inefficiencies in transportation and distribution networks, and a significant lack of customer awareness and understanding of circular economy products. Additionally, there is a low willingness to pay for sustainable products, exacerbated by the lack of alignment in regulatory frameworks and inconsistent environmental laws. The framework also highlighted issues such as unclear and overly stringent regulatory requirements, the absence of standardized norms, competitive pricing challenges, and a lack of supportive infrastructure and incentives for circular economy initiatives.

To address these barriers, the research developed a series of niche strategies tailored to the specific challenges identified in the Latin American context. These strategies include the Demo, Experiment, and Develop Niche Strategy, which focuses on creating experimental spaces for innovation; the Subsidized Niche Strategy, aimed at providing financial support to emerging circular innovations; and the Geographic Niche Strategy, which targets specific regions with unique challenges and opportunities. Other strategies include the Educate Niche Strategy, which emphasizes the importance of raising awareness and knowledge among consumers and policymakers; the Top Niche Strategy, which focuses on leveraging high-impact innovations; and the Policy Advocacy Strategy, which involves engaging with regulatory bodies to align policies with circular economy goals.

These strategies were derived from the adapted TIS framework by systematically analyzing how various influencing conditions affect the framework's building blocks. The connection between these influencing conditions and the identified barriers provided a clear pathway for developing strategies that are both targeted and effective. The study highlights the critical role of niche strategies in promoting circularity in Latin America, ensuring that circular innovations can

achieve large-scale impact and contribute significantly to sustainable development in the region.

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Finally, I would like to acknowledge TU Delft for providing an environment that fosters growth and learning. The experiences and knowledge gained here have not only contributed to this thesis but also to my personal and professional development.

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1 Introduction

1.1 Background and Rationale

Latin America, rich in natural resources, faces profound environmental and socio-economic challenges driven by its predominant economic model. Characterized by "extract, transform, and dispose" practices, these activities threaten the stability of its economies and the integrity of its natural ecosystems—critical for human survival (Betancourt Morales & Zartha Sossa, 2020).

The region grapples with significant waste management issues: it generates approximately 1 kg of waste per capita daily, with urban areas producing around 230 million tonnes of municipal solid waste annually. Despite high collection rates, less than 4% of this waste is recycled, leading to substantial environmental pollution and landfill overload (Circle Economy, 2023). Adding complexity to these challenges are potential international waste trade agreements, such as a debated proposal in Ecuador to import waste from China, raising concerns about the adequacy of local waste processing capabilities and environmental standards (Gonzalez, 2024).

Moreover, the region's secondary material consumption—or the reuse of materials—is distressingly low, estimated at below 1%. This stark contrast with the global average points to a high dependency on virgin raw materials and underscores the critical need for enhanced recycling and reuse practices. The current waste generation and management practices, coupled with a minimal rate of material recycling, highlight a broader systemic issue that not only undermines the region's ecological integrity but also poses considerable risks to its social wellbeing (Circle Economy, 2023).

Furthermore, Latin America's economy heavily relies on the extraction and export of raw materials, contributing over 11% of the world's raw materials by weight, despite representing only 8.3% of the global population. This significant output positions the region as a crucial supplier in the global market but at a high environmental cost (Circle Economy, 2023). The extraction activities, often lacking remediation and mitigation measures, not only lead to severe degradation of local ecosystems but also raise issues of green colonialism. This dynamic, raises concerns about the geographic outsourcing of labor and natural resources that perpetuate historical North-South imbalances under the guise of environmental progress (Dorn, 2022). Notably, the extraction of materials like lithium, essential for modern technologies, has imposed severe environmental and social costs on local communities, as seen in the conflicts in places like the Salar de Atacama in Chile (Zografos & Robbins, 2020; Jerez et al., 2021).

In response to these pressing challenges, the Circular Economy (CE) emerges as a crucial alternative. CE stands out stands out as an innovative approach that deviates from traditional linear *take-make-dispose* models. CE can be defined as an economic model that focuses on sustainable development by designing out waste and extending the life cycle of resources. It emphasizes reusing, recycling, and reducing the use of materials to create environmental quality, economic prosperity, and social equity (Kirchherr et al., 2017). Although CE has gained global momentum, its interpretation and implementation vary significantly across regions.

In Latin America, CE resonates with global themes but presents unique nuances. The region's involvement with CE is deeply influenced by its sociocultural and historical context, with practices rooted in Indigenous knowledge and culture (Circle Economy, 2023; Paño Yañez, 2021). Furthermore, CE in Latin America extends beyond economic or environmental sustainability, representing a broader mission for social equality, cultural preservation, and a reimagining of production and consumption paradigms (Betancourt Morales & Zartha Sossa, 2020). While CE has seen a significant increases in scholarly research and consultancies reports in the *Western world*,

its actual implementation has been limited (Kirchherr et al., 2017, 2018).The situation in Latin America reflects a similar trend but is compounded by a more pronounced gap in formally recognized research and application. Most scientific inquiries and publications on CE are relatively recent and few in number, indicating that the region is still in the early stages of both understanding and applying these principles as defined by Western benchmarks. (Betancourt Morales & Zartha Sossa, 2020; Ospina-Mateus et al., 2023; Rodriguez-Sanchez et al., 2022). However, as mentioned before, it's important to recognize that many existing practices in Latin America, though not formally recognized under the conventional CE label, effectively align with the core concepts of circularity. These practices often reflect circular economy principles through local and indigenous methods, contributing significantly to sustainability, yet they may not fully conform to established Western standards.

Recognizing these realities, achieving a CE is not solely the responsibility of individuals but requires systemic changes across businesses, industries, and the entire economic landscape. This shift is driven by deep transformations in societal values, norms, and behaviors and is tightly linked to innovations in environmental practices that reshape how laws are applied, products are manufactured, and resources are utilized (Suchek et al., 2021). Among all the forms of environmental innovations that support this transformation, this research focuses on those led by businesses, particularly encompassing products and services. These innovations, referred to as Circular Innovations (CIs), include a range of products and services from simple, low-tech approaches to advanced technological applications, all developed to align with the overarching goals and principles of CE. These innovations are particularly crucial in Latin America, where they are tailored to meet local needs and contribute significantly to sustainable development by tackling unique regional challenges and leveraging local opportunities.

Significant scholarly work, including contributions like Kirchherr et al. (2018), has looked into barriers impeding the progress of CE. Given that CIs are developed to operationalize CE principles within business practices, obstacles facing CE inevitably influence the diffusion and adoption of these innovations. Despite this understanding, there is a significant gap in the literature concerning barriers to circularity within the Latin American context and strategies to overcome them. The Technological Innovation System (TIS) framework, notably explored by Ortt and Kamp (2022), and based in the premise that innovations thrive within socio-technical systems, presents a compelling perspective to explore the barriers to CIs and craft potential strategies. This research will specifically focus on adapting the TIS framework to identify and address barriers to CIs in Latin America, reflecting on both the broader CE and the specific innovations within this framework.

1.2 Knowledge Gaps

Several knowledge gaps have been identified that warrant further investigation:

1. Regional Specificity: While there is a growing body of literature on CE barriers globally (see section 3.2.3) there is a limited focus on the unique challenges and barriers specific to Latin American countries. The socio-political, economic, and cultural nuances of Latin America and of specific Latin American countries and industries might present distinct barriers not covered in global studies.

   Addressed in: Chapter 3 (Literature Review, partially), Chapter 5 (Framework Application, partially).

2. Strategies for Overcoming Barriers: While general strategies to overcome CE barriers are discussed (see section 3.2.5), region-specific strategies for Latin America are not extensively covered in the literature.

Addressed in: Chapter 3 (Literature Review, partially), Chapter 5 (Framework Application, partially), Chapter 6 (Strategy Development, partially).

3. Case Studies in Latin America: There's a noticeable gap in in-depth case studies that validate the effectiveness of strategies in overcoming CE barriers in Latin America (see section 3.2.6) for the state of Latin American CE strategies). Such case studies can provide practical insights and real-world examples of how barriers can be addressed.

   Addressed in: Chapter 5 (Framework Application).

4. TIS Framework Application: While the TIS framework is well-established in the context of technological innovations, its application to the Circular Economy, especially in Latin America, is not extensively explored (see sections 3.3.1, 3.3.2, 3.3.3 and 3.3.4). How the TIS framework can be tailored to address CE barriers in this region remains an area with limited research.

   Addressed in: Chapter 3 (Literature Review, partially), Chapter 4 (Adaptation of the TIS framework, partially).

All these reflect two main overall scientific gaps: the adaptation of the TIS framework for circular innovations and the adaptation of the TIS framework for the Latin American environment. Addressing these knowledge gaps is crucial to providing a complete understanding of the challenges and opportunities associated with the implementation of CE in Latin America. The subsequent research questions and methodology will aim to bridge these gaps and contribute to the existing body of knowledge.

1.3 Problem Statement

Reflecting on the context presented in the previous sections, the journey of Latin America towards a CE and the effective development and implementation of CIs is deeply intertwined with its unique societal, economic, and environmental fabric. This distinct context shapes the region's approach to adopting CIs but also gives rise to specific challenges, such as those stemming from its role as a significant supplier for the global market's demand for raw materials and energy resources (Circle Economy, 2023). These challenges are not isolated but directly impact the region's environmental stability and socio-economic equity.

The core of these challenges lies in the intensive extraction practices and the export-oriented economic model that not only depletes local natural resources but also perpetuates a form of green colonialism (Circle Economy, 2023). This dynamic contributes to environmental degradation and socioeconomic disparities, making the transition to CE both crucial and complex. The region's reliance on exporting primary materials to support the global North's energy transition underscores the urgent need for local sustainable development strategies that consider the environmental and social impacts on the local communities (Dorn, 2022).

The motivation for focusing this research on Latin America stems from a combination of personal and scholarly interests. As a Latin American, there is an inherent drive to contribute meaningfully to the region's sustainable development and to address the local challenges with context-specific solutions. Beyond personal connections, Latin America presents a compelling case study due to its rich biodiversity, diverse cultural and economic landscapes, and the pressing need for sustainable development strategies amidst various challenges such as income inequality, environmental degradation, and political instability. These factors collectively create a complex yet intriguing environment for exploring and implementing CIs.

Utilizing the TIS framework as a foundational tool, this research seeks to bridge the existing gap in literature by delving into these unique barriers specific to Latin America. The aim is to propose strategies that are not only effective but are also tailor-made for the nuanced realities of the region.

The exploration will consider whether these strategies can be empirically tested through a specific case study or validated through expert opinions as the research progresses. The central question at this stage is: *How can the TIS framework be adapted to identify the unique barriers to CIs in Latin America, and what strategies can be derived from this adapted framework to overcome these barriers?*

1.4 Research Significance

Strategizing for CIs application in Latin America is not just about following a global trend; it's an opportunity to recognize and capitalize on the region's unique sociocultural and economic landscape. Bridging the gap between CIs barriers and actionable strategies, rooted in the nuances of the Latin American context, has the potential to redefine sustainable solutions for the region, both ecologically and economically.

1.5 Research Questions

In this section, the main focus is to define and articulate the fundamental questions that will guide the research into the central topic, establishing the basis for the research objectives and methodology.

Main research question:

How can the TIS framework be adapted to identify the unique barriers to Circular Innovations in Latin America and what strategies can be derived from this adapted framework to overcome these barriers?

The main research question can be divided into the following sub-questions:

1. *How can we define CE and CIs within the Latin American context?*
2. *What are the barriers impacting the adoption of CIs in Latin American contexts?*
3. *What modifications are required in the TIS framework to make it suitable for analyzing and addressing the barriers specific to CIs?*
4. *How can the TIS framework, already adapted for CIs, be further modified to specifically address the barriers unique to Latin America?*
5. *How can the adapted TIS framework be used to derive and conceptualize effective strategies tailored to overcome the identified barriers to CIs in Latin America?*
6. *How do strategies derived from the adapted TIS framework compare to other theoretical and practical strategies for Latin America?*

1.6 Research Approach

The main objective of this research is to understand the barriers of CIs in Latin America. Given that the topic is still emerging within the Latin American context and presents inherent complexities, this research incorporates an exploratory approach as a foundational element. This

is complemented by descriptive methods, which capture the current state of knowledge, and explanatory methods, which delve deeper into qualitative insights.

This approach encompasses:

1. Literature Review: The foundational review aims to map out the current state of CE barriers in Latin America. This approach will primarily address Sub-question 1 regarding the definition of CE within the Latin American context, and Sub-question 2, which seeks to identify the barriers impacting the adoption of CE in the region. Additionally, the Literature Review will extend to an in-depth exploration of the TIS framework and its relevance and applications in the context of CIs. This segment of the review is critical for laying the groundwork to address Sub-question 3, which involves identifying the necessary modifications in the TIS framework to make it suitable for analyzing and addressing the barriers specific to CIs. Furthermore, the review will explore strategies for implementing CE derived from existing literature. By reviewing these strategies, this section anticipates the later comparison with strategies developed through the adapted TIS framework, and in doing so, it partially addresses the theoretical aspects of Sub-question 6.

2. Comparative Analysis and Integration: In this segment, a comparative analysis and integration of the previously reviewed adaptations of the TIS framework specific to CIs is conducted. The primary objective is to develop an intermediate framework, termed Circular TIS (C-TIS), which synthesizes the effective elements from the reviewed adaptations. This stage is essential in addressing Sub-question 3 by determining the necessary modifications to the TIS framework for CIs.

3. Contextual Adaptation: This segment involves the tailoring of the Circular TIS (C-TIS) framework to the unique circumstances and barriers of Circular Innovations in Latin America, as identified in the Literature Review. This step is designed to address Sub-question 4 and focuses on the modification of the C-TIS framework to align it with the specific challenges and dynamics in Latin America.

4. Empirical Assessment: This component will employ case studies and expert interviews to explore the real-world application of CE in Latin America. The case studies will provide insights into CE definitions, barriers, and strategies, directly addressing Sub-question 5, which examines the framework's applicability. These insights also partially address Sub-questions 1 and 2 by offering firsthand perspectives that complement the literature on CE definitions and barriers. Additionally, the strategies discussed in the interviews will later be compared with those from the literature and the adapted TIS framework, partially addressing Sub-question 6.

5. Strategy Development: In this phase, the research utilizes the findings from the case studies to develop strategies through the adapted TIS framework. This directly addresses Sub-question 5, focusing on the practical application of the framework. Additionally, this phase presents and compares these newly formulated strategies with those derived from the literature and interviews. Such a comparison thoroughly addresses Sub-question 6 by evaluating various theoretical and practical approaches to CE strategies.

The multi-methodological approach adopted brings a unique strength to this research. The exploratory component provides depth into emerging elements of the CE and CIs, the descriptive component shows the existing landscape, and the explanatory aspect offers clarity on complex relationships. Together, they ensure a balance between academic depth and practical relevance, making the findings applicable for both academic discussions and real-world applications in Latin America. Nonetheless, inherent challenges include potential subjectivity in interpreting qualitative data, biases that may arise in participant responses, and the limitations of the literature

review scope due to time constraints.

Detailed discussions on the execution of each of these components, ethical considerations, and more are provided in the subsequent *Research Methods* chapter.

1.7 Reading Guideline

After this introduction, Chapter 2 looks into the research methodologies, highlighting both conceptual and empirical tools utilized to determine and answer the research questions. In Chapter 3, readers will be guided through a comprehensive literature review. This chapter explores the principles of CE on a global scale, examines Latin America's unique interaction with the concept, and introduces the TIS framework and its adaptations. Chapter 4 discusses how the TIS framework is adapted for the study, specifically focusing on its application to Circular Innovations in the context of Latin America. Chapter 5 shows the application of the framework through empirical findings from case studies and expert interviews. In Chapter 6, the strategies developed from the framework, as well as other theoretical and practical strategies are presented and compared. Chapter 7 interprets the results, and presents the practical implications and scientific contribution. It also discusses other views of circularity in Latin American and global circular economy implications to the region. Finally, Chapter 8 summarizes the research findings in the context of the research questions, and points out general limitations.

For a structured journey through the research:

- Chapter 1: Introduction
- Chapter 2: Methodology
- Chapter 3: Literature Review
- Chapter 4: Adaptation of the TIS Framework
- Chapter 5: Framework Application
- Chapter 6: Strategy Development
- Chapter 7: Discussion
- Chapter 8: Conclusion

2 Methodology

Building on the broader framework presented in the research approach, this chapter provides insights into the chosen methodologies and their implementation. Each methodology serves a distinct purpose within the study, from uncovering new insights and mapping the current landscape to understanding and affirming research findings. In this chapter, the specifics of each method are examined, along with their interactions and how they contribute to a thorough and comprehensive exploration of Circular Innovations in Latin America.

2.1 Literature Review

The literature review serves as the foundational stage and will focus on:

- Circular Economy and Its Definitions: Reviewing both global and Latin American literature that defines and discusses the concept of Circular Economy, particularly in relation to its principles and practices.
- Barriers to CE Adoption: Identifying barriers to the adoption of CE as documented in global and Latin American contexts. This includes an in-depth exploration of literature discussing challenges such as economic constraints, policy issues, cultural factors, and environmental considerations.
- Strategies for CE Adoption: Identifying strategies for the adoption of CE documented in global and Latin American literature. The aim is to compare these strategies with those developed using the adapted TIS framework.
- Technological Innovation System (TIS) Framework: Investigating literature on the TIS framework, especially its application in studying innovation systems and its relevance to sustainability and Circular Economy.
- Adaptations of TIS Framework for CIs: Exploring how the TIS framework has been adapted or proposed to be adapted for studying Circular Innovations. This will involve examining modifications made to accommodate the unique characteristics and requirements of CIs.

The methodology for the literature review will involve:

- Database Search: Conducting comprehensive searches in academic databases such as Web of Science (WoS), Google Scholar, and Scopus, using a predefined set of keywords and search criteria tailored to each focus area.
- Screening and Selection: Applying a systematic approach to screen and select relevant publications. This process will involve criteria such as the publication's relevance to the research questions, the credibility of the sources, and the publication date to ensure current understanding.
- Review and Synthesis: Analyzing the selected literature to draw out key findings, trends, and gaps. The focus will be on synthesizing this information to provide a clear picture of the current state of knowledge in each of the key areas: CE in Latin America, barriers to CE, the TIS framework, and its adaptations.

Refer to Chapter 3 for a detailed discussion on the search criteria and strategy used in this review.

2.2 Comparative Analysis and Integration

The following steps outline the comparative analysis and integration process undertaken to adapt the TIS framework for CIs:

1. Identify relevant TIS framework adaptations: Begin by identifying various adaptations of the TIS framework specific to CIs. This involves conducting a thorough review of existing literature to select frameworks that address the unique challenges of CIs.

2. Conduct detailed comparative analysis of TIS adaptations: Perform a detailed comparative analysis of the selected TIS framework adaptations. This involves systematically examining how each adaptation has modified the original TIS framework to better fit the needs of Circular Innovations. Focus on the strengths, weaknesses, and specific modifications made in each adaptation.

3. Extract effective elements and practices from adaptations: Extract the most effective elements and practices from each adaptation that address the challenges associated with CIs. Evaluate which components have been successful in overcoming barriers to circular innovation and sustainability.

4. Synthesize elements into integrated Circular TIS (C-TIS) framework: Combine the identified effective elements and practices into a cohesive, integrated framework, referred to as the Circular TIS (C-TIS). This synthesis process involves merging the best practices and strategies from each adaptation to form a robust and comprehensive framework.

5. Document integration decisions for the C-TIS framework: Clearly document the decisions made during the synthesis process, detailing how and why certain elements were integrated into the new framework. This documentation ensures transparency and provides a rationale for the inclusion of specific practices in the C-TIS framework.

2.3 Contextual Adaptation

This stage is dedicated to adapting the CI adapted TIS model to the Latin American context:

- Review of Societal Assumptions: A critical aspect of this stage is the examination of societal and systemic assumptions present in the standard TIS model. Recognizing that many of these assumptions might be rooted in Western perspectives, this step involves a careful review to determine their applicability and relevance to Latin America. It will involve scrutinizing assumptions about societal structures, economic models, and innovation ecosystems to ensure they align with Latin American realities.

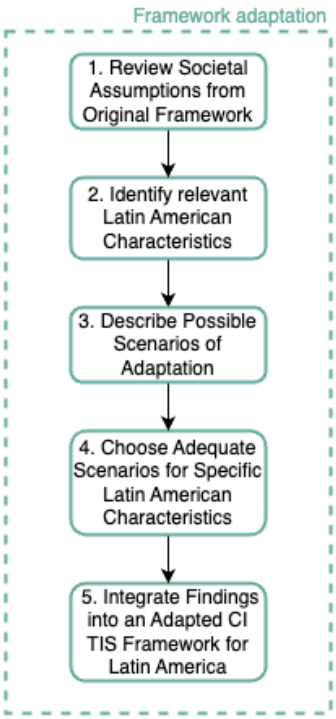
- Analysis of Latin American Characteristics under Adaptation Scenarios: The Latin American characteristics resulting from the assumption review will be analyzed under four possible adaptation scenarios:

    1. Scenario 1: The realization that the assumptions are so different they warrant the creation of a whole new model different from the TIS framework to fit these differences.
    2. Scenario 2: The addition of some characteristics/new assumptions to the whole context of the TIS framework. This refers to a change in context rather than a new model.
    3. Scenario 3: The addition of these characteristics as new influencing conditions.
    4. Scenario 4: The addition of these characteristics as new building blocks.

- Development of the Latin America-specific CI TIS Model: The outcome of this stage is the development of a TIS model tailored for CIs in Latin America. This model will be adjusted to reflect the integrated regional definitions, barriers, and revised societal assumptions. The adaptation can be either under one scenario by itself or any combination of scenarios 2, 3, and 4. It will be designed to address the unique socio-economic, cultural, and environmental aspects of the region, making it a specialized tool for understanding and fostering CIs in Latin America.

In this stage, the focus is on ensuring that the adapted TIS model is contextually relevant and sensitive to the unique characteristics of Latin America. The aim is to create a theoretical framework that is not only conceptually robust but also deeply resonant with the region's specific needs and challenges in the realm of CE and CIs. Figure 1 illustrates the steps involved in adapting the framework to this context.

Figure 1: Contextual adaptation steps



2.4 Empirical Assessment through Case Studies and Expert Interviews

To gain empirical depth and validate the adapted TIS framework, this methodology employs case studies and expert interviews focused on CI in Latin America. The case studies aim to provide a tangible examination of CI barriers and strategies, demonstrating the framework's applicability in real-world contexts. Expert interviews are designed to assess how well the adapted framework corresponds with industry perspectives and to gather expert insights on barriers and strategies concerning CE and CIs.

Case Studies: Each case study involves an in-depth look at specific instances of circular innovations, identifying and analyzing the unique barriers and strategies:

- Case Study 1 - Recycling of Mining Tires in Chile: This case study examines the processes and challenges involved in the recycling of mining tires in Chile, focusing on technological

aspects, logistical challenges, and regulatory considerations.

- Case Study 2 - Compost Production in Peru: This case study explores the production and market dynamics of compost from organic waste in Peru, emphasizing the operational, regulatory, and market-related challenges faced by the industry.

Expert Interviews: The approach here is to engage with CE experts to gather insights on circularity in Latin America, focusing on their definitions of circularity, perceptions of barriers, and strategic approaches. Experts will also provide their opinions on the fit and applicability of the newly adapted model for analyzing and addressing CI in the region.

Interview Process
This segment outlines the systematic approach used to conduct interviews with participants. The procedure is designed to ensure that both the case study subjects and expert interviewees are selected, prepared, and engaged in a manner that supports the objectives of our research. It includes detailed steps from participant recruitment to data analysis, ensuring transparency and rigor in gathering and interpreting the insights that inform our findings. The following steps will guide the procedure:

1. Participant Recruitment
    - Objective: Recruit two types of participants: those knowledgeable about specific circular innovations and experts in circular economy broader concepts.
    - Methods: Leverage LinkedIn, organizational websites, and referrals for participant recruitment.
    - Selection Criteria:
        - For Case Study Participants: Individuals directly involved in a company's innovation projects, with substantial knowledge of the specific sector, and involved with an innovation in its early stages of adoption (either not yet launched, recently launched, limited time in the market, or present on a smaller scale).
        - For Expert Interviewees: Recognized professionals with a proven track record of knowledge, practice, consultancy, or expertise in circular projects, innovations, or transformations specifically in Latin America. This includes those with broad knowledge of circular economy topics and implementation in the region.
    - Languages: Conduct all communications in Spanish, with translation services available for consent forms. .
2. Initial Contact
    - Methods: Reach out to potential participants via email and LinkedIn messaging.
    - Selection: Compile a list of willing and suitable candidates.
    - Communication: Maintain subsequent communications via email to confirm participation.
3. Interview Preparation
    - Question Design: Tailor separate question sets for case study participants and experts to cover their understanding of circularity, barriers, and strategic implementations.
    - Pilot Interviews: Conduct preliminary interviews to refine questions and interview structure based on participant feedback.
4. Scheduling Interviews

- Plan detailed interview timelines following initial contacts and pilot interview feedback.

5. Conducting Interviews
   - Platform: Utilize Microsoft Teams for audio and video recording, with automatic transcription enabled.
   - Participant Option: Allow participants to review interview transcripts to ensure accuracy and comfort with the shared information.
6. Follow-Up Interviews
   - Objective: Conduct additional sessions if needed to clarify responses or delve deeper into certain topics.
7. Data Analysis
   - Process: Manually analyze interview data to compare practical insights with the theoretical framework, focusing on identified barriers, causes, and strategies.
   - Integration: Synthesize case study and expert interview data within the framework, documenting all findings comprehensively.
8. Reporting Findings
   - Objective: Compile and present detailed findings in the designated report sections, including a summary of key insights from translated interviews.

The interview outline for the case studies and the expert interview participants are presented in Appendix E.

2.5 Strategy Development

Building upon the insights derived from the case studies, this research phase advances into strategy development. The strategies are developed based on the findings from the barriers and influencing conditions identified within the Latin American context through the adapted TIS framework. Although exploratory in nature, this stage is characterized by a methodical approach that employs logical reasoning to interconnect these identified barriers and conditions.

The process begins with a detailed analysis of the barriers and influencing conditions previously uncovered. This analysis is critical for understanding the complexities of the challenges and opportunities that characterize the region's journey towards a Circular Economy. There is a specific focus on how these barriers and conditions interact and impact one another.

Informed by this comprehensive understanding, the focus shifts to the conceptual development of potential strategies. These strategies are not formulated in isolation but as logical outcomes of the barriers and conditions identified from the case studies. The aim is to adapt and apply the TIS framework in such a way that it results in the creation of tailor-made strategies, specifically designed to address the distinct CI barriers in Latin America.

Following the formulation of these strategies, the research proceeds to a comparative analysis phase. This phase presents and compares the newly formulated strategies with those derived from the literature and expert interviews. Each proposed strategy is accompanied by a detailed and descriptive account, outlining its rationale, intended impact, and the logical basis for its formulation. This ensures that each strategy is not only grounded in the contextual realities of

Latin America but also forms a logical response to the unique combination of challenges and conditions identified through the research.

The outcome of this stage is a set of strategically formulated, logical, and contextually relevant approaches to overcoming the specific barriers to CE in Latin America. These strategies represent the practical application of theoretical insights gained through the adapted TIS framework. By comparing these strategies with those derived from literature and interviews, the research thoroughly evaluates various theoretical and practical approaches to CE strategies, enhancing the depth and applicability of the strategic outcomes.

2.6 Ethical Considerations

In all phases of the research, ethical considerations will be paramount. Particularly for the interviews, participants will be thoroughly informed about the purpose and scope of the research. Prior to participation, their explicit consent will be obtained. The research will adhere to strict confidentiality protocols, ensuring that all personal information and responses are anonymized. This commitment to ethical research practices not only ensures participants' rights and privacy but also improves the credibility and trustworthiness of the study's findings.

2.7 Ensuring Validity and Reliability

Ensuring the validity and reliability of this research is critical. Every step in the data collection and analysis process will be transparent, detailed, and replicable, emphasizing the research's integrity and commitment to producing findings that are both credible and trustworthy.

2.8 Limitations

While the chosen methodologies are rigorous and comprehensive, it's essential to acknowledge potential limitations that might influence the research outcomes. Some of the anticipated limitations include:

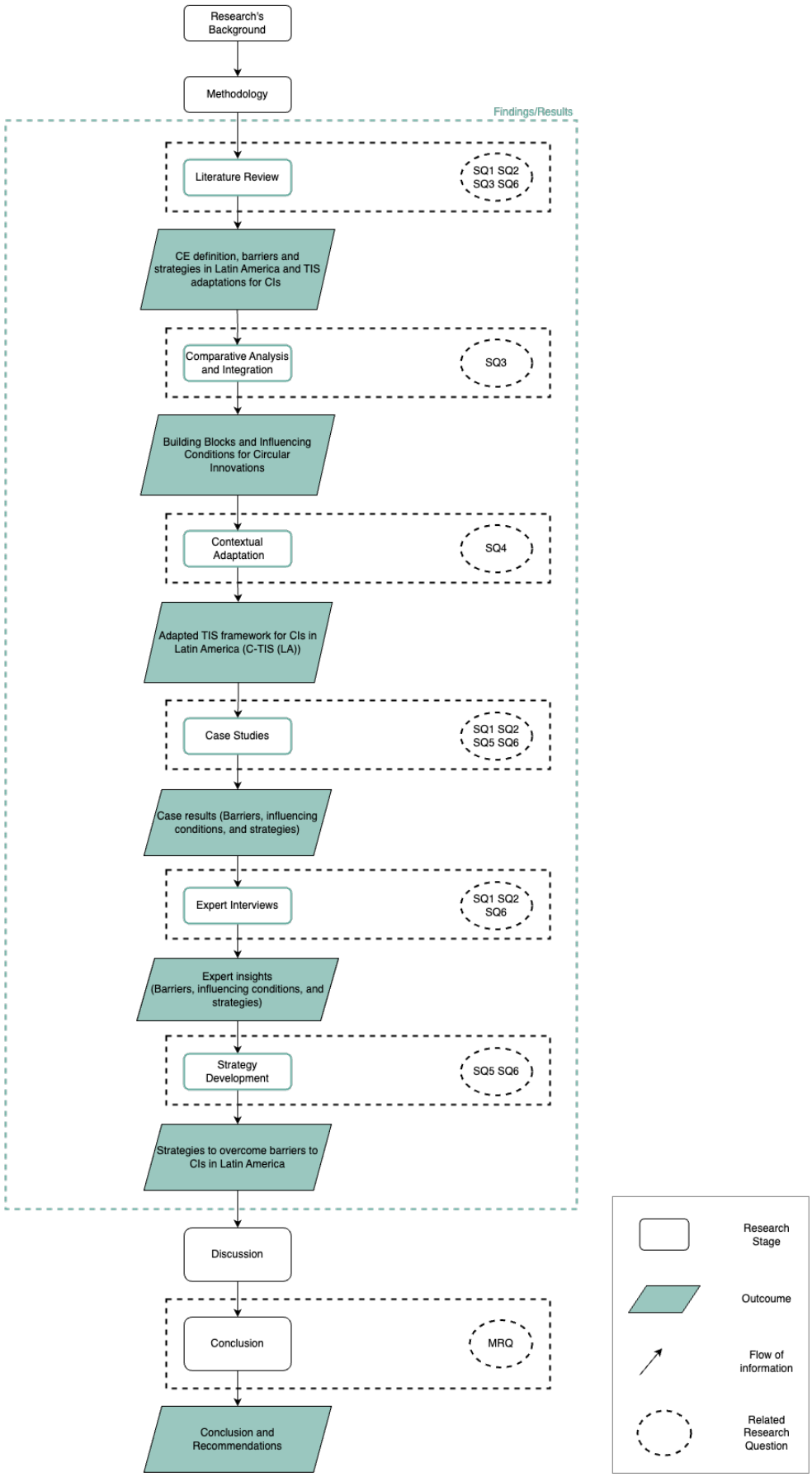
- Subjectivity in Qualitative Data: The nature of qualitative research inherently involves subjective interpretation. While this provides depth and nuance, it can also introduce biases.
- Participant Biases: Responses from interviewees might be influenced by their personal experiences, beliefs, or the desire to present themselves in a certain light.
- Scope of the Literature Review: Time constraints might limit the depth of the literature review, potentially excluding some relevant studies or perspectives.

Despite these limitations, by being transparent about potential biases and constraints and following the methodology, the research aims to provide valuable insights into CIS in Latin America. Recognizing these limitations not only offers a realistic perspective on the findings but also identifies areas for potential further research.

2.9 Research Flow Diagram

The following research flow diagram illustrates the systematic progression of this study, with each stage tied to specific sub-questions (SQ) and culminating in the main research question (MRQ). By detailing how each phase contributes to the broader research objectives, the diagram offers a clear outline of the research path to be followed.

Figure 2: Research Flow Diagram



3 Literature Review

This literature review will look into the present status of research on relevant CE and CIs barriers in general and in Latin America specifically. The objective is to offer an in-depth understanding of barriers and potential solutions related to the adoption of CIs. The review will also introduce readers to the TIS framework and some relevant adaptations that have been made to align the framework with CIs.

This chapter is structured to first describe the search process and criteria for the selected literature. It then presents key findings, organized into several subsections. These subsections explore the definition of CE, its unique interaction within the Latin American context, and the barriers faced by countries in the region. The review also delves into strategies, both general and Latin America-specific, that have been proposed to overcome these barriers. A special emphasis is given to the TIS framework and some adaptations, exploring its relevance and potential application in addressing CIs challenges.

3.1 Search Description and Selection Criteria

As a starting point for the review, literature on CE as the general topic of interest was scanned. This was accomplished by searching "circular economy" and "circular economy definition" in Google Scholar and Web of Science. While several heavily cited papers were identified, the selection process aimed to capture a diverse range of CE definitions. As such, a filtered set of articles, both highly cited and those offering unique definitions of CE, were selected.

Building on this foundation, attention shifted to barriers within the CE. Following the guidance of an academic advisor, *Barriers to the CE: Evidence From the European Union (EU)* by Kirchherr et al. (2018) was consulted. This lead to a deeper dive using the keyword combination "circular economy barriers". The search was further refined by introducing "strategies" as an additional keyword. Because this search produced a large volume of results, the 20 most relevant publications were chosen. The search showed that Kirchherr et al. (2018)'s paper was the most referenced work regarding CE barriers, with 1058 citations, confirming its importance on the topic. Another ten related articles were chosen from among the papers citing Kirchherr et al. (2018).

Subsequently, a regional focus on Latin America was introduced. Keywords such as "circular economy", "barriers", "strategies", and "Latin America" were combined to narrow down the search. To ensure a comprehensive exploration and given the significance of Spanish-language literature in the context of Latin America, translations of the keywords — "economia circular", "barreras", "estrategias" and "latinoamerica" — were combined and incorporated into the search. Informed by contributions from *Circular economy in Latin America: A systematic literature review* by Betancourt Morales and Zartha Sossa (2020) and *Analysis in circular economy research in Latin America: A bibliometric review* by Ospina-Mateus et al. (2023), the search parameters were broadened to encompass related concepts to circular economy that could provide additional relevant data. Therefore, a suite of supplementary keywords such as "circularity", "sustainability", "waste management", "bioeconomy", "industrial symbiosis", "recycling", and "supply chain management", all in conjunction with "Latin America", were included in both English and Spanish searches. To incorporate a critical perspective as advised by an academic supervisor, the term "green colonialism" (and "colonialismo verde" in Spanish) was also explored.

Initially, citation count was a primary selection criterion. However, when examining the Latin American context, many relevant papers, especially the more recent ones, exhibited fewer ci-

tations than might be expected in other contexts. Insights from Ospina-Mateus et al. (2023) revealed that publications on the topic from Latin America have been cited an average of approximately 10 times in various other publications. Notably, 30% of these articles have not been cited at all, and another 13% have received only one citation. With this information, the selection threshold based on citation count was adjusted for Latin American-focused papers. As a result, an additional 34 papers on the context of CE in Latin America were selected.

In addition to the primary focus on CE, the relevance of the TIS framework was highlighted. Accordingly, one foundational paper and three thesis, recommended by the academic advisor, were incorporated into the literature review to ensure a comprehensive understanding of the TIS framework and its adaptations for CIs (Ortt & Kamp, 2022; Shankar, 2023; Warns, 2023; Engelen, 2023).

From the 68 pre-selected articles, 32 were chosen for the literature review. Some studies were excluded because their findings were too specialized to certain scenarios or industries, or they were outside the scope of this literature review. Finally, several publications had results that were too similar to others and lacked substantial citations.

Table 1 delineates the inclusion and exclusion criteria applied during the literature review for both general and Latin American contexts.

The citation criteria were more strictly followed in the beginning of the process, when the volume of papers was more considerable. As the selection process advanced, especially when considering more current papers, this criterion was relaxed. In terms of publication year, the selection criteria specified 2013 as the earliest year to ensure a focus on the most recent and relevant research in the rapidly evolving field of circularity. However, despite this initial specification, the oldest article ultimately chosen was from 2017. This reflects the limited research on this topic in the region, which has only recently begun to attract significant attention. Papers too similar in their findings to those previously selected were omitted to avoid excessive redundancy; likewise, papers that were too niche would be difficult to compare and were considered out of scope.

Table 1: Inclusion and Exclusion Criteria for General and Latin American Specific Searches

Criteria	**General Search**	**Latin American Search**
Papers with more than 100 citations	Inclusion	Inclusion
Papers with less than 100 citations	Exclusion	Inclusion
Papers published after 2013	Inclusion	Inclusion
Papers published before 2013	Exclusion	Exclusion
Papers with new data or ideas	Inclusion	Inclusion
Papers with findings similar to more highly-cited works	Exclusion	Exclusion
Papers too specific to certain contexts	Exclusion	Exclusion

3.2 CE, barriers and strategies

The following section summarizes the key findings of the literature review on the topic of CE, its barriers, and strategies, with a particular focus on Latin America. The chapter is structured into six subsections. The first subsection, *Circular Economy definition*, explores the various interpretations of the term and analyzes how they compare or contrast. The second subsection, *Circular Economy in the Context of Latin America*, inquires into the unique interpretations,

practices, and nuances of CE within the Latin American context. The third subsection, *Circular Economy barriers*, presents an overview of the numerous difficulties described in the literature as impeding the adoption of CE. The fourth subsection, *Barriers to Circular Economy in Latin America*, focuses specifically on the unique obstacles and challenges faced by Latin American nations in their journey towards CE. The fifth subsection, *General Strategies to Overcome CE Barriers*, outlines the various strategies proposed in the literature to address and overcome the barriers to CE adoption universally. Lastly, the sixth subsection, *Strategies to Overcome CE Barriers in Latin America*, discusses strategies customized for or relevant to the Latin American context.

3.2.1 Circular Economy definition

The CE concept has drawn a lot of interest recently as a way to promote sustainable development. According to Kirchherr et al. (2017), CE refers to an economic system that introduces the idea of the reduction, reuse, recycle, and recovery of resources. Nonetheless, depending on the context, various researchers and academics imply different things when they discuss of CE.

According to Kirchherr et al. (2018) and Gedam et al. (2021), CE is a concept that strives to create sustainable development by designing out waste and pollution, keeping goods and resources in use, and renewing natural systems.

Grafström and Aasma (2021) describe CE as a regenerative economy that strives to maintain goods, components, and materials at their most useful and valuable, differentiating between technological and biological processes. The report also says that CE has been present for decades but has been given different names in different industries.

Hartley et al. (2020), similarly, define CE as a framework for creating and running regenerative economic systems that strive to retain goods, components, and materials optimally at all times. It is a counter-model to the classic linear economy, which is built on the take-make-dispose concept. Gedam et al. (2021) and Hartley et al. (2020) also say that CE is a comprehensive approach that analyzes the whole life cycle of goods and materials and aspires to develop a closed-loop system that minimizes waste and conserves resources.

These first definitions of CE consider it to be a larger economic system in which resources are conserved and waste is eliminated. The following definitions, on the other hand, examine CE from a business standpoint.

CE is defined by Ritzén and Ölundh Sandström (2017) as a collaborative process of developing and realizing new values for consumers; it is individuals who discover possibilities and create and implement new ideas through interactions with others. According to the research, CE is appealing to industrial firms since it embraces the vital integration of sustainability concerns and commercial development, and it is only rarely and partially utilized in practice in industry.

According to Kumar et al. (2019), CE is a concept that strives to close the loop of product life cycles through resource reuse and recycling. It tries to maximize resource utilization for as long as feasible, extract as much value from resources while they are in use, and recover and regenerate materials and products at the end of their useful lives. Kumar et al. (2019) further mentions that CE provides a multitude of social, economic, and environmental benefits, such as reduced waste creation, new job possibilities, increased competitiveness, improved public relations, and access to new markets.

Additionally, it's worth noting the work of Calisto Friant et al. (2020) in the paper titled *A typology of circular economy discourses: Navigating the diverse visions of a contested paradigm.* They explore the diverse range of CE discourses, illustrating that the interpretations and visions associated with the CE concept are numerous. The paper categorizes these discourses into four main types:

1. Technocentric Circular Economy: Emphasizes the role of technological innovations in transforming industrial systems. It is closely aligned with definitions like those of Kumar et al. (2019), who discuss closing product life cycles through resource reuse and recycling, and (Ritzén & Ölundh Sandström, 2017), who view CE as a collaborative innovation process. Both definitions emphasize technological innovation as a key driver in transforming industrial systems, fitting well within this discourse.

2. Reformist Circular Society: Focuses on social justice and participatory governance while addressing the resource nexus. The description by (Grafström & Aasma, 2021) resonates well with this discourse, where CE is portrayed as a regenerative economy that separates technological and biological cycles. This discourse values the systemic change incorporating social dimensions, which (Grafström & Aasma, 2021) stress by maintaining goods and materials at high utility and value.

3. Transformational Circular Society: Advocates for a complete overhaul of socio-economic systems to address all challenges associated with the CE. This discourse aligns with (Hartley et al., 2020)'s view of CE as a framework for developing regenerative economic systems that aim to retain goods at their highest utility and value consistently. This definition suggests a radical transformation of the economic system, mirroring the discourse's call for comprehensive socio-economic overhaul.

4. Fortress Circular Economy: Prioritizes managing crises in a top-down manner, often sidelining comprehensive social considerations. While this discourse is less directly connected to a specific definition, it could encompass approaches that focus on efficiency and crisis management within controlled, top-down frameworks.

These diverse discourses underscore the multifaceted nature of the CE concept, with each vision offering distinct perspectives on how circularity can be achieved. Such diversity in interpretation demonstrates the complexity and richness of the CE paradigm, reaffirming the idea that it extends beyond only waste reduction and resource optimization. It encompasses many approaches, from technical solutions to societal transformations. An overview of the definitions and discourses is presented in Table 2.

For the main research objective of developing strategies for businesses to overcome barriers to their circular innovations in Latin America, the "Technocentric Circular Economy" discourse appears most directly relevant. This discourse emphasizes the role of technological innovations in transforming industrial systems, which aligns closely with the focus on CIs in the TIS ramework used in this research.

Among the definitions reviewed, the one provided by Kumar et al. (2019), which describes the Circular Economy as a system striving to close product life cycles through resource reuse and recycling, fits well with the Technocentric discourse. This definition underscores the utilization of technological advancements to enhance resource efficiency and aligns with the business-oriented approach of developing circular strategies that are embedded in technological innovation.

While the Technocentric Circular Economy discourse is selected based on the focus of this research, it is crucial to acknowledge that this does not diminish the relevance or applicability

Table 2: Summary of Circular Economy Definitions and Their Corresponding Discourses

Author	**Definition Summary**	**Matching Discourse (Calisto Friant et al., 2020)**
Kirchherr et al. (2017)	Economic system focusing on reduction, reuse, recycle, and recovery of resources.	-
Kirchherr et al. (2018), Gedam et al. (2021)	Sustainable development by designing out waste, keeping goods and resources in use.	-
Grafström & Aasma (2021)	Regenerative economy maintaining goods at high utility, distinguishing technological and biological cycles.	Reformist Circular Society
Hartley et al. (2020)	Regenerative economic systems that retain goods at high utility at all times.	Transformational Circular Society
Ritzén & Ölundh Sandström (2017)	Collaborative process developing new values, integrating sustainability with business growth.	Technocentric Circular Economy
Kumar et al. (2019)	Closes product life cycles through resource reuse and recycling, emphasizing social and economic benefits.	Technocentric Circular Economy
No specific match	*Definitions focusing on top-down crisis management could align here.*	Fortress Circular Economy

of other discourses within different contexts across Latin America. Each country in the region presents unique socio-economic conditions and challenges that might make other discourses, such as the "Reformist Circular Society" or "Transformational Circular Society," more applicable in certain situations.

For instance, the "Reformist Circular Society" focuses on social justice and participatory governance, which could be highly relevant in contexts where environmental justice is a significant concern, especially in regions affected by green colonialism and the exploitation by the Global North. This discourse could provide a framework for addressing these broader socio-economic issues within the circular economy strategies.

The initial selection of the Technocentric discourse and the definition from Kumar et al. (2019) will be used as a starting point for the literature review and theoretical framework of the thesis. However, this choice is considered provisional and will be revisited and potentially revised based on further exploration in the subsequent section on CE in the context of Latin America, as well as empirical insights gained from the interviews and case studies. The real-world applications and experiences of businesses in Latin America may highlight the need to integrate or shift towards other discourses and definitions that better address the observed challenges and opportunities.

Overall, the numerous definitions of CE provided in the literature share a common emphasis on the need of maximizing resource use and limiting waste and contamination. They also emphasize CE's regenerative and holistic character, as well as its ability to provide social, economic, and environmental advantages. While these definitions offer a broad, general perspective, it's crucial to examine regions with distinct socioeconomic situations. These regions not only face unique challenges but also bring forth invaluable insights from their cultural and historical contexts, advancing the CE dialogue.

In this exploration, the selection of the 'Technocentric Circular Economy' discourse and the definition by Kumar et al. (2019) serves as a preliminary theoretical foundation for defining CE

within the Latin American context, partially addressing the first subquestion of this thesis. This choice underscores the role of technological innovations in transforming industrial systems and aligns with the focus on CIs within the TIS framework used in this research. It is important to note that this approach is provisional and subject to further refinement based on upcoming sections that delve deeper into CE within the Latin American context, as well as empirical data from interviews and case studies. Such additional insights may necessitate integrating or shifting towards other discourses and definitions that more effectively meet the region's specific needs and challenges.

3.2.2 Circular Economy in the Context of Latin America

The global discourse on CE has been predominantly influenced by European perspectives. In this context, Latin America's perspective has been notably undermined. Betancourt Morales and Zartha Sossa (2020), in their bibliometric analysis of the journal *Business Strategy and the Environment*, highlight that Latin America contributes 5 articles out of the 104 CE articles they analyzed, representing 4.81% of the total. Similarly, a more comprehensive study by Ospina-Mateus et al. (2023) found that Latin America contributes to 2.4% of the Scopus-indexed literature on CE, representing 500 articles out of the 20,833 they reviewed[1]. Complementing this academic perspective, Rodriguez-Sanchez et al. (2022) report that Latin America accounts for only 10.2% of the identified circular initiatives around the world, which is minimal compared to the European Union's 61.7%, as detailed in their study on sustainability policies for circularity in Latin America.

The implications of this limited scholarly engagement, alongside the region's small share of circular initiatives, are reflected in the economic practices of the region. The *Circularity Gap Report Latin America and the Caribbean* by the foundation Circle Economy (2023) points out that the economy of Latin America and the Caribbean (LAC) is mainly represented by linear models. In spite of having just 8.3% of the global population, this region contributes more than 11% of the world's total raw material weight, underscoring its role as a significant supplier in a *take-make-dispose* economic model. This significant contribution to the global supply of raw materials, as Dorn (2022) discusses, continues to position Latin America as a crucial supplier in the global energy transition, a dynamic that has historical roots and is increasingly recognized as a form of *green colonialism*. This term, used not only by activists but also by researchers as a concept and theoretical framework, critiques the geographic outsourcing of labor and natural resources that sustains the region's role in the global market while raising concerns about environmental justice and the perpetuation of historical North-South imbalances (Dorn, 2022). The significance of "green colonialism" in the context of Latin America implies a need for a critical evaluation of the objectives of the energy transition. These objectives are rooted in a dominant "Euro-North American-centric modernity" and promote "techno-optimistic" solutions (Dorn, 2022). Continuing along these lines, Zografos and Robbins (2020) highlight the risk of initiatives like the Green New Deal leading to *green colonialism*, where the Global South may continue to be exploited for resources under the pretense of environmental progress. With the expected surge in demand for materials like lithium, predominantly found in the *Lithium Triangle* of South America, there is a pressing need to address the potential environmental and social costs that such extraction could impose on local ecosystems and communities (Zografos & Robbins, 2020). To underscore this concern, Jerez et al. (2021) examine the Salar de Atacama in Chile, where the demand for lithium has imposed severe water injustices and socio-environmental conflicts on the indigenous Atacameño communities, serving as a specific instance of the broader *green colonialism* issue.

[1] The significant difference in the number of articles between the two studies can be attributed to their distinct focuses, scopes, and methodologies.

Amid these challenges, there is a growing recognition within Latin America of the need for a paradigm shift. The region's commitment to transitioning towards a circular economy is gaining momentum, as evidenced by the establishment of the Latin America and the Caribbean Circular Economy Coalition in 2021, highlighted by Circle Economy (2023). Additionally, Ospina-Mateus et al. (2023)'s bibliometric analysis reveals a rising trend in CE research in the region, with Brazil emerging as a leader. Within this context of increasing engagement, the Latin American CE concept shares global themes but also has its unique nuances. Both Betancourt Morales and Zartha Sossa (2020), and Ospina-Mateus et al. (2023), highlight that CE in the region has often been primarily associated with waste management, seen as an economical alternative. This perspective, while pragmatic, tends to focus on the end-of-life phase of products. Such an approach does not fully encapsulate the holistic and regenerative nature of CE as discussed by researchers like Kirchherr et al. (2017). Moreover, recent negotiations of trade agreements, such as the controversial discussions in Ecuador about importing waste from China, underscore a power imbalance that threatens to reduce parts of the region to a dumping ground for foreign waste (Gonzalez, 2024). These developments raise significant concerns about environmental standards and the adequacy of local waste processing capabilities in Ecuador and similar situations across Latin America, further emphasizing the urgent need for sustainable waste management solutions that adhere to the principles of circular economy.

Expanding on the singular characteristics of CE in Latin America, it is essential to also consider the informal sector, a significant yet often overlooked component of CE. As reported by Circle Economy (2023), informal workers, who make up about half of the region's employment, are predominantly responsible for waste management and recycling activities. Despite their substantial contribution to the circular practices of reducing, reusing, and recycling materials, these workers are often not formally acknowledged within the official waste management systems. This frequent oversight leads to challenges in accurately measuring their impact on circularity and sustainability in the region. Highlighting the need for their integration into formal systems becomes even more crucial when considering that their contributions to environmental sustainability and resource efficiency often remain invisible in policy-making and economic planning. In this context, the efforts of organizations like Cempre in Colombia stand out as examples of positive change. Cempre actively works with informal recyclers to integrate them into the national recycling framework (Cempre, n.d.). This initiative not only legitimizes their role but also enhances the effectiveness of the circular economy by ensuring their contributions are recognized and valued. By showcasing how Cempre facilitates this integration, the example serves as a model that highlights the critical importance and benefits of recognizing and incorporating informal workers into formal systems, thereby amplifying their impact on sustainability and circularity in the region.

Looking closer at the circular practices across the region, it becomes apparent that circularity is also rooted in the local culture. Drawing from the findings of Circle Economy (2023), many practices in the region associated with the CE concept are based on traditional knowledge, cultural heritage, and costumes of Indigenous people, which is a sentiment echoed by Paño Yañez (2021). This author underscores the unique approach to CE in Latin America, deeply influenced by its sociocultural and historical context. The article highlights that in the Southern region, there are established local customs that align with the principles of CE, such as higher rates of reuse and repair, and reduced consumption. Notably, indigenous communities in the region have long practiced sustainable resource management, emphasizing harmony with nature, a concept that resonates with modern CE principles. For instance, as detailed by Almeida Guzmán et al. (2023) in a study focusing on the ancestral productive customs of the Natabuela community in Ecuador, the agricultural practices, particularly in corn production, are aligned with CE principles, integrating equity, resilience, and transparency, as well as sustainable resource

procurement and efficient end-of-life management of products and materials, which are integral to their worldview. Paño Yañez (2021) emphasizes the importance of these practices, which are significantly connected with Latin American development concepts, such as *Buen Vivir*. This perspective from a strictly rational and production-centric mindset, presenting alternative methods for achieving social equity and living in balance with nature.(Paño Yañez, 2021). Moreover, Almeida Guzmán et al. (2023) describe the entrepreneurial activities of Kiwicha women through the community enterprise *Warmikuna NATABUELA*, which demonstrate the application of CE in business models that incorporate sustainable development dimensions, reflecting a transformative economy based on self-management, cooperation, associativity, and solidarity. These practices and business models highlight the inherent circularity within the community economies of indigenous peoples, such as the Natabuela, and their historical application of CE principles.

Drawing similarities with Europe's evolving understanding of CE, Latin America, in its readiness to facilitate change, has mimicked some of Europe's conceptual missteps. The region has been presenting CE as an avenue for generating economic value through recycling and waste management, a perspective that European scholars and policymakers have identified as limited and are currently revisiting (Betancourt Morales & Zartha Sossa, 2020).

However, the CE narrative in Latin America is not only about economic or environmental sustainability. As Betancourt Morales and Zartha Sossa (2020) elaborate, it represents a quest for social equality, a radical shift in wealth creation, and a reimagining of the production, distribution, and consumption of goods and services. Furthermore, there's an emphasis on cultural recovery, aiming to integrate CE into the societal structure, positioning it as a sustainable path forward. Drawing from the insights of Svampa (2019), the *Latin American critique of development* underscores the need for sustainable consumption patterns and practices rooted in local contexts and values, resonating with the principles of CE. The Zapatista movement in Mexico, as highlighted by Leyva-Solano (2019), offers a radical alternative to the established system. Emphasizing autonomy, resistance, and grassroots struggles, the movement provides insights into the importance of recognizing and integrating diverse voices into the broader CE narrative in the region. The concept of *Buen Vivir*, as presented by Chuji et al. (2019), originates from indigenous worldviews in South America. It embodies a social value that aligns closely with CE and challenges the dominant development paradigm by emphasizing harmony with nature, community, and well-being over material accumulation. It underscores relationships based on reciprocity and communalism, reflecting the regenerative nature of CE (Chuji et al., 2019).

Table 3 presents a concise summary of the main points and themes discussed in this section, outlining the region's unique contributions and challenges.

In conclusion, the exploration of the Circular Economy (CE) within Latin America highlights a distinctive blend of global influences and local dynamics, such as traditional knowledge, the informal sector, and the focus on waste management. This region's approach, deeply rooted in its unique sociocultural context and sustainability practices, presents a distinctive perspective on the concept. The complex interplay of traditional knowledge, the pivotal role of the informal sector, and an ongoing focus on waste management underscores the region's unique contributions to the global CE dialogue.

The 'Technocentric Circular Economy' discourse, as introduced earlier, initially aligns well with the current regional priorities, particularly waste management and the integration of the informal sector. Yet, the insights from this section suggest that these focuses, while essential, only partially encompass the breadth of CE practices necessary for the region. The prevalent focus

Table 3: Summary of Circular Economy Context in Latin America

Theme	**Key Points**
Scholarly Engagement	Latin America contributes a minor percentage to CE articles (Betancourt Morales & Zartha Sossa, 2020; Ospina-Mateus et al., 2023) and circular initiatives globally (Rodriguez-Sanchez et al., 2022).
Economic Practices	The economy is mainly linear with significant raw material contributions (Circle Economy, 2023) and a role in the global supply chain, tied to 'green colonialism' (Dorn, 2022).
Regional Commitment	A rising trend in CE research (Ospina-Mateus et al., 2023) and the establishment of the LAC Circular Economy Coalition (Circle Economy, 2023) indicate growing momentum for CE in Latin America.
CE Concept Nuances	CE is primarily associated with waste management in Latin America (Betancourt Morales & Zartha Sossa, 2020; Ospina-Mateus et al., 2023) and lacks the holistic nature as discussed globally (Kirchherr et al., 2017).
Informal Sector	Informal workers are crucial in waste management but often not recognized in official systems (Circle Economy, 2023). Organizations like Cempre work to integrate them formally (Cempre, n.d.).
Cultural Roots	CE practices in Latin America are tied to traditional knowledge and customs, like the sustainable agricultural practices of indigenous communities (Circle Economy, 2023; Paño Yañez, 2021; Almeida Guzmán et al., 2023).
CE Narratives	Beyond economy and environment, the Latin American CE narrative includes social equality, cultural recovery, and concepts like 'Buen Vivir' (Betancourt Morales & Zartha Sossa, 2020; Chuji et al., 2019).

on waste management represents just one facet of the broader spectrum required for a truly holistic circular economy.

Further discussions later on will expand on the cultural nuances and historical practices identified here. These elements, though beyond the immediate scope of the current focus, are crucial for a comprehensive understanding of CE in Latin America.

3.2.3 Circular Economy barriers

Implementing a CE is a complicated and difficult process that requires overcoming several obstacles. One of the key barriers highlighted in the literature is cultural barriers. According to Kirchherr et al. (2018), the most urgent challenges to the adoption of a CE are cultural barriers, with companies and policymakers seeing "Lacking consumer interest and awareness" and "Hesitant company culture" as the most pressing impediments. Addressing these challenges calls for a shift in society beliefs and views of the CE, which may be accomplished through awareness-raising and education campaigns, as well as the development of incentives that promote the implementation of CE methods.

Market barriers, like "low raw material prices" and "high upfront investment expenditures", and economic barriers, like challenges in funding CE business models and expensive up-front investment costs have also been recognized as significant challenges to the adoption of a CE. Kirchherr et al. (2018), Grafström and Aasma (2021) and Kumar et al. (2019) emphasize that these barriers may be solved by implementing policies and incentives that promote a CE, such as tax cuts and subsidies. Furthermore, the creation of innovative business models that make the shift to a CE financially feasible for firms might assist to solve these issues.

Next, technological barriers, like product design and a lack of infrastructure for proper waste treatment are also significant obstacles to the adoption of a CE. According to Grafström and Aasma (2021) and Ritzén and Ölundh Sandström (2017), overcoming these barriers would demand investments in R&D, as well as the creation of new systems and equipment. Government funds, private sector initiatives, and public-private partnerships can accomplish this.

Another barriers identified as impediments to the adoption of a CE are institutional barriers, like the lack of property rights and conflicting legislation across the value chain. In order to establish a favourable climate for the CE, Grafström and Aasma (2021) asserts that overcoming these barriers requires a collective effort including all stakeholders, from the government to private sector. This may be accomplished by developing a national CE plan that aligns policies, legislation, and standards in order to facilitate the shift to a CE.

Finally, Ritzén and Ölundh Sandström (2017) recognizes organizational barriers as relevant in the implementation of CE in businesses. The author claims that between these barriers the lack of integration between different functions, perspectives, and domains within the organization is significant. This lack of integration results in a shallow understanding of the concept of CE, a lack of strategic focus on sustainability issues, and a lack of collaboration between different departments and hierarchical levels. This barrier also results in difficulties in developing new business models and solutions that are more sustainable and circular.

Table 4: Summary of Barriers to Circular Economy Implementation

Barrier Type	**Key Points and Strategies**
Cultural Barriers (Kirchherr et al., 2018)	Lack of consumer interest and company resistance; addressed through education and incentives.
Market and Economic Barriers (Kirchherr et al., 2018; Grafström & Aasma, 2021; Kumar et al., 2019)	High upfront costs and low raw material value; mitigated by financial incentives and supportive policies.
Technological Barriers (Grafström & Aasma, 2021; Ritzén & Ölundh Sandström, 2017)	Gaps in product design and waste management infrastructure; requires R&D and public-private investments.
Institutional Barriers (Grafström & Aasma, 2021)	Conflicts in legislation and property rights; needs alignment of policies and a cohesive national plan.
Organizational Barriers (Ritzén & Ölundh Sandström, 2017)	Internal disintegration and strategic focus gaps; calls for enhanced interdepartmental collaboration.

It is worth noting that different papers claim that specific barriers are the most influential in preventing CE adoption. Kirchherr et al. (2018) and Kumar et al. (2019) contend that cultural barriers are more significant, whereas Vermunt, Negro, Verweij, Kuppens, and Hekkert (2019) argue that market barriers are more significant. Ritzén and Ölundh Sandström (2017), on the other hand, believe that organizational barriers are the most important obstacle to the implementation of CE practices. This suggests that the relevance of barriers varies between levels (micro, meso, macro), geographies, sectors, and even firms within the same industry. Table 4 summarizes the main barriers presented in this section.

This analysis serves as an initial presentation of the barriers to Circular Economy, offering a preliminary insight into answering the sub-question regarding what barriers impact the adoption of Circular Innovations (CIs) in Latin American contexts. It is worth noting that this section provides a baseline for later discussions which will explore more specific barriers within the Latin American context, supplemented by practical insights identified through interviews. By highlighting these general barriers first, this thesis sets the stage for a comprehensive analysis of more localized and direct barriers, ensuring a robust foundation for understanding and addressing

the challenges specific to Latin America.

3.2.4 CE barriers in Latin America

The transition to a CE in Latin America presents unique challenges and opportunities. This subsection seeks to explore the barriers to the adoption of CE in Latin America, with an emphasis on both the region's distinct socioeconomic and cultural characteristics as well as the parallels with more general barriers identified in the broader literature.

The social and economic landscape of Latin America, characterized by challenges such as high unemployment, income and gender inequality, and extensive informal sectors, plays a significant role in shaping these barriers. According to Circle Economy (2023), the complexities of LAC's labor market can be seen as both a challenge and an opportunity, highlighting the potential of CE to address some of these socio-economic challenges and providing a deeper understanding of the context in which CE is being implemented in the region.

Infrastructure irregularities, including the lack of formalization and inclusion of the informal sector, pose a significant barrier to the implementation of CE in Latin America (Cantú et al., 2021). The term 'infrastructure irregularities' specifically encompasses both physical infrastructure challenges and broader systemic issues such as the exclusion of informal networks from official recognition and economic structures. Circle Economy (2023) alongside Cantú et al. (2021) both acknowledge that the informal sector's role in waste management and recycling is critical yet underrecognized. This sector, which encompasses a substantial part of the labor force, faces challenges due to its exclusion from formal economic structures and official statistics. The absence of formal recognition not only hinders the measurement of their contributions to circularity but also limits their potential in scaling up CE practices across the region.

Cultural barriers play a significant role in Latin America. There's a hesitancy in company culture and a lack of consumer interest and awareness, as highlighted by Betancourt Morales and Zartha Sossa (2020). The prevalence of a "buy and own" society is evident, where social status is often linked to property, and there is skepticism and lack of trust in renting or leasing models (Cantú et al., 2021). Challenges in collaboration, as noted by Ospina-Mateus et al. (2023), may also be rooted in cultural factors, impeding the transition to a CE.

On the legislative and regulatory front, challenges posed by legislation and regulations, particularly the need for vertical integration and harmonization between policies, have been emphasized. Da Costa (2022) also points to a need for change in public policies and regulation concerning polluting waste. A distinct lack of governmental support is evident in the region (Ospina-Mateus et al., 2023). Obtaining necessary licenses and permits, bureaucratic delays in licensing processes, and dependence on subsidies or support from public agencies further complicate CE implementation (Van Hoof et al., 2023).

Finances also present hurdles. High initial costs and perceptions of lower short-term returns deter sustainable investments, posing a barrier to funding opportunities for CE initiatives (Van Hoof et al., 2023). Economic challenges, such as funding CE business models, high upfront investment costs, and medium-term fiscal reform, are prevalent in the region, as detailed by Betancourt Morales and Zartha Sossa (2020). Unique to the region is the emphasis on the user's low ability to pay, which impacts the accessibility of sustainable products (Cantú et al., 2021).

Technologically, there's a need to encourage the development of technologies that favor raw material reduction and promote reuse and recycling. Cantú et al. (2021) discuss challenges arising from irregular or unavailable infrastructure, particularly in waste management and financial sys-

tems. The limited technological innovation in the region further inhibits the full adoption of CE practices (Ospina-Mateus et al., 2023).

Organizational aspects cannot be overlooked either. Commitment from management or key stakeholders might change, potentially affecting the continuity and scaling of initiatives. Such managerial and organizational challenges have been noted as barriers to the scaling of certain CE initiatives (Van Hoof et al., 2023).

Barriers related to supply chains emphasize the need for a more integrated approach and the challenges posed by market dynamics in the region, as touched upon by Betancourt Morales and Zartha Sossa (2020).

It is noteworthy to observe the varying emphasis different authors place on certain barriers to the adoption of CE in Latin America. Cantú et al. (2021) chose to describe certain barriers "mainly due to their novelty and relevance". Additionally, Betancourt Morales and Zartha Sossa (2020) literature review suggests a consensus on frequently mentioned barriers, such as economy/finance and legislation/regulations, indicating their recognized significance.

While the barriers to adopting a CE in Latin America exhibit unique characteristics, several parallels can be drawn with general barriers identified in the broader literature. Cultural barriers, prominently highlighted by Kirchherr et al. (2018) and Kumar et al. (2019) as crucial impediments in a global context, emerge as equally significant in the Latin American scenario. Similarly, market barriers, stressed by Vermunt et al. (2019), and organizational barriers, emphasized by (Ritzén & Ölundh Sandström, 2017), find resonance in the Latin American context, albeit with regional nuances.

However, the Latin American landscape also brings to the fore specific challenges. For instance, the emphasis on the user's low ability to pay, a barrier highlighted by Cantú et al. (2021), underlines the socio-economic disparities more acutely experienced in this region. Furthermore, while barriers like legislation and regulation are universally acknowledged, the Latin American region faces distinct bureaucratic complexities, as highlighted by Van Hoof et al. (2023). Table 5 summarizes the main barriers presented in this section.

The barriers to the adoption of CE in Latin America are multifaceted, influenced by the region's unique socioeconomic and cultural characteristics. From cultural hesitations to legislative challenges and technological needs, these barriers underscore the need for targeted strategies. While there's a consensus on the existence of these barriers, the emphasis on their significance varies across authors, underscoring the complex nature of CE implementation in the region.

This detailed analysis contributes to addressing Sub-question 2, which seeks to uncover the barriers impacting the adoption of CI in Latin American contexts. By identifying these region-specific barriers, the insights provided here establish a foundational understanding that is essential for the next phases of the thesis. The literature-derived barriers will enrich the contextual framework for interpreting the empirical data gathered through interviews, thus enhancing our comprehension of the challenges and facilitating the development of effective, localized strategies to overcome these barriers.

3.2.5 General strategies to overcome CE barriers

Among the papers already reviewed, Kirchherr et al. (2018) presented some proposals for strategies to address CE barriers. The paper Hartley et al. (2020) was also included because it

Table 5: Summary of CE Barriers in Latin America

Barrier Type	**Description**
Socioeconomic (Circle Economy, 2023)	Challenges like high unemployment, income inequality, and extensive informal sectors influencing CE adoption.
Infrastructure Irregularities (Cantú et al., 2021; Circle Economy, 2023)	Lack of formalization and inclusion of the informal sector, and inadequate infrastructure for waste management.
Cultural Barriers (Betancourt Morales & Zartha Sossa, 2020; Cantú et al., 2021; Ospina-Mateus et al., 2023)	Resistance due to a "buy and own" culture, and low consumer interest in sustainable practices.
Legislative and Regulatory (Da Costa, 2022; Ospina-Mateus et al., 2023; Van Hoof et al., 2023)	Complex regulations and bureaucratic processes that hinder CE implementation.
Financial Constraints (Van Hoof et al., 2023; Betancourt Morales & Zartha Sossa, 2020; Cantú et al., 2021)	High initial costs, perceived low returns, and limited funding opportunities for sustainable investments.
Technological Gaps (Cantú et al., 2021; Ospina-Mateus et al., 2023)	Insufficient development of CE-favorable technologies and lack of infrastructure.
Organizational Challenges (Van Hoof et al., 2023)	Lack of management commitment and internal integration, impacting CE initiatives.
Supply Chain Issues (Betancourt Morales & Zartha Sossa, 2020)	Need for more integrated approaches and challenges in adapting market dynamics.

presented some policies to deal with barriers. The main strategies from both papers are:

1. Government measures aimed at removing recognized market barriers: According to Kirchherr et al. (2018), specific government interventions such as the abolition of subsidies that favor linear products and the implementation of financial incentives for circular investments might give a push for CE transformation. It also emphasizes that the EU may consider requiring that all externalities be included into the price of resources and energy, and the EU may decide to implement intervention strategies in favor of circular goods in order to expedite the transition to a CE. Another solution proposed in the article is to reduce the high early investment costs for CBMs by government action, such as financial support.

2. Changing taxes on CE-based products: According to Hartley et al. (2020), the pressures to change production decisions are caused by price movements in input factors, and if manufacturing products using CE-based practices lacks financial feasibility in comparison to linear products, producers will behave accordingly. To circumvent this barrier, it also suggests changing tariffs on CE-based items.

3. Hartley et al. (2020) also supports waste trading deregulation as a technique to promote CE transition; comparable mechanisms should be established to allow manufacturers to sell a broader range of production by-products.

4. Law, policy, and regulation: Hartley et al. (2020) argues that, while the government is aware of the CE advantages, significant efforts in the areas of law, policy, and regulation are needed to be supplemented. The growing regulatory stages for the adoption of CE in the EU and China have already begun, while developing nations such as India require considerable efforts to make CE a reality.

5. Hartley et al. (2020) advocates the establishment of a worldwide material flow accounting database in order to improve the transparency and fluidity of the secondary resource market.

In conclusion, this exploration of general strategies for overcoming CE barriers has revealed significant policy-driven and economic incentives that, while essential for creating a conducive

environment for Circular Economy (CE), predominantly target macro-level changes. These broad strategies, such as the abolition of subsidies for linear products, implementation of financial incentives for circular investments, and regulatory changes, set the stage for a systemic transformation towards CE. For companies, particularly those in the introductory phase of implementing CE practices, leveraging these strategies can be challenging due to their broad scope. However, through lobbying efforts, companies have the opportunity to tailor these broad, policy-driven strategies to better align with their specific operational needs. By advocating for policies that directly benefit CE principles, companies can play a proactive role in shaping the regulatory landscape to support sustainable practices more effectively. This strategic involvement is essential for establishing a foundational baseline within the thesis, as it introduces and reviews strategies from the literature that are critical for addressing Sub-question 6. This sub-question focuses on comparing these literature-derived strategies with those developed through the adapted TIS framework and the practical strategies gathered from interviews. The subsequent analysis will assess if these general strategies are overly focused on broader policy interventions, thus necessitating more directly actionable strategies for companies at the introduction stage.

3.2.6 Strategies to overcome CE barriers in the Latin American context

The transition to a CE in Latin America has prompted numerous strategies from scholars. These strategies are customized to address the region's unique socioeconomic and cultural characteristics.

Betancourt Morales and Zartha Sossa (2020) emphasize the critical role of education in simplifying and propagating the CE concept, which can counter the cultural barrier of a "buy and own" society prevalent in the region. In a similar manner, Cantú et al. (2021) underscore the importance of understanding user behavior, a tactic that addresses both company culture hesitancy and a lack of consumer awareness.

On the legislative side, Cantú et al. (2021) highlight the important role that governments can play by providing necessary infrastructure and incentives. Ospina-Mateus et al. (2023) emphasize the need for collaborative efforts between the public and private sectors, which are crucial for establishing clear regulatory frameworks. This sentiment resonates with the insights of Schröder et al. (2020), who explore the need for effectively implementing the Extended Producer Responsibility (EPR) system. According to Schröder et al. (2020), EPR is a policy framework wherein specific manufacturers are mandated to manage the recovery, treatment, or disposal of waste once their products have reached the end of their consumer use, shifting the responsibility from solely being on national or local authorities to the producers. Rodriguez-Sanchez et al. (2022) explain that the EPR approach has been adopted by Colombia since 2007, which places financial and operative duties on manufacturers and sellers. However, the authors note that it fails to include other actors in the product lifecycle, there is a lack of governmental incentives for full product recovery. Rodriguez-Sanchez et al. (2022) state that expanding the scope of producers' responsibilities might encourage a shift towards more environmentally conscious design of industrial products, enhance the ease with which products can be recycled, and decrease the production of hazardous materials. Additionally, Schröder et al. (2020) discuss the importance of establishing good governance and transparent institutions. They point out that these are essential for addressing the region's legislative and regulatory challenges, as well as the lack of governmental support.

Furthermore, incorporating the informal waste sector into formal waste management systems has been identified as a critical legislative consideration. Circle Economy (2023) proposes that formalizing the employment of informal waste workers can enhance waste management efficiency and sustainability. This includes providing legal recognition and protection for these workers,

ensuring their participation in policy processes, and recognizing their economic contributions, as highlighted by Hettiarachchi et al. (2018). The success of cooperatives like *Reciclando Sueños* (Recycling Dreams), discussed by Becerra et al. (2020), serves as an example of how integrating waste picker cooperatives can boost the recyclability rate and make the retrieval of materials more efficient. This not only improves employment and income for traditionally marginalized groups but also contributes to a more equitable circular economy. Legislative efforts to address occupational safety, improve working conditions, and assist in organizing cooperatives are essential strategies that could bolster a robust and equitable CE (Circle Economy, 2023).

Strategic collaboration emerges as a central theme in the literature. Cantú et al. (2021) advocate for harmonizing top-down and bottom-up approaches, while Schröder et al. (2020) stress regional integration and the setting of national standards. Salas et al. (2021) accentuate the significance of knowledge sharing, community engagement, and advisory roles in policy-making. These approaches are particularly relevant in a region marked by collaboration challenges and a significant reliance on public agency support.

Ospina-Mateus et al. (2023) directs attention to the technological dimension, advocating for increased research collaboration, a broadened focus in CE research, and the adoption of sustainable methods and technologies. Concurrently, Van Hoof et al. (2023) spotlight the need for reforms in municipal waste management systems and robust public policy mechanisms. Such strategies address the region's limited technological innovation and the challenges posed by inconsistent infrastructure.

In summary, the transition to a CE in Latin America involves a diverse array of strategies tailored to the region's unique challenges. Like in the broader global context, lobbying remains a key tool for companies to influence policy in ways that support CE practices. Specifically, initiatives such as voluntarily adopting EPR showcase how companies can not only comply with but lead in the creation of sustainable practices that exceed current legislative requirements. This proactive stance is vital for companies during the introductory phase of implementing CE, as it demonstrates a commitment to environmental responsibility and can set industry benchmarks. The upcoming comparison of these strategies with those developed through the adapted TIS framework, as well as insights from interviews, will critically assess their effectiveness and alignment with the needs of Latin American companies, addressing Sub-question 6 of this thesis.

3.3 TIS frameworks

This section of the literature review introduces the TIS framework, a model initially developed by Ortt and Kamp (2022) and presented in *A technological innovation system framework to formulate niche introduction strategies for companies prior to large-scale diffusion.* The TIS framework is designed to guide the introduction of new technological innovations, particularly in niche markets, by outlining critical elements and conditions that influence their successful diffusion (Ortt & Kamp, 2022). Central to the framework are distinct building blocks and influencing factors that collectively shape the innovation's journey from development to market adoption.

After the presentation of the original TIS framework, the discussion will shift to exploring three adaptations of the model. These adaptations specifically tailor the TIS framework for circular innovations, highlighting the framework's flexibility and relevance in addressing the unique challenges of sustainable and resource-efficient innovation. Each adaptation, derived from different theses, offers a nuanced perspective on applying and modifying the TIS framework to better suit the evolving landscape of circular economy and sustainability.

3.3.1 Original TIS framework

Ortt and Kamp (2022) introduce the TIS framework as instrumental for companies during the early stages of introducing radical innovations. It provides a comprehensive view, integrating technological, social, and institutional dimensions to form a holistic understanding of the innovation ecosystem. This framework is particularly vital in navigating the challenges inherent in the early-stage diffusion of new technologies.

The TIS framework, rooted in socio-technical systems and innovation management, offers a company-centric perspective (Ortt & Kamp, 2022). This approach is crucial for navigating the adaptation phase and addressing the slow adoption rates of new technologies. It specifically highlights the importance of niche strategies, focusing on targeted customer groups with distinct needs, to successfully bridge the early diffusion "chasm" (Ortt & Kamp, 2022).

Ortt and Kamp (2022) further detail that the TIS framework is comprised of seven key building blocks, each representing a critical aspect of the innovation process:

1. Product Performance and Quality: This block stresses the importance of the innovation's functionality and reliability. It's vital that the product not only meets current standards but also demonstrates superior performance or unique features that make it stand out.

2. Product Price: This involves considering all costs associated with acquiring and using the product, not just its purchase price. For the product to be widely adopted, its overall cost must be competitive and justifiable.

3. Production System: The production system must efficiently produce high-quality products in large quantities. Over time, the focus should shift towards improving quality and reducing costs to support wider market adoption.

4. Complementary Products and Services: Success of the innovation is linked to the availability of supporting products and services. These complementary elements are crucial throughout the product's lifecycle, from development to disposal.

5. Network Formation and Coordination: Building and coordinating a network of supply chain actors is crucial. Effective collaboration and alignment of goals among suppliers, producers, distributors, and service providers is essential for success.

6. Customers: Early identification of potential customers is key. These customers should recognize the need for the innovation, understand its benefits, and have the means and willingness to adopt it.

7. Innovation-specific Institutions: This involves navigating formal and informal rules like government policies and standards. Supportive institutional environments provide stability and encourage investment and adoption of the innovation.

These building blocks are influenced by seven conditions, which the Ortt and Kamp (2022) describe as critical in shaping the innovation's path to market:

1. Knowledge and Awareness of Technology: This encompasses both the fundamental and applied technological knowledge necessary for developing and managing the innovation's components. Effective knowledge transfer through education and training is vital.

2. Knowledge of Application and Market: Understanding the potential uses of the innovation and the market dynamics is crucial. This knowledge can be developed through market research, experimentation, and interactions with market actors.

3. Natural, Human, and Financial Resources: Availability of necessary resources, including natural, human, and financial, is crucial for developing the innovation's components and bringing them to market.

4. Competition: It's important to understand the competitive landscape, including how the new innovation stacks up against existing technologies and solutions.

5. Macro-economic and Strategic Aspects: Economic trends and strategic business practices influence the innovation's success. This includes understanding market structures and aligning innovation strategies with current business practices.

6. Socio-cultural Aspects: The norms and values of potential customers and stakeholders can significantly influence their acceptance and use of the innovation. These aspects, though less formal than institutional rules, are important for shaping market behavior.

7. Accidents and Events: Unforeseen incidents, either internal or external to the innovation system, can impact the development and adoption of the innovation. These events can either pose challenges or open up opportunities.

For original descriptions of both the building blocks and conditions as defined by the authors, see Appendix Appendix A.

Ortt and Kamp (2022) argue that a thorough understanding and strategic management of these blocks and conditions are essential for successfully introducing technological innovations in niche markets. The TIS framework thus serves as a comprehensive tool for companies to navigate the complexities of innovation introduction, particularly in the early stages of diffusion. A visual representation of the framework can be seen in Figure 3.

Ortt and Kamp (2022)'s paper fills a significant gap in the literature on innovation systems by providing a company-centric perspective and offering concrete strategies for niche market introduction. This work is instrumental for companies seeking to navigate the challenging landscape of introducing radical technological innovations.

3.3.2 TIS framework adapted for CI by Raghav Shankar

In his master's thesis, Shankar (2023) extensively adapts the TIS framework to address circular innovation, with a particular focus on the Dutch high-tech sector. Building upon foundational elements from (Ortt & Kamp, 2022), Shankar (2023) integrates circular principles across all aspects of the TIS framework, reflecting the complex dynamics and unique challenges of circular innovation.

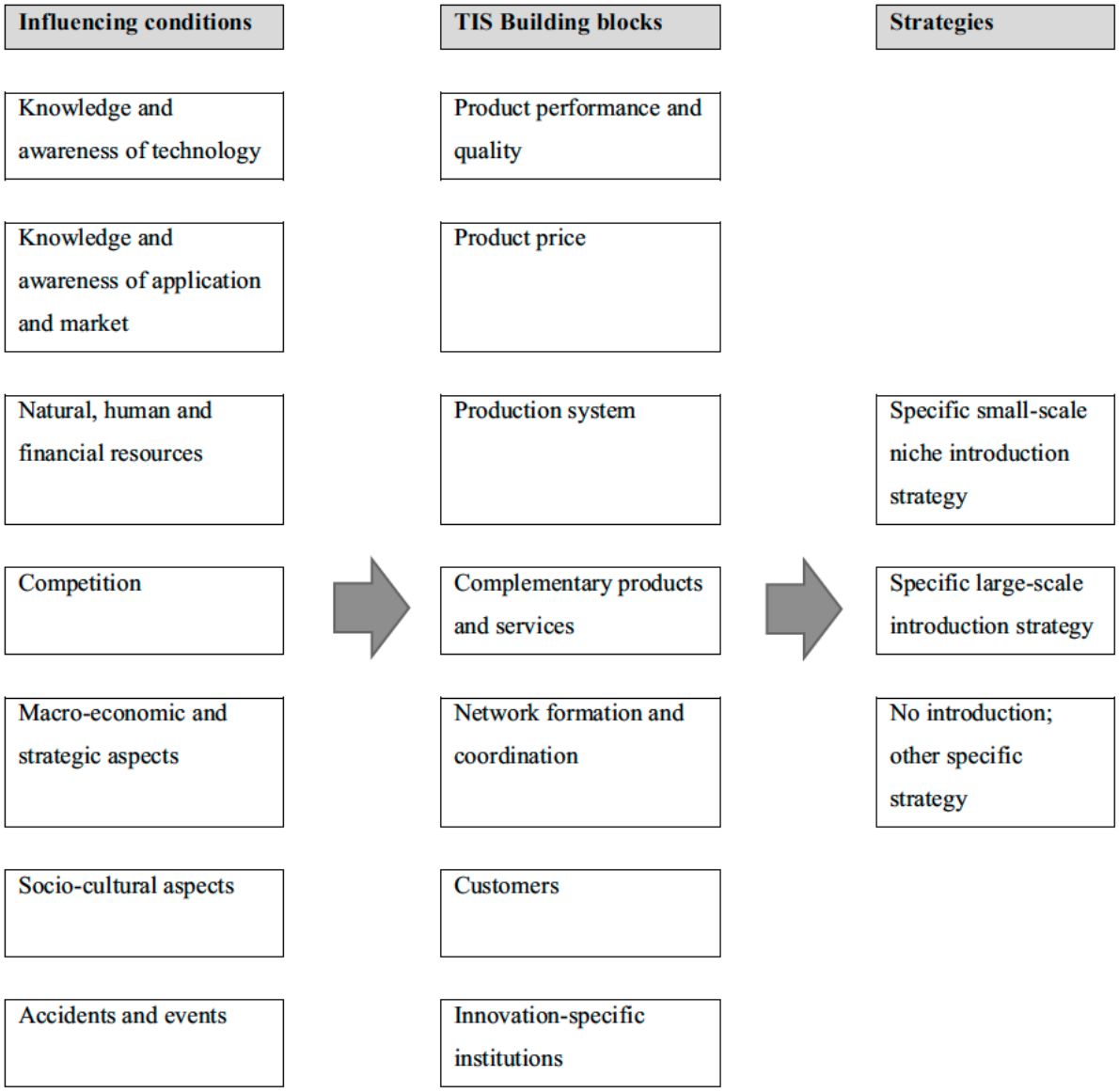
Shankar (2023) systematically infuses circular principles into all TIS building blocks and influencing conditions, enhancing their applicability to circular innovation:

- Building Blocks: Modifications ensure that elements like product design, production processes, and market dynamics align with sustainability, emphasizing durability, resource efficiency, and lifecycle thinking.

- Influencing Conditions: Adjustments focus on broadening stakeholder knowledge about circular technologies, optimizing resource flows, and fostering regulatory environments supportive of circular practices.

A detailed visual representation of the adapted framework is shown in Figure 4, illustrating the integration of circular innovation principles. This visualization helps clarify the modifications

Figure 3: TIS framework



Note: Retrieved from "A technological innovation system framework to formulate niche introduction strategies for companies prior to large-scale diffusion" by J. R. Ortt and L. M. Kamp, 2022, Technological Forecasting and Social Change, p.7.

for readers. Shankar (2023) substantiates his theoretical adaptations through consultations with industry experts, ensuring the framework's relevance and applicability in real-world settings.

For an extensive review of the specific keywords, concepts, and detailed modifications introduced by Shankar (2023) to each building block and influencing condition, refer to Appendix B. Shankar (2023) acknowledges the limitations in scope due to the regional focus and qualitative approach, suggesting careful application of the findings beyond the contexts directly studied.

By infusing circular principles into the TIS framework, Shankar (2023) not only retains the framework's analytical depth but also broadens its relevance to contemporary issues in sustainability within high-tech industries. His work underscores the TIS framework's flexibility to

adapt to new challenges and highlights its potential as a tool for fostering innovation in circular economy contexts. This thoughtful integration of circular innovation dynamics ensures that the framework remains a relevant and powerful tool for analyzing and promoting sustainable practices.

3.3.3 R-TIS framework by Ruben Warns

Warns (2023)'s thesis, 'Niche strategies for reuse innovations,' introduces a refined adaptation of the TIS framework, termed the Reuse Technological Innovation System (R-TIS). This adaptation is tailored specifically for the circular economy, with a focus on the reuse within the European soft drinks industry's supply chains. Warns' R-TIS framework is designed to address the original TIS framework's limitations in capturing the complexities of circular and reuse strategies, enhancing its applicability to sustainability-centric innovations.

In adapting the TIS framework, Warns (2023) strategically revised various elements to enhance their relevance to reuse and sustainability practices. The core modifications made to the framework include:

Building Blocks Adjustments:

- The adaptation includes significant enhancements to align with circular economy principles, emphasizing durability and lifecycle value. Notably, elements such as the "Circular Product Service System" have been introduced in performance, quality, and pricing blocks.
- Adjustments in "Circular Production System" and "Complementary Products and Services" emphasize recycling and reverse logistics, crucial for sustainable transformations in the industry.

New and Enhanced Influencing Conditions:

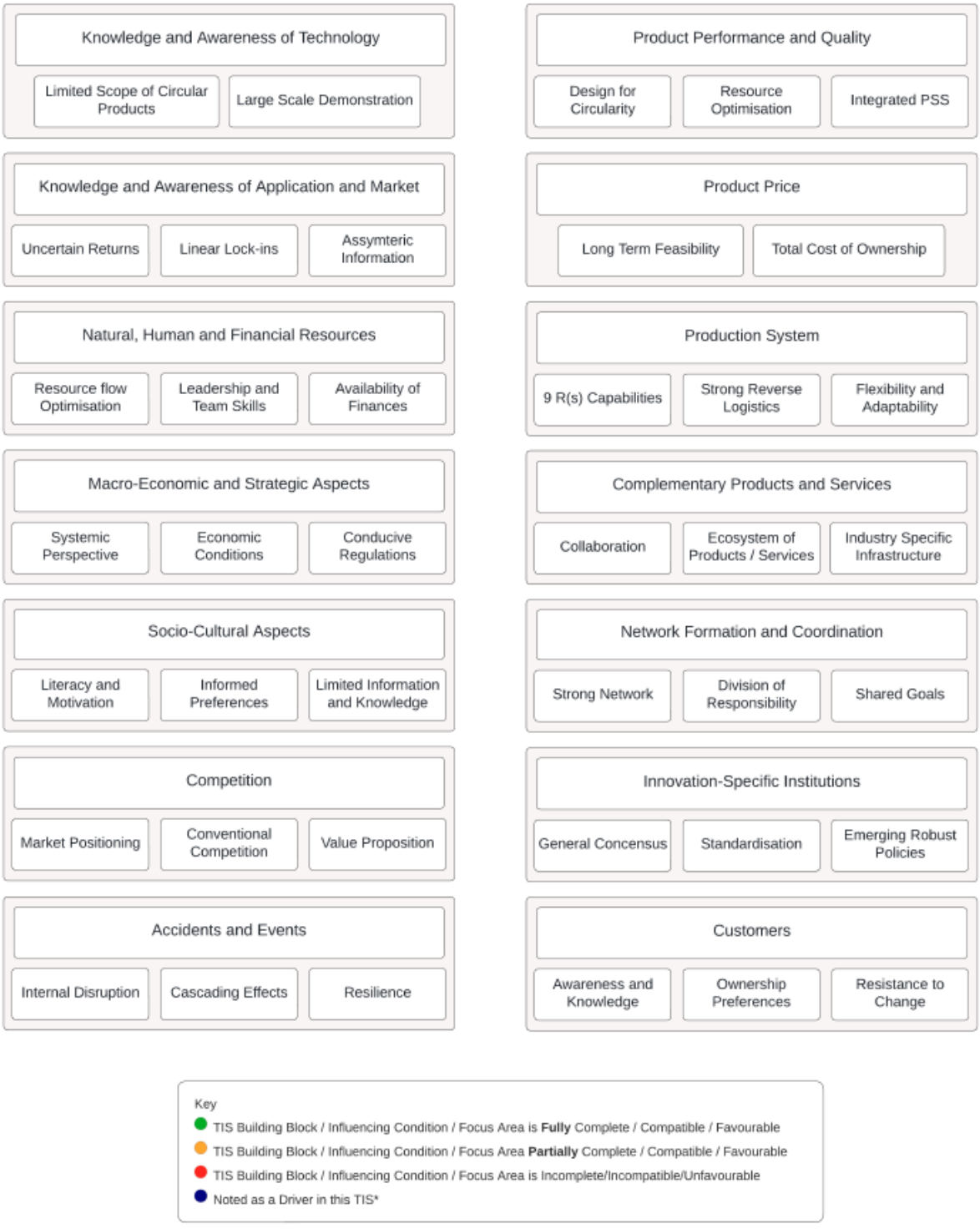
- A new condition, "Environmental and Strategic Aspects," has been added to emphasize the need for supportive policies and strategic alignment with environmental objectives.
- Expansion of existing conditions to include a broader understanding of circular economy practices and challenges in implementing reuse strategies effectively.

Barriers and Challenges:

- Key barriers identified include the substantiation of environmental claims, enhancement of reverse logistics capabilities, and fostering of supportive environmental policies. These barriers influence several building blocks and conditions, necessitating targeted adjustments within the framework.

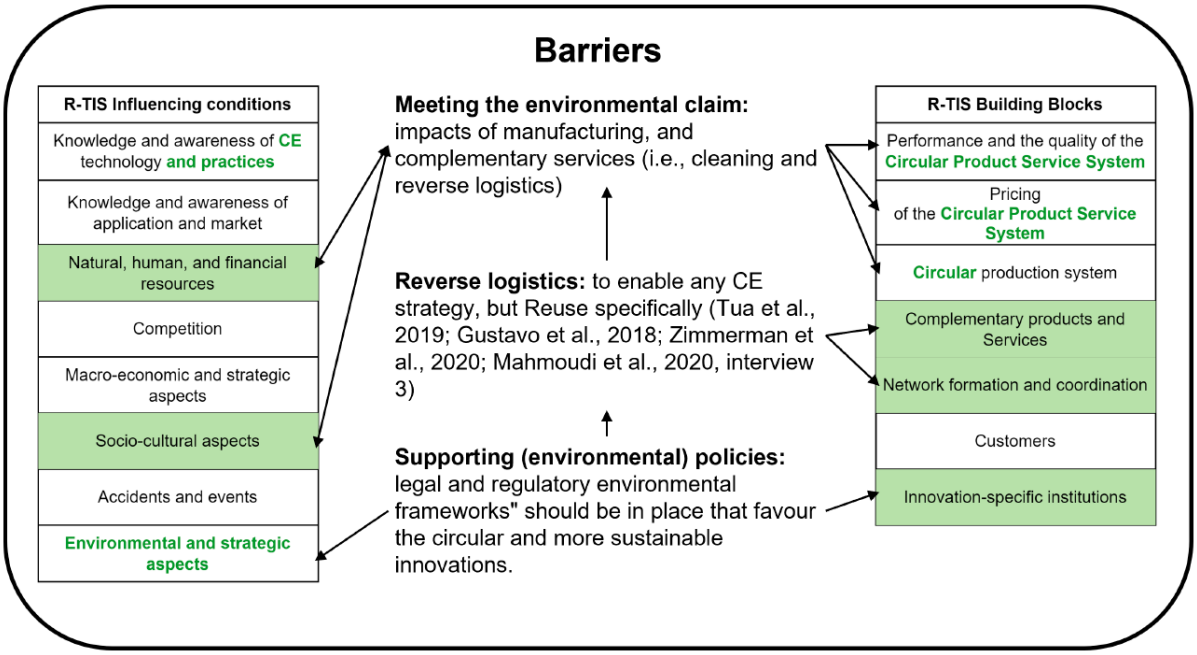
A visual representation of these modifications (Figure 5) illustrates the integration of circular innovation principles into the framework. Detailed descriptions of all specific modifications, including precise keywords and changes to each element, are available in Appendix Appendix C. This adaptation not only extends the TIS framework's applicability to circular innovations but also ensures it is well-suited to address specific challenges of implementing sustainable practices in high-consumption industries. Warns (2023)' methodical approach to modifying the TIS framework reflects a deep understanding of the circular economy's dynamics and the critical role of reuse strategies in achieving sustainability goals.

Figure 4: Adapted TIS framework by Raghav Shankar



Note: Retrieved from "Exploring the role of niche strategies in overcoming barriers to circular innovation: Exploratory case studies of circular high-tech firms in the Netherlands" by R. Shankar, 2023, TU Delft Education Repository, p.36.

Figure 5: Adapted TIS framework by Ruben Warns



Note: Retrieved from "Niche strategies for reuse innovations: Niche introduction strategies for large scale diffusion of reuse innovations in the European domestic soft drinks industry" by R. Warns, 2023, TU Delft Education Repository, p.73.

3.3.4 TIS framework adapted for CI by Jules Engelen

Engelen (2023), in his thesis "Overcoming barriers to circular innovations: Exploring niche strategies for successful introduction," adapts the Technological Innovation System (TIS) framework specifically for the challenges of circular innovations. Similar to other adaptations aimed at enhancing the framework's applicability to sustainability, Engelen (2023)'s revision focuses on addressing the unique barriers that impede the diffusion of circular strategies within existing systems. His approach is methodical, emphasizing the integration of circular principles to address specific systemic challenges in circular economies.

Engelen (2023)'s approach introduces critical modifications and additions to the TIS framework that align with the principles of circular innovation:

Changes to building blocks:

- **Introduction of a new building block:** Reverse Logistics is newly added, emphasizing its crucial role in end-of-life resource management, pivotal for enabling effective circular economy strategies.
- **Modifications to existing blocks:** Enhancement to Production System, Complementary Products and Services, and Customers reflect a heightened focus on adaptability, lifecycle services, and consumer participation in circular processes.

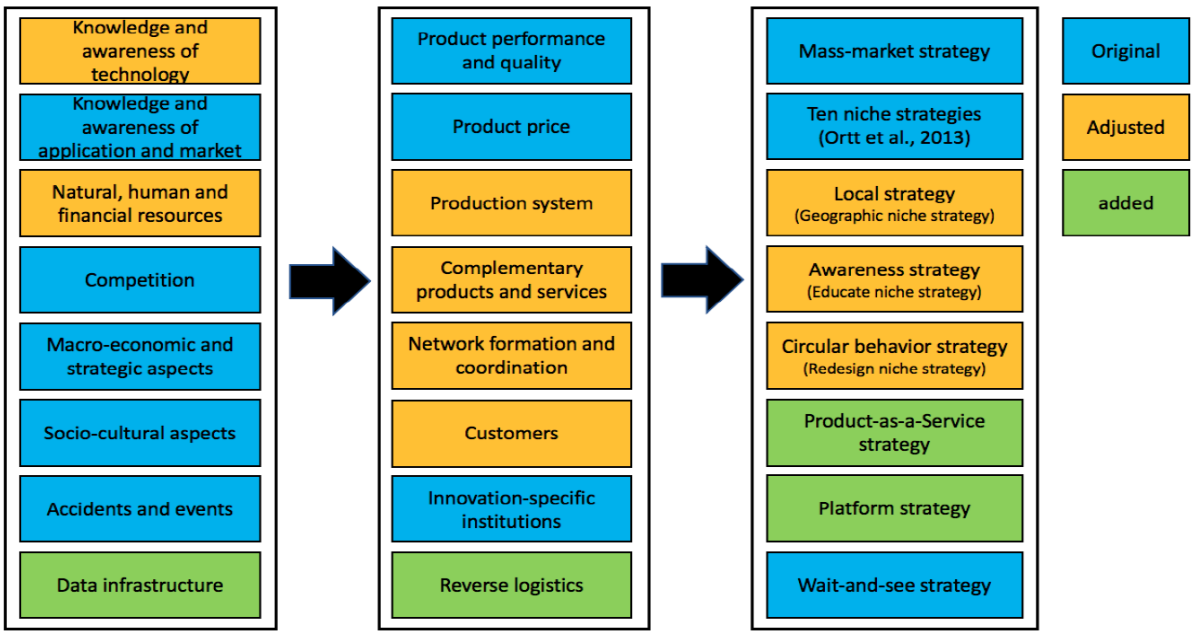
Adjustments to influencing conditions:

- **Introduction of a new influencing condition:** Data Infrastructure is added to enhance the management of circular processes throughout a product's lifecycle, improving efficiency and coordination.

- **Modifications to existing conditions:** Enhancements in Knowledge and Awareness of Technology and Natural, Human, and Financial Resources broaden the scope to include essential aspects like reverse logistics and a sustainable resource base, crucial for circular production systems.

For a comprehensive list of specific changes to the building blocks and influencing conditions, see Appendix D. A visual representation of these changes is also provided in Figure 6, illustrating the integration of circular principles within the TIS framework.

Figure 6: Adapted TIS framework by Jules Engelen



Note: Retrieved from "Overcoming barriers to circular innovations: Exploring niche strategies for successful introduction" by J. Engelen, 2023, TU Delft Education Repository, p.94.

Engelen (2023) also critically evaluates the limitations of his adapted TIS framework, noting the added complexity circular innovation introduces to the analysis. He highlights the potential for the framework's 'inward-oriented' nature to overlook essential contextual dynamics, impacting its utility and relevance across different spatial, technological, and value chain demarcations. Additionally, the framework's static nature may not fully capture the dynamic relationships between its elements, potentially leading to cascading effects where deficiencies in one area adversely affect others. Engelen (2023) stresses the importance of incorporating temporal considerations to effectively tailor strategies over time and accommodate the evolving market dynamics within and beyond the TIS context.

3.3.5 Comparative analysis and selection for circular TIS framework adaptation

This section aims to compare the various adaptations of the TIS framework, focusing specifically on the building blocks and influencing conditions as modified by Shankar (2023), Warns (2023), and Engelen (2023). It will outline the positions taken and the adaptations made by each, facilitating the selection of the most effective elements for incorporation into the model being developed in this thesis. The comprehensive adaptation, integrating these selected elements within the Latin American context, will be fully detailed in the subsequent chapter.

In examining the adaptations, significant differences in focus, methodology, and industry application are evident, each addressing different aspects of circular innovations. Shankar (2023)'s adaptation, designed for Dutch high-tech firms, integrates circular principles like resource efficiency and product longevity essential for sustainability in resource-intensive environments. Warns (2023) focuses on the European soft drinks industry, emphasizing operational improvements such as reverse logistics and environmental product claims to support a sustainable reuse model. Engelen (2023), on the other hand, offers a broader, more generalized framework that goes beyond specific industry constraints, aiming to identify systemic barriers and facilitators of circular innovations across sectors. This variety in approaches highlights a shared challenge in balancing the specificity needed for practical application with the generalizability to broader contexts.

Having presented the overarching approaches of Shankar (2023), Warns (2023), and Engelen (2023) in adapting the TIS framework, the section will now shifts its focus to comparing the specific modifications made to its building blocks:

1. **Product Performance and Quality:**

   - Shankar (2023): Focus on sustainable and durable product design.
   - Warns (2023): Integration of Circular Product-Service Systems for enhanced functionality.
   - Engelen (2023): Does not address changes in this block.

   Decision for own circular adaptation: While adapting the new model, the aspect of **Perceived Performance and Quality** from the original framework is retained, emphasizing the importance of ensuring that circular products match or exceed the quality and performance of traditional products. This retention underscores the continuity of our core principles in circular innovation. Additionally, Shankar (2023)'s emphasis on durable designs has been adopted as **Circular Design**, ensuring products are built to last and are easier to repair and recycle. Warns (2023)' integration of **Circular Product-Service Systems** has also been included to further promote operational efficiency and extend product life, aligning with our goal of optimizing the lifecycle of products.

2. **Product Price:**

   - Shankar (2023): Focus on long-term costs and environmental benefits, reflecting a broader view of product pricing within a circular economy.
   - Warns (2023): Introduces the 'True Price' concept, which encompasses the full lifecycle costs of a product, integrating environmental and social factors.
   - Engelen (2023): Does not address changes in this block.

   Decision for own circular adaptation: Shankar's approach, focusing on long-term costs and environmental benefits, is adopted as an integral part of the **Economic Viability** of the innovation, ensuring pricing strategies are comprehensive and consider the full economic and environmental impacts. Warns' 'True Price' concept is utilized to underpin **Price Transparency**, clearly communicating all lifecycle costs and externalities to consumers. It is also important to consider that the basis of the original framework on **Competitive Pricing** is especially crucial when discussing circular innovations, ensuring that circular products are positioned competitively in the market to encourage consumer adoption.

3. **Production System:**

   - Shankar (2023): Emphasizes recycling and resource optimization. Stresses the need for production systems to be flexible and adaptable. Also mentions the importance of 9R capabilities and scalability.
   - Warns (2023): Transforms this block to support recycling and reuse, emphasizing the adaptability of production systems to extend their lifecycle and enhance their reuse potential.
   - Engelen (2023): Advocates for localized and adaptable production capacities, concentrating on scalability and the flexibility to adjust to new technologies and market conditions, similar to Shankar (2023)'s emphasis but with a specific focus on local conditions.

   Decision for own circular adaptation: In the newly developed model, the emphases on **Flexibility and Adaptability** highlighted by both Shankar (2023) and Engelen (2023) will be integrated to underline their crucial roles in maintaining circularity. This integration showcases the model's ability to incorporate adaptive changes effectively while adhering to circular principles. The insights on **Scalability** shared by the same authors are also crucial, as they illustrate how the model can be adjusted and scaled up without compromising its commitment to circular objectives. Additionally, Shankar (2023)'s focus on recycling and resource optimization is adapted specifically to emphasize the **3R(s) Capabilities**, chosen over the broader 9R(s) due to their more straightforward applicability and effectiveness in the Latin American context.

4. **Complementary Products and Services:**

   - Shankar (2023): Highlights industry-specific infrastructure and collaborative ecosystems.
   - Warns (2023): Stresses the importance of the proximity of complementary products and services to enhance efficient reverse logistics.
   - Engelen (2023): Broadens the block to cover lifecycle services with a focus on product longevity and material recovery.

   Decision for own circular adaptation: The new model will integrate Shankar (2023)'s highlighted industry-specific infrastructure and **Collaborative Ecosystem** aspects, emphasizing effective partnerships and resource sharing across industries. This component is critical for enhancing the accessibility and effectiveness of circular products and services. From Warns' adaptation, the emphasis on the proximity of complementary products and services is adopted, forming the basis of the **Proximity Optimization** aspect. This adaptation is crucial for ensuring efficient reverse logistics, reducing environmental impacts, and enhancing operational efficiency within circular practices. Engelen's focus on comprehensive **Lifecycle Services** will also be included, aiming at extending product longevity and optimizing material recovery.

5. **Network Formation and Coordination:**

   - Shankar (2023): Discusses the necessity for strong networks and effective coordination among stakeholders in the value chain, emphasizing clear roles, shared goals, and a proactive approach to overcoming challenges like communication, division of responsibilities, and infrastructure.
   - Warns (2023): Focuses on reverse logistics, highlighting the importance of local and bidirectional connections, and proximity of service providers to efficiently manage return streams and facilitate collaboration between new and incumbent actors.

- Engelen (2023):Emphasizes emergent and explicit coordination among actors for comprehensive lifecycle management, highlighting the importance of networks for fostering relationships, guiding technological development, shaping public perception, and creating a shared vision.

Decision for own circular adaptation: The new model will integrate Shankar (2023)'s emphasis on **Clear Roles and Shared Goals** and Engelen (2023)'s emphasis on the importance of a shared vision. This approach ensures that stakeholders have defined roles and align with shared goals for effective collaboration, addressing challenges such as communication and responsibility division. Warns (2023)' focus on reverse logistics and local connections will shape the **Interconnected Network** aspect, enabling efficient resource circulation and robust stakeholder collaboration. The perspective of a **Strong Network**, highlighted by all three authors, will be central, emphasizing effective collaboration, resource sharing, and sustained relationships for technological development.

6. **Customers:**

   - Shankar (2023): Emphasizes enhancing customer awareness and shifting ownership preferences towards sustainable models. Highlights the importance of addressing barriers such as limited perception, lack of involvement, and resistance to change through effective communication strategies.
   - Warns (2023): Focuses on encouraging consumer adoption by emphasizing product convenience, competitive pricing, and strong environmental claims. Stresses that willingness to pay and use is critical for large-scale diffusion.
   - Engelen (2023):Discusses the need for customer awareness, understanding benefits, and addressing skepticism about circular products. Highlights the importance of cultural changes and environmental attitudes in influencing customer behavior.

   Decision for own circular adaptation: The new model will integrate Shankar (2023)'s emphasis on enhancing customer awareness and shifting ownership preferences, along with Engelen (2023)'s discussion on customer awareness and understanding benefits, to support the **Customer Awareness and Engagement** aspect. This integration will ensure that customers are well-informed about the benefits of circular models and are more inclined towards sustainable consumption practices. Additionally, the **Willingness to Pay and Use** aspect from the original model will be maintained, emphasizing product convenience, competitive pricing, and strong environmental claims to make circular products more appealing and competitive in the marketplace. Engelen (2023)'s focus on active customer participation, addressing skepticism about performance, and fostering cultural changes will inform the **Customer Integration** aspect, ensuring that customers are engaged throughout the entire product lifecycle, thereby enhancing the effectiveness and sustainability of circular practices.

7. **Innovation-Specific Institutions:**

   - Shankar (2023): Highlights the importance of regulatory frameworks, environmental and waste management legislation and regulations, and the legal system in general. Emphasizes the need for global coordination and robust enforcement mechanisms, while identifying barriers such as misalignment of incentives and institutional shortcomings.
   - Warns (2023): Does not make significant changes but emphasizes the necessity for supportive and stable legal and regulatory environmental frameworks that favor circular and sustainable innovations, noting that the absence of these frameworks can obstruct large-scale diffusion.

- Engelen (2023):Does not make significant changes but discusses the role of formal policies, laws, and regulations in creating an enabling environment for circular innovations. Highlights the need for policies that support CI through interventions like tax benefits, infrastructure development, and public education.

Decision for own circular adaptation: The new model will integrate Shankar (2023)'s emphasis on regulatory frameworks, environmental laws, and global coordination, along with Warns (2023)' emphasis on supportive and stable legal frameworks, to form the basis of the **Regulatory Alignment and Stability** aspect. This ensures that legal systems and policies align with circular economy principles and facilitate large-scale diffusion. Shankar (2023)'s focus on standardization will inform the **Standardization and Legitimacy** aspect, creating a supportive environment for circular innovations through interventions in material pricing and public education. Additionally, Engelen (2023)'s discussion on the need for clear and stable legislation and formal policies will contribute to the **Supportive Policy Infrastructure** aspect, focusing on robust policies such as tax benefits, infrastructure development, and public education that favor circular innovations.

8. **Reverse Logistics:**

- Shankar (2023): Embeds reverse logistics concepts within the production system, integrating it into existing structures.
- Warns (2023): Recognizes reverse logistics as a key challenge in his R-TIS framework, acknowledging its importance but not elevating it to a standalone category.
- Engelen (2023): Is the only one among the three authors to introduce Reverse Logistics as a completely new building block, emphasizing its critical role in circular innovations' end-of-life processes.

Decision for own circular adaptation: The new model will adopt Engelen (2023)'s approach of introducing Reverse Logistics as a standalone building block, recognizing its critical role in managing end-of-life processes for circular innovations. This block will be detailed into three aspects: **Collection and Inspection**, which involves collecting products from end-users and assessing their condition; **Product Recovery Management**, which includes sorting and processing products for reuse, repair, upgrade, remanufacturing, or disposal; and **Waste Management**, which deals with the responsible disposal of products unsuitable for recovery.

Similarly, the focus will then move to the influencing conditions within the TIS framework, examining how these elements have been uniquely adapted and integrated in each author's framework:

1. **Knowledge and Awareness of Technology:**

- Shankar (2023): Expands this condition to include a broader scope for circular products and advocates for large-scale demonstration projects to enhance understanding and visibility.
- Warns (2023): Emphasizes the necessity of understanding both the technological and circular economy practices, crucial for reuse strategies.
- Engelen (2023): Updates this condition to include knowledge about reverse logistics, a key barrier to innovation.

Decision for own circular adaptation: The new model will integrate the perspectives of Shankar (2023), Warns (2023), and Engelen (2023) to form the **Circular Technological Knowledge** aspect, which highlights the necessity of both fundamental and applied

technological knowledge in circular innovation. This includes understanding technological principles involved in product development and production processes. Additionally, Shankar (2023)'s advocacy for large-scale demonstration projects is adopted to form the Circular Innovation Demonstration aspect, underscoring the importance of showcasing circular practices to enhance understanding and visibility.

2. **Application and Market Dynamics:**

   - Shankar (2023): Addresses uncertain returns, linear lock-ins, and asymmetric information.
   - Warns (2023): Emphasizes understanding market structures and potential applications.
   - Engelen (2023): Highlights the need for knowledge of market structure and relevant actors but does not significantly modify this condition.

   Decision for own circular adaptation: The new model will incorporate Warns (2023)' focus on **Market Structure and Dynamics**, emphasizing the need for comprehensive understanding of market structure and the roles of social actors in circular economy applications. Shankar (2023)'s perspective on **Return Predictability** is also adopted, highlighting the importance of predictability in returns for circular businesses to secure necessary financial resources. Additionally, Shankar (2023)'s emphasis on Information Symmetry is included, ensuring balanced information flow between stakeholders to build trust and reduce uncertainty.

3. **Natural, Human, and Financial Resources:**

   - Shankar (2023): Focuses on resource flow optimization and the efficient utilization of resources throughout the product life cycle.
   - Warns (2023): Emphasizes geographical and logistical resource proximity.
   - Engelen (2023): Highlights the need for human resources development and ensuring the availability of natural and financial resources, noting the importance of high-quality secondary materials.

   Decision for own circular adaptation: The new model will maintain the **Resource Availability** aspect from the original framework, emphasizing the necessity of having readily accessible natural, human, and financial resources for circular innovation. Shankar (2023)'s focus on efficient utilization and flow of resources will form the basis for the **Resource Flow Optimization** aspect, highlighting the importance of minimizing waste generation and maximizing resource efficiency. Engelen (2023)'s perspective on the development of human resources through education and training programs is adopted as the **Human Resources Development** aspect, ensuring that individuals possess the necessary knowledge and competencies for circular innovation.

4. **Competition:**

   - Shankar (2023): Focuses on market positioning and navigating competition, highlighting the challenges posed by both traditional and circular competitors.
   - Warns (2023): Notes the difficulties in protecting process-based innovations within circular economy contexts.
   - Engelen (2023): Discusses competition between different circular innovations and emphasizes the importance of differentiating circular solutions.

Decision for own circular adaptation: The new model will integrate Shankar (2023)'s emphasis on **Market Positioning**, which involves understanding customer needs, formulating compelling value propositions, and effectively communicating the benefits of circularity. Both Shankar (2023) and Engelen (2023) highlight the challenges posed by conventional competitors, forming the **Conventional Competition** aspect, which addresses the need for circular businesses to navigate competition from traditional linear products. Additionally, both authors' insights on competition between circular innovations contribute to the **Circular Competition** aspect, emphasizing the differentiation of various circular solutions and the importance of positioning these solutions effectively in the market.

5. **Macro-economic and Strategic Aspects:**

   - Shankar (2023): Suggests a systemic perspective and regulatory alignment for innovation.
   - Warns (2023): Highlights the importance of macroeconomic factors and strategic policies without making significant changes to the model.
   - Engelen (2023): Discusses the impact of macroeconomic and strategic aspects but does not specifically modify this influencing condition.

   Decision for own circular adaptation: The new model will integrate Shankar (2023)'s systemic perspective and emphasis on **Systemic Economic Integration**, acknowledging the interconnectedness of various actors and factors within the economy and the need for collaboration to implement circular principles effectively. The **Economic Conditions** aspect, maintained from the original framework, focuses on the impact of overall economic conditions, such as growth, recessions, income inequality, and poverty levels, on the development and adoption of circular innovations. This aspect highlights the necessity of understanding and adapting to these economic realities to ensure the viability and success of circular initiatives.

6. **Socio-cultural Aspects:**

   - Shankar (2023): Emphasizes the alignment of social and cultural norms, values, and beliefs with circular economy principles.
   - Warns (2023): Places greater emphasis on norms and values that promote circular economy principles.
   - Engelen (2023):Highlights the influence of socio-cultural aspects but does not significantly modify this condition.

   Decision for own circular adaptation: The new model will maintain the **Norms and Values Alignment** aspect from the original framework, emphasizing the importance of aligning social and cultural norms with circular principles. Shankar (2023)'s insights on overcoming resistance to change and limited consumer perception will inform the **Cultural Preferences and Resistance** aspect, focusing on understanding and influencing cultural aspects to foster a circular economy-oriented culture. Additionally, the new model will incorporate Shankar (2023)'s perspective on the pivotal role of **Societal Awareness and perception** in adopting circular practices, ensuring that consumers are aware of the benefits of circularity and can make informed decisions.

7. **Accidents and Events:**

   - Shankar (2023): Includes managing internal disruptions and building resilience.

- Warns (2023): Acknowledges the influence of significant events on material transitions but does not make significant changes.
- Engelen (2023): Discusses the impact of external factors like wars and natural disasters on circular innovation.

Decision for own circular adaptation: The new model will maintain the **Internal Factors** and **External Factors** aspects from the original framework, recognizing the significant impact of both internal disruptions (such as manufacturing errors and product failures) and external events (such as natural disasters and geopolitical tensions) on circular innovation processes. Additionally, Shankar (2023)'s emphasis on **Resilience and Adaptability** will be incorporated, highlighting the importance of organizations' ability to recover from disruptions and continue progressing towards circular innovation.

8. **Environmental and Strategic Aspects:**

   - Shankar (2023): Integrates environmental considerations through design and policy elements.
   - Warns (2023): Introduces Environmental and Strategic Aspects as a new influencing condition, emphasizing environmental policy and strategic decision-making.
   - Engelen (2023):Implicitly addresses these areas through localized production systems and lifecycle services.

   Decision for own circular adaptation: The new model adopts Environmental and Strategic Aspects as a new influencing condition, following Warns (2023)' approach. This includes the **Institutional Policies** aspect, recognizing the crucial role of policies and regulations in enabling or obstructing circular and reuse innovations. The **Governmental Support** aspect emphasizes the importance of financial and regulatory backing from governments to create a conducive environment for circular practices. Finally, the **Strategic Sustainability Vision** aspect highlights the need for a long-term perspective that incorporates environmental considerations into national and international strategies, fostering the development and scaling of circular innovations.

9. **Data Infrastructure:**

   - Shankar (2023): Indirectly addresses this through his focus on logistics and service ecosystems.
   - Warns (2023): Touches on data management aspects under "Knowledge and Awareness of CE Technology and Practices".
   - Engelen (2023): Adds Data Infrastructure as a new condition, highlighting the importance of data management.

   Decision for own circular adaptation: The new model will include Engelen (2023)'s Data Infrastructure, recognizing its critical role in facilitating data exchange and integration throughout TIS networks. Originally, Data Infrastructure was going to be added as a standalone influencing condition. However, after analyzing the specific characteristics of Latin America and conducting the first case study, it was decided to integrate it as a sub-condition under a new, broader influencing condition "Transportation and Information Infrastructure", which will be presented later. Data Infrastructure encompasses real-time data sharing, strategic data utilization for optimizing product and resource efficiency, and supporting service innovations in circular business models to enhance customer satisfaction (Engelen, 2023).

Table 6 provides an overview of the comparison between the three adapted frameworks. It also highlights the elements and modifications that are being incorporated into the new adapted model presented in this thesis. It is important to note that this table only includes elements related to circularity. The specifics concerning the Latin American context will be detailed in the next chapter.

Table 6: Comparative Analysis of the TIS framework adaptations

Aspect	**Shankar (2023) Adaptation**	**Warns (2023) R-TIS Framework**	**Engelen (2023) Adaptation**	**C-TIS Framework**
Key Challenges Addressed	Resource efficiency, Sustainable practices, Product longevity	Reverse logistics, Environmental claims, Supportive policies	Lifecycle process, Systemic changes, Data management	Latin American and circular specific challenges
Industry Focus	High-tech firms in the Netherlands	European soft drinks market	General circular innovation	Latin American circular innovations
Validation Method	Industry consultations, Case studies	Case studies	Systematic literature review	Case Studies, Expert interviews
Limitations Noted	Geographical focus, Qualitative biases	Complexity in categorization, Emerging technology data scarcity	Framework static nature, Inward-oriented analysis	Latin America's diversity (countries and industries)
New Building Blocks	-	-	Reverse Logistics	Reverse Logistics
New Influencing Conditions	-	Environmental and Strategic Aspects	Data Infrastructure	Environmental and Strategic Aspects, Data Infrastructure[a]
Modified Building Blocks				
Product Performance and Quality	Integrates circular principles such as "Design for Circularity"	Durability and CPSS integration	-	Circular Design, Perceived Performance and Quality, Circular Product Service System
Product Price	Long-term viability and total cost of ownership	Represents environmental and social costs ('True Price')	-	Economic Viability, Price Transparency, Competitive Pricing
Production System	9 R(s) Capabilities, Strong Reverse Logistics, flexibility and adaptability	More amenable to recycling and reuse, waste reduction	Emphasizes localized and adaptable production capacities	3R(s) Capabilities, Scalability, Flexibility and Adaptability
Complementary Products and Services	Ecosystem of circular products/services, industry-specific infrastructure	Includes maintenance, repair, and reverse logistics services	Covers full spectrum of lifecycle services emphasizing longevity	Collaborative Ecosystem, Proximity Optimization, Lifecycle Services
Network Formation and Coordination	Strong networks, clear division of responsibility, shared goals	Coherent collaboration for a supportive circular infrastructure	Enhanced coordination with a focus on material and value recirculation	Strong Network, Interconnected Network, Clear Roles and Shared Goals
Customers	Awareness and knowledge, shifting ownership preferences, resistance to change	Engaging consumers in circular product adoption	Active customer participation in circular processes	Customer Awareness and Engagement, Willingness to Pay and Use, Customer Integration

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Table 6 continued from previous page

Aspect	Shankar (2023) Adaptation	Warns (2023) R-TIS Framework	Engelen (2023) Adaptation	C-TIS Framework
Innovation-specific Institutions	Promoting standardization and robust policies for circularity	-	-	Regulatory Alignment and Stability, Standardization and Legitimacy, Supportive Policy Infrastructure
Modified Influencing Conditions				
Knowledge and Awareness of Technology	Expanded scope of circular products, large scale demonstration	Recognition of process innovations like reverse logistics	Includes knowledge of reverse logistics	Circular Technological Knowledge, Circular Innovation Demonstration
Application and Market Dynamics	Addressing uncertain returns, overcoming linear lock-ins	Understanding market structures for circular economy	-	Market Structure and Dynamics, Return Predictability, Information Symmetry
Natural, Human, and Financial Resources	Resource flow optimization, leadership and team skills	Proximity of resources in supply chain management	Emphasizes a diverse resource base including secondary materials	Resource Availability, Resource Flow Optimization, Human Resources Development
Macro-economic and Strategic Aspects	Systemic perspective, economic conditions, conducive regulations	Importance of macroeconomic factors and strategic policies	-	Systemic Economic Integration, Economic Conditions, Policy and Regulation Alignment
Socio-cultural Aspects	Literacy and motivation, informed preferences	Greater emphasis on promoting circular economy principles	-	Norms and Values Alignment, Cultural Preferences and Resistance, Societal Awareness and Perception
Competition	Market positioning, conventional competition	No conceptual difference, but notes challenges	-	Market Positioning, Conventional Competition, Circular Competition
Accidents and Events	Building resilience and managing internal disruption	Potential influence of significant events on material transitions	-	Internal Factors, External Factors, Resilience and Adaptability

a Data Infrastructure is included as a new sub-condition under the new influencing condition "Transportation and Digital Infrastructure", which will be presented later.

3.4 Conclusion

This chapter has provided a comprehensive literature review, critically examining existing research on CE, with a particular focus on definitions, barriers, and strategies relevant to Latin America. It also explored existing adaptations of the TIS framework to incorporate circular principles. The main findings and contributions from each section are summarized below.

Defining CE within the Latin American Context

The literature review began by exploring various definitions of CE, emphasizing sustainability, resource efficiency, and lifecycle thinking. Within the Latin American context, unique socio-economic and cultural dimensions play a significant role in shaping CE. Traditional practices and cultural heritage emphasize sustainable resource management and harmony with nature. Additionally, the informal sector is pivotal in waste management and recycling, necessitating its formal recognition and inclusion in CE strategies. Social equity and sustainability are also critical, incorporating concepts such as 'Buen Vivir,' which focus on community well-being and balance with nature.

The technocentric discourse and the definition by Kumar et al. (2019), which describes CE as an economic system aimed at closing product life cycles through resource reuse, recycling, and recovery, fit best with this research and the TIS framework. This definition aligns particularly well with the Latin American nuances of waste management and the integration of the informal sector, addressing Sub-question 1.

It is essential to recognize that while the chosen definition and discourse align well with the focus on waste management and the informal sector, other socio-cultural dimensions in Latin America remain crucial. These aspects, although outside the immediate scope of this research, are integral to a comprehensive understanding of CE in the region. Sub-question 1 is thus partially addressed and will be further complemented by empirical insights in the subsequent stages of the research.

Barriers to the CE in Latin America

The literature review specifically identified barriers to the adoption of CE in Latin America, highlighting several unique challenges that hinder progress in the region. These barriers were categorized and as follows:

- Socioeconomic Barriers: High unemployment, income inequality, and extensive informal sectors complicate the transition to a sustainable economy.
- Infrastructure Irregularities: Lack of formalization and inclusion of the informal sector and inadequate infrastructure for waste management.
- Cultural Barriers: Resistance due to a "buy and own" culture and low consumer interest in sustainable practices; hesitancy in company culture.
- Legislative and Regulatory Barriers: Complex regulations and bureaucratic processes; lack of supportive regulatory frameworks and governmental support.
- Financial Constraints: High initial costs and perceived low returns; limited funding opportunities.
- Technological Gaps: Insufficient development of technologies for raw material reduction and recycling; limited technological innovation and infrastructure.
- Organizational Challenges: Lack of management commitment and internal integration; difficulties in developing sustainable business models.
- Supply Chain Issues: Need for more integrated approaches and adaptation to market dynamics; challenges in creating efficient, circular supply chains.

These identified barriers contribute theoretically to answering Sub-question 2 by providing a foundational understanding of the obstacles to CE adoption in Latin America. However, the full answer to this question will be achieved when the adapted TIS framework is applied empirically, revealing the actual barriers faced by businesses and stakeholders in the region. This empirical application will validate and expand upon the theoretical insights gained from the literature review.

Strategies to overcome barriers

The literature review identified and compared various strategies to overcome barriers to the CE in Latin America, integrating insights from both theoretical and practical perspectives. These are the main strategies found:

- **Education and Awareness:** Enhancing consumer interest and company culture through education and awareness campaigns.
- **Legislative Support:** Developing clear regulatory frameworks and government incentives to support CE practices.
- **Integration of Informal Sector:** Formalizing the informal sector's role in waste management to improve efficiency and sustainability.
- **Technological Innovation:** Investing in R&D and infrastructure for recycling and resource optimization technologies.
- **Financial Incentives:** Providing tax incentives, subsidies, and funding opportunities to reduce initial costs and encourage sustainable investments.
- **Collaborative Networks:** Promoting collaboration between public and private sectors, including knowledge sharing and regional integration.
- **Public Policies and Governance:** Implementing extended producer responsibility (EPR) systems and fostering good governance and transparent institutions.
- **Supporting Social Equity:** Incorporating social justice and participatory governance into CE strategies, focusing on local contexts and community well-being.

It is important to acknowledge that many of the strategies found in the literature are policy-driven or not directly applicable at the introductory stage. While they set the stage for systemic transformation towards CE, they often target macro-level changes and may not be immediately actionable for companies at the beginning of their CE journey. For some of these strategies, lobbying can be applied to tailor them to specific operational needs, but for others, this may not be feasible. These issues will be further discussed and clarified in the comparison with strategies derived from interviews and those developed through the adapted TIS framework, fully addressing Sub-question 6.

Modifications for CI

The literature review explored and compared existing circular adaptations to the TIS framework to understand which components are most relevant when analyzing circular innovations. This resulted in a preliminary list of building blocks and influencing conditions tailored for circular innovations, thus addressing Sub-question 3. It is important to mention that this is only partially complete, as the Latin American adaptation will be addressed in the next chapter. The following tables shows the building blocks and influencing conditions with their respective sub-elements.

Table 7: Building Blocks and Sub-blocks for Circular Innovations

Building Block	**Sub-blocks**
1. Product Performance and Quality	Circular Design, Perceived Performance and Quality, Circular Product Service System
2. Product Price	Economic Viability, Price Transparency, Competitive Pricing
3. Production System	3R(s) Capabilities, Scalability, Flexibility and Adaptability
4. Complementary Products and Services	Collaborative Ecosystem, Proximity Optimization, Lifecycle Services
5. Network Formation and Coordination	Strong Network, Interconnected Network, Clear Roles and Shared Goals
6. Customers	Customer Awareness and Engagement, Willingness to Pay and Use, Customer Integration
7. Innovation-specific Institutions	Regulatory Alignment and Stability, Standardization and Legitimacy, Supportive Policy Infrastructure
8. Reverse Logistics	Collection and Inspection, Product Recovery Management, Waste Management

Table 8: Influencing Conditions and Sub-conditions for Circular Innovations

Influencing Condition	**Sub-conditions**
1. Knowledge and Awareness of Technology	Circular Technological Knowledge, Circular Innovation Demonstration
2. Application and Market Dynamics	Market Structure and Dynamics, Return Predictability, Information Symmetry
3. Natural, Human, and Financial Resources	Resource Availability, Resource Flow Optimization, Human Resources Development
4. Competition	Market Positioning, Conventional Competition, Circular Competition
5. Macro-economic and Strategic Aspects	Systemic Economic Integration, Economic Conditions, Policy and Regulation Alignment
6. Socio-cultural Aspects	Norms and Values Alignment, Cultural Preferences and Resistance, Societal Awareness and Perception
7. Accidents and Events	Internal Factors, External Factors, Resilience and Adaptability
8. Environmental and Strategic Aspects	Institutional Policies, Governmental Support, Strategic Sustainability Vision
9. Data Infrastructure[a]	-

a Data Infrastructure is included as a new sub-condition under the new influencing condition "Transportation and Digital Infrastructure", which will be presented later.

4 Adaptation of the TIS framework: C-TIS(LA)

In this chapter, we finalize the adaptation of the Circular Technological Innovation System framework in the context of Latin America (C-TIS (LA)). The chapter begins with 4.1, which involves outlining the unique characteristics of Latin America relevant to this adaptation. Following this, in Section 4.2, the chapter explores various adaptation scenarios, ultimately selecting specific scenarios for the Latin American characteristic. Finally, the chapter concludes with Section 4.3, which presents a comprehensive adapted C-TIS (LA) framework, detailing the elements and modifications informed by both the analysis of existing circular frameworks and the distinct context of Latin America.

4.1 Latin American characteristics

This section outlines the distinctive characteristics of Latin America critical for tailoring the framework to the region. It encompasses a range of factors, including socio-economic disparities, infrastructure limitations, consumer behavior, systemic challenges, and geopolitical dynamics. By examining these unique aspects, foundational knowledge is laid necessary for the subsequent adaptation of the framework. The aim is to address and leverage these characteristics for the effective implementation of circular economy practices in Latin America.

Socio-Economic Disparities in Latin America

Latin America presents a paradox within its socio-economic fabric, where most countries are classified as upper-middle-income nations, yet they grapple with high degrees of inequality. This disparity is quantitatively underscored by high GINI index scores, a widely recognized measure of inequality. Despite the middle-income classification, the region is characterized by "significant pockets of poverty," reflecting a deep-seated imbalance within societies (Schröder et al., 2020). For instance, while Chile has made strides in reducing net poverty over the last decade, it still records one of the highest rates of inequality in Latin America, with a GINI index score that stands as the highest within the Organization for Economic Co-operation and Development (OECD) countries. Similarly, Guatemala and Mexico showcase this contradiction vividly, with 62% and 42% of their populations living in poverty, respectively, alongside high GINI index scores that indicate a greater degree of inequality than even in Haiti, the region's only low-income country (Schröder et al., 2020). This stark inequality has direct implications for the consumer market, particularly concerning the adoption of circular products. Cantú et al. (2021) highlight a critical barrier to circular economy initiatives: a significant segment of the population, due to their low to middle income, may find circular products unaffordable.

Infrastructure Challenges

The advancement of CE innovations in Latin America is significantly constrained by the prevalence of irregular or unavailable infrastructure. Latin America's investment in infrastructure is significantly lower than other developing regions. Fay et al. (2017) report that the region invests less than 3% of Gross Domestic Product (GDP) in infrastructure.

This infrastructure deficiency is particularly evident and relevant in regard to waste management and selective disposal. Only a small fraction of the population in countries like Brazil has access to facilities that support selective disposal, such as recycling bins and collection services (Batista et al., 2018). The insufficiency of public infrastructure not only limits the efficiency of waste management practices but also leads to a higher reliance on landfills for waste disposal. Consequently, this contributes to the alarmingly low percentages of urban solid waste being recycled across the region. For example, studies have shown that only 4.5% of waste generated in

Latin America is recycled, pointing to a substantial gap in the waste management infrastructure that is essential for supporting CE initiatives (Medina Abad & Freire Pesántez, 2023).

The region's transportation infrastructure, encompassing roads, railways, ports, and urban transport systems, is generally underdeveloped, poorly maintained, and inadequate to meet current demands. One significant issue is the inadequacy and poor maintenance of these systems, with only 23% of roads in Latin America paved, compared to 60-80% in other parts of the world (Rodríguez & Montes, 2021). The region's challenging geography, including vast distances and difficult terrain, further exacerbates these problems. For instance, Brazil, the fifth-largest country in the world by area, requires logistics operations that involve transporting goods over continental-scale distances (Batista et al., 2018). Examples of incomplete or unstarted projects highlight these challenges, such as Brazil's Transnordestina railway, which remains unfinished despite over a decade of work, and a new airport in Cusco, Peru, proposed in the 1970s but discarded in 2017 due to bureaucratic delays (Economist, 2018). Corruption has also played a significant role in halting infrastructure projects, for instance, the corruption scandal involving the Brazilian construction giant Odebrecht implicated multiple Latin American governments and paused projects like Ruta del Sol 2, a 500km highway intended to connect Bogota to the Caribbean coast (Economist, 2018). The sparse population in the region makes it challenging to establish a dense, cost-effective transport network, leading to significant pockets of inaccessibility, for example in rural areas in the Amazon rainforest and in coastal regions of Colombia and Ecuador (Fay et al., 2017). Additionally, climate change poses further challenges, causing extensive damage to infrastructure through extreme weather events, as evidenced by the substantial damage to road networks in Guatemala, Honduras, and Nicaragua in 2020 (Rodríguez & Montes, 2021).

Communication infrastructure also poses significant challenges to the implementation of circular economy practices in Latin America. 35% percent of the population, or about 225 million people, lack mobile internet access (GSMA, 2024). Most challenges stem from rural regions, where limited coverage results from the high costs of network deployment. These costs, combined with lower population density and average revenue per customer, lead to poor returns on investment (Martínez Garza et al., 2020; Telefónica, 2022). In these areas, internet penetration can be as low as 10%, while urban areas achieve over 60% penetration. Regionally, there are notable disparities in internet usage both between and within countries, influenced by factors such as income levels, geographic location, and the availability of quality connectivity infrastructure. These issues are further compounded by economic, social, and geographic barriers, making it challenging to bridge the connectivity gap and improve network quality (Telefónica, 2022). This lack of reliable internet and telecommunications services hampers the ability of businesses and consumers to engage in digital platforms that facilitate circular practices, such as online marketplaces for second-hand goods or resource-sharing platforms.

Moreover, the lack of financial infrastructure compounds these challenges, further inhibiting the region's transition towards a circular economy. This includes limitations in access to financial services and credit facilities, which are crucial for both consumers and companies engaging in CE practices. For instance, in Mexico, the challenge of securing deposits for product rentals in a peer-to-peer leasing company highlights the broader issue of inadequate financial systems that are not conducive to circular business models. The reluctance of national banks to accommodate the financial transactions required by such business models, coupled with the low circulation of credit cards among the population, exemplifies the financial barriers to CE adoption (Cantú et al., 2021).

Consumer Behavior and Knowledge

In Latin America, consumer behavior towards CE practices, including recycling and selective disposal, is predominantly passive, marked by skepticism towards the effectiveness and utility of circularity. This attitude is evident in Brazil, where despite significant efforts to encourage active consumer participation in recycling and selective disposal, the shift in behavior remains limited (Batista et al., 2018). Such skepticism and passivity undermine the potential for widespread adoption of CE practices across the region. The deficiency in public awareness about the circular economy, its innovations, and products further complicates this scenario. Many consumers in Latin America are not fully informed about the principles of CE or the environmental and economic benefits that CE practices can bring. This lack of awareness contributes to the low compliance rates observed in selective collection programs, reflecting a broader disconnect between the public's understanding of CE and its implementation in daily life. Compounding these issues is a general unwillingness among consumers to pay additional costs for sustainable innovations, products, or services. This reluctance is rooted in immediate economic needs and priorities, where environmental considerations often take a backseat. In contexts where economic pressures are acute, such as in many Latin American countries, consumers may prioritize other concerns over sustainability. This prioritization is influenced by cultural norms, geopolitical situations, and the immediate economic landscape, all of which shape consumer attitudes towards spending on CE-related initiatives (Cantú et al., 2021).

Systemic Challenges

In LAC, systemic challenges deeply impact the region's ability to foster social innovation and implement circular economy CE practices, marked by a notable inefficiency and sometimes absence of robust public policies. This scenario is further complicated by the inefficient or lacking enforcement of even those policies that do exist, significantly restricting scalable, sustainable development. For instance, Chile's Potential Chile initiative, which developed a product significantly reducing particulate emissions from biomass combustion, showcases the potential for innovation. Despite initial support, the project's scaling was hampered by insufficient follow-up investment, reflecting a broader trend where government-backed social innovation programs remain marginal and under-supported (Schröder et al., 2020). Moreover, the region's slow adoption of resource-efficient production practices exemplifies governmental reluctance, perpetuating reliance on intensive natural resource use and highlighting a significant gap between policy potential and its realization. Many existing policies aimed at promoting sustainability and modernizing industries toward sustainability are not applied effectively, leading to a sustained resource-intensive trajectory for the region's economies and industries (Schröder et al., 2020).

The situation is exacerbated by the intertwined challenges of high bureaucracy and widespread corruption, which significantly hinder sustainable development and the adoption of CE practices. The dense bureaucracy, with its complex regulatory frameworks and extended administrative processes, presents formidable barriers to project initiation and execution. This complexity deters investment and complicates the effective implementation of sustainability policies, with many projects finding themselves mired in procedural delays. Corruption further aggravates these challenges, introducing a layer of difficulty where unofficial payments often become the means to bypass bureaucratic inertia or secure necessary approvals. Such practices not only erode trust in public institutions but directly obstruct efforts towards sustainability. The synergistic effects of bureaucracy and corruption create a hostile environment for the circular economy, where the potential for innovation and sustainable practices is frequently stifled by inefficiencies and ethical dilemmas.

Geopolitical Challenges

Geopolitical dynamics in LAC present significant challenges to the region's sustainable development and the effective implementation of CE initiatives. Political volatility, characterized by frequent changes in policies and leadership, introduces a level of uncertainty and inconsistency that complicates long-term planning and investment in sustainability efforts. This instability often results in the reversal of important gains in institutional accountability, social protection, equity, and environmental protections, which are crucial for achieving social, environmental, and economic Sustainable Development Goals (SDGs). Suppressed economic growth, influenced by falling commodity prices since 2011, has contributed to dramatic political shifts in some countries, with voters increasingly favoring populist parties that promise prosperity. Such shifts have raised concerns that some incoming governments may prioritize economic growth at the expense of environmental and social standards, potentially reversing critical advancements and relaxing environmental protections. (Schröder et al., 2020).

The lack of public trust in political leaders, exacerbated by perceptions and instances of corruption, poses a formidable barrier to the acceptance and success of transparent and participatory processes essential for sustainable development and CE transitions. In LAC, there is a long history of social innovation promoting health, education, food, and energy security, where government institutions have sometimes fallen short. Achieving circular economic development in the region will necessitate more transparent and accountable institutions (Schröder et al., 2020).

The informal Sector

The literature review previously identified the informal sector as a barrier to the efficient implementation of circular economy practices, often pointing to the challenges of formalizing these activities to ensure regulatory compliance and improve efficiency. However, while these challenges are real, this study takes a different perspective by highlighting the crucial role that the informal sector plays in municipal waste management and recycling in Latin America. Rather than viewing the informal sector solely as an obstacle to be overcome, it is essential to recognize the significant contributions of informal workers—particularly waste pickers—who are fundamental to the collection and recycling of materials across the region.

In Latin America, the informal sector, encompassing a wide array of economic activities outside formal systems, plays a pivotal role in municipal waste management and recycling efforts. This sector's contribution is particularly pronounced in the sorting and recycling sector, where informal workers, often referred to as waste pickers, are fundamental to the collection of recyclable materials in many cities across the region. Their integration into waste management schemes is increasingly recognized as crucial for fostering just, inclusive, and livable urban environments in LAC. Despite this, as nations and urban areas aim to modernize and streamline waste management processes, there's a looming risk of further marginalizing these essential workers (Schröder et al., 2020).

Highlighting the integral role of informal workers, Circle Economy (2023) reports that they constitute about half of the region's employment, primarily driving waste management and recycling activities. Yet, their substantial contributions to circular practices—reducing, reusing, and recycling materials—are not formally recognized within official waste management frameworks. This oversight complicates the task of gauging their impact on enhancing circularity and sustainability across LAC. Informal recycling, repair, and upcycling activities, critical to the region's economy, remain largely invisible in policy-making and economic planning, underscoring a broader challenge of integrating these workers into formal systems while acknowledging their

contributions to environmental sustainability and resource efficiency.

Schröder et al. (2020) illustrates that efforts to address this challenge and foster inclusion have been noted in various contexts. For instance, the term 'waste picker' gained formal recognition at the First World Conference of Waste Pickers in Bogotá in 2008. Following this, Bogotá's mayor in 2013 introduced a formal payment system for waste pickers, compensating them for their services in collecting and transporting recyclable materials—a significant step towards formalizing their role in waste management, this would allow 790 waste pickers and their families to potentially double or even triple their usual income (WIEGO, n.d.). Similarly, countries like Chile and Brazil have initiated efforts to incorporate informal waste pickers into new waste management frameworks, acknowledging their importance in the ecosystem. International projects, such as the EcoVecindarios project led by the Bolivian branch of Swisscontact, have supported the inclusion of waste pickers into the solid waste management system of Cochabamba, with subsequent extensions to other cities including El Alto, La Paz, and Santa Cruz. This initiative has contributed to the collection of 24,000 tons of recyclable solid waste and 603 tons of electrical and electronic equipment waste (BEAM Exchange, 2019). These examples illuminate a growing recognition of the need to integrate informal sector workers into formal waste management systems, ensuring their contributions are valued and their livelihoods protected as the region transitions towards a circular economy.

4.2 Adaptation Scenarios

This section outlines adaptation scenarios for the C-TIS (LA) framework. Potential scenarios for integrating Latin American aspects will be presented and then the most appropriate scenario for these adaptations will be decided.

Scenario 1: New Separate Environment

This scenario addresses situations where the environment's unique dynamics, characteristics, and challenges necessitate operating beyond the C-TIS framework's original application. It involves significant adjustments or a complete redesign of its components to cater to this distinct setting. Adapting the framework to a new separate environment allows for a deep understanding of unique factors, facilitating the creation of effective strategies. The aim is to leverage opportunities and address challenges specific to this environment, enhancing the framework's applicability to diverse contexts of circular innovation diffusion.

Scenario 2: Changes in the Framework's Context

In this scenario, the focus is on how an aspect influences the broader context within which the C-TIS framework operates, without constituting a separate environment. This requires adjustments within the framework to reflect the aspect's impact on its overall context. The core components of the framework are retained but are modified to ensure their effectiveness in the changed context. This scenario emphasizes the need for the framework to remain flexible and responsive to new dynamics, ensuring that it can effectively identify barriers to innovation diffusion within its adapted context.

Figure 7: Scenario 1

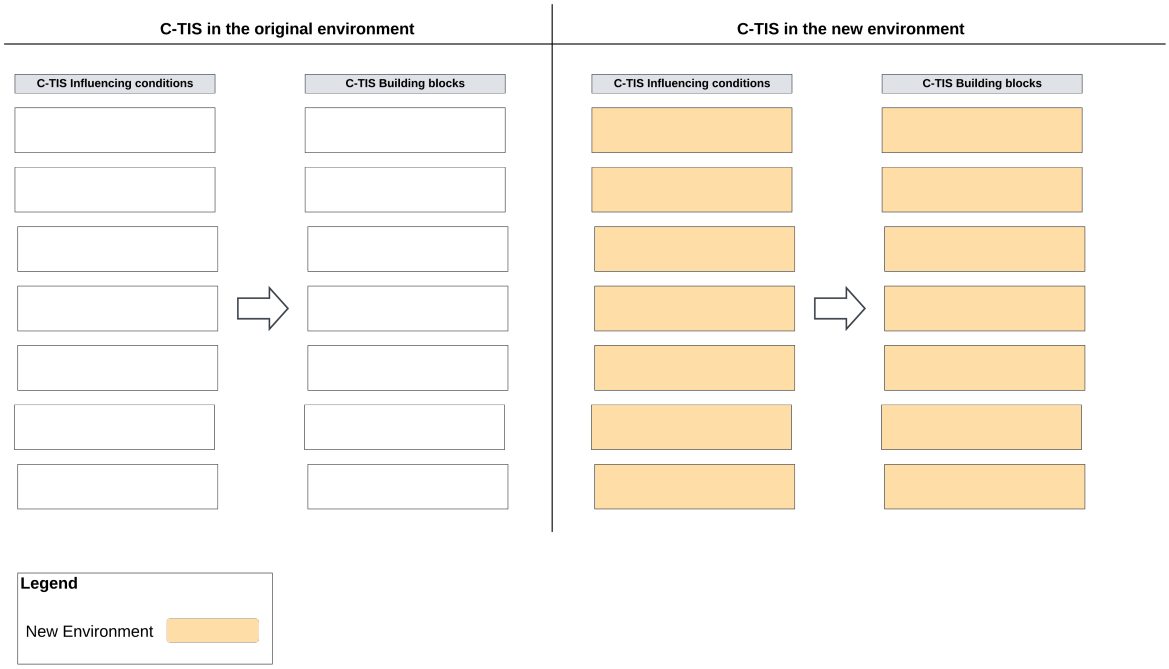
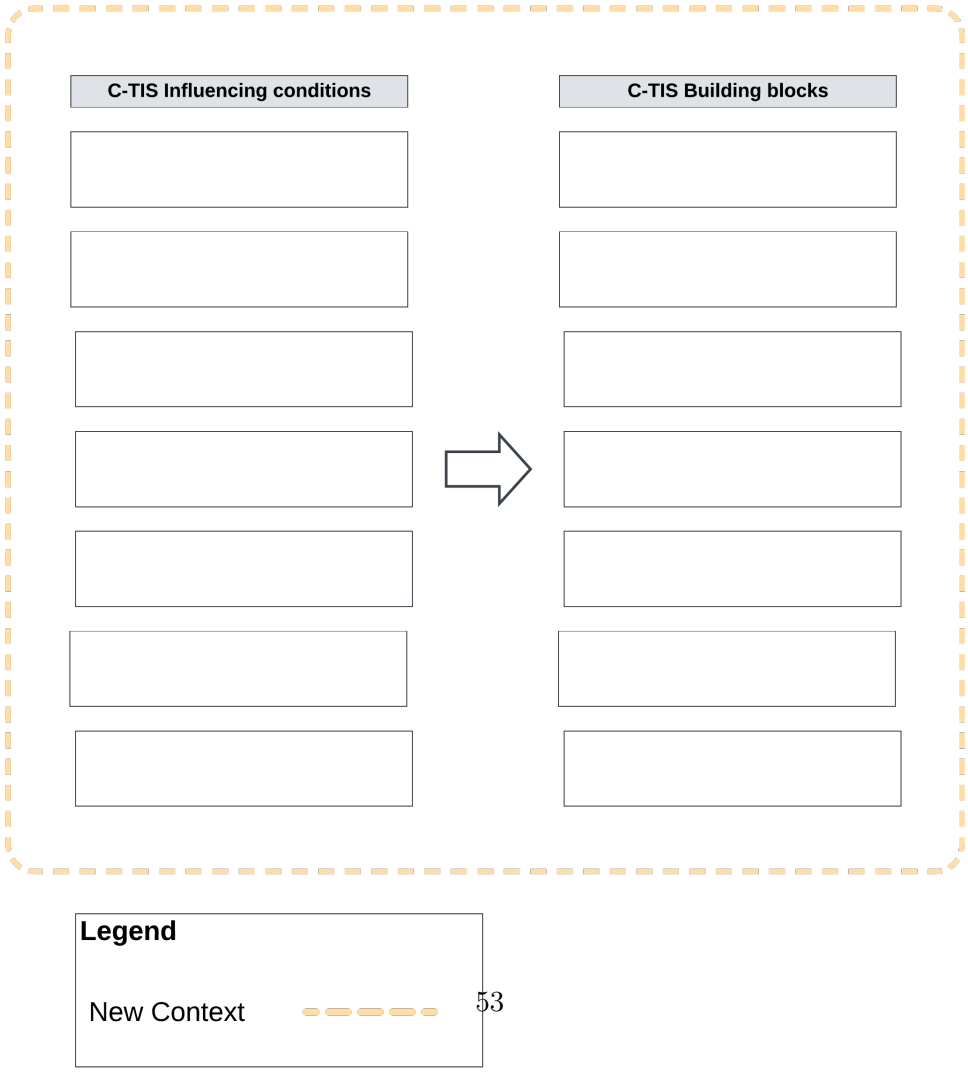


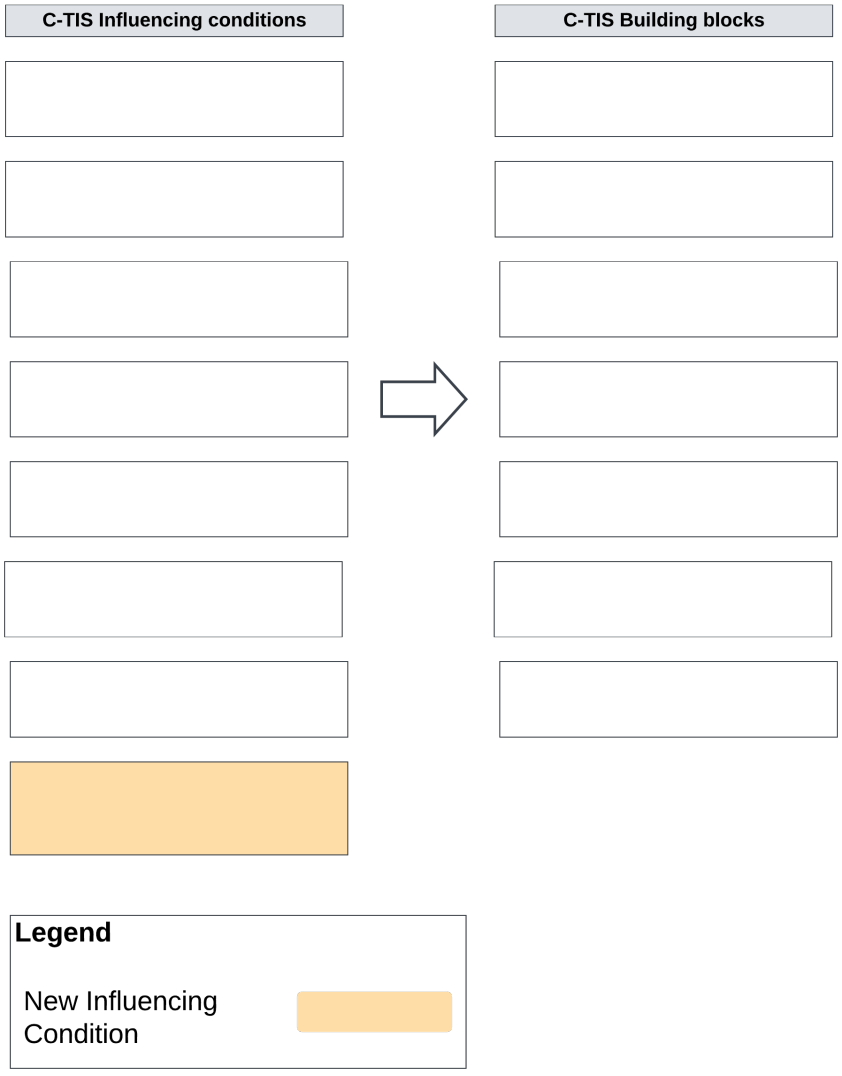
Figure 8: Scenario 2



Scenario 3: New Influencing Condition

Identifying an aspect as a new influencing condition emphasizes its role as a fundamental component that shapes the development and effectiveness of the C-TIS framework's building blocks. This scenario highlights the direct integration of the aspect into the framework, enriching its analysis of barriers to circular innovation diffusion. By understanding how this new influencing condition affects the framework, stakeholders can develop nuanced strategies that address specific challenges, making the framework more adaptable and relevant.

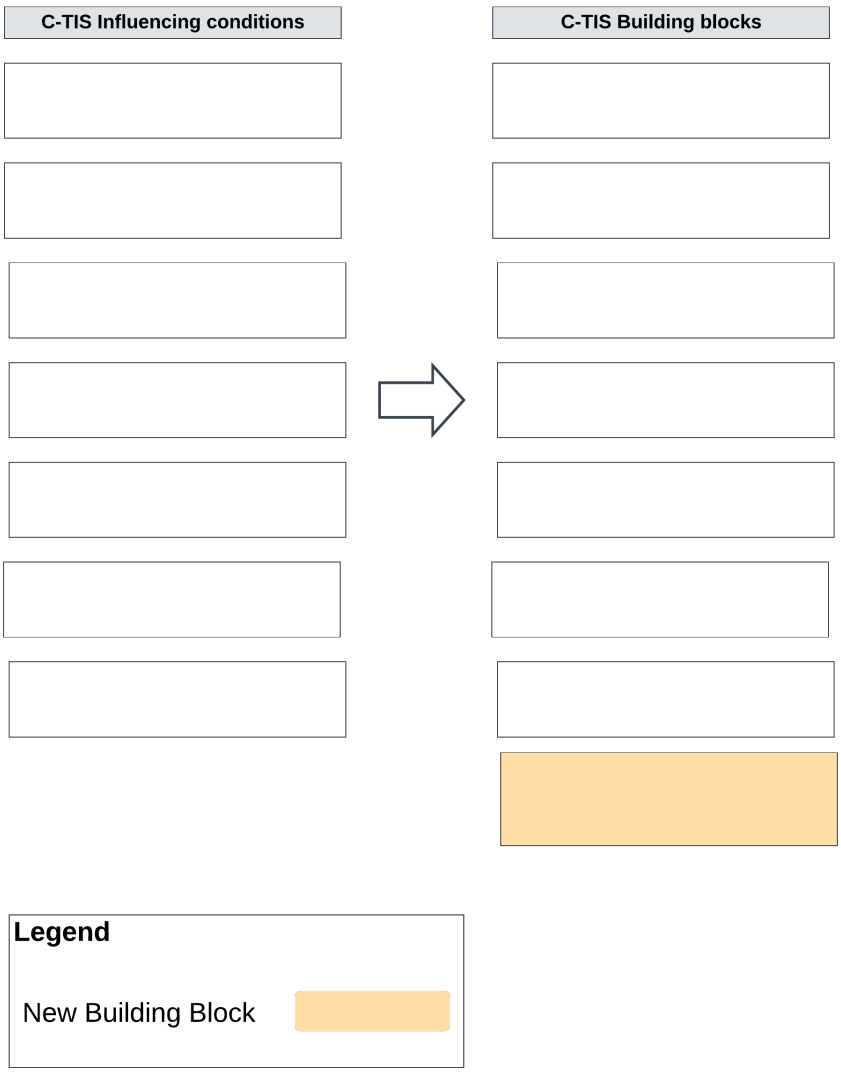
Figure 9: Scenario 3



Scenario 4: New Building Block

Incorporating an aspect as a new building block signifies its essential role in the framework's functionality and its contribution to the diffusion of circular innovations. This scenario involves reevaluating the C-TIS framework to ensure that it includes critical components necessary for overcoming barriers to innovation diffusion. It underscores the need to integrate new aspects effectively, ensuring they contribute to the framework's objectives and enhance its capacity to facilitate the large-scale adoption of circular innovations.

Figure 10: Scenario 4



Upon careful consideration of each Latin American characteristic presented and its potential influence on the framework, the broad contextual challenges of the region were identified for analysis. Following this, two specific aspects were selected for further detailed exploration: the informal sector and geopolitical dynamics. This analysis aims to discern the most fitting adaptations for the C-TIS (LA) framework, thereby ensuring its efficacy and relevance in addressing the unique dynamics of Latin America.

Latin American Contextual Challenges

After evaluating the adaptation scenarios for their applicability to Latin America's characteristics, Scenario 2 was found to be particularly fitting and was therefore chosen for integrating the broad contextual challenges of the region into the C-TIS (LA) framework. This scenario recognizes that while the core components of the framework remain relevant, they must be adapted to address the unique and pervasive challenges of the region. Importantly, it acknowledges that not all of the original TIS framework's assumptions are met in the Latin American context. These unmet assumptions necessitate significant adjustments to the framework. The specific challenges include:

- Underdeveloped Infrastructure: Many regions suffer from underdeveloped transport systems, uneven communication networks, and inadequate waste management facilities. These deficiencies impede the efficient movement of goods, information, and proper waste disposal necessary for circular economy activities, diverging from the original TIS assumption of reliable and comprehensive infrastructure.
- Legal and Administrative Inefficiency: Legal systems in Latin America can be inconsistent and plagued by bureaucratic inefficiencies and corruption. These issues create barriers to business operations and innovation diffusion, challenging the original TIS assumption of robust and efficient legal and administrative systems.
- Informality: A significant portion of economic activities is conducted informally, particularly in areas like recycling and waste management. These activities often operate outside the formal regulatory framework, which is not adequately captured in the original TIS assumptions that presume formal and regulated economic activities.
- Recurrent Socio-Political Instability: Many Latin American countries experience periodic and unpredictable changes in political and social environments, including frequent shifts in government policies, economic volatility, and periods of civil unrest. This instability challenges the original TIS assumption of a stable socio-political environment.

By addressing these contextual challenges through Scenario 2, the framework can be adapted to better reflect the realities of the Latin American environment. This scenario sets the stage for more specific adaptations that will be explored in subsequent scenarios. The adjustments made under Scenario 2 provide a foundational understanding of the broader context, which informs the integration of new building blocks and influencing conditions.

The Informal Sector

Building on the contextual analysis provided by Scenario 2, it was decided to further integrate the informal sector into the C-TIS (LA) framework using Scenario 4. This decision is rooted in recognizing the informal sector's central role within the circular innovation ecosystem, underscoring its critical impact on the diffusion of circular innovations.

Initially, there was consideration to include the informal sector as extensions of already established building blocks, such as waste management, competition, and complementary products and services. However, given its substantial influence and relevance in the circular system, it became evident that treating the informal sector merely as an addition to existing components would not sufficiently capture its importance. The informal sector's integral role in recycling, waste management, and the provision of essential services marks it as a pivotal force in advancing circular economic practices.

Therefore, integrating the informal sector as a new building block reflects a strategic enhancement of the C-TIS framework. This approach ensures a comprehensive analysis of how the informal sector contributes to and influences circular economic practices. It is a recognition of the need to leverage the informal sector's potential while addressing barriers to the widespread adoption of circular innovations, facilitating a transition towards more inclusive and sustainable circular economies in Latin America. The decision to adopt Scenario 4 emphasizes the importance of incorporating the informal sector's insights into the C-TIS (LA) framework, ensuring that strategies are effectively aligned with the realities of circular innovation within the region.

Transportation and Digital Infrastructure

Following the contextual analysis provided by Scenario 2, it was decided to further integrate transportation and communication infrastructure into the C-TIS (LA) framework using Scenario 3. Additionally, the data infrastructure adapted from the circular analysis is incorporated within this new influencing condition, emphasizing its crucial role in the system. This decision highlights the significant impact of these infrastructures on circular innovation in Latin America.

Initially, transportation and communication infrastructures were considered merely as contextual elements. However, insights from the first case study underscored their critical influence on the formation and completeness of building blocks within the circular innovation system. The state of transportation and communication infrastructures, coupled with the need for robust data infrastructure, creates conditions that significantly affect the effectiveness and efficiency of circular innovations.

Incorporating these elements as a part of a new influencing condition allows for a more targeted examination of how infrastructural challenges shape the circular innovation system. This approach ensures the development of contextually appropriate strategies that are responsive to the unique challenges faced in Latin America.

By adopting Scenario 3, the C-TIS (LA) framework gains a nuanced tool for navigating infrastructural limitations, ensuring strategies are both effective and resilient. The new influencing condition, "Transportation and Digital Infrastructure," reflects a strategic enhancement, enabling a comprehensive analysis and addressing the underlying causes that impact the widespread adoption of circular innovations.

Geopolitical Aspects

Similarly, it was decided to further integrate the geopolitical aspects into the C-TIS (LA) framework using Scenario 3, recognizing these factors as a new influencing condition within the C-TIS (LA) framework. This decision acknowledges the substantial and pervasive impact of geopolitical dynamics on the region's circular innovation system. Given that political instability, policy shifts, and regional relationships are prevalent and often expected conditions within Latin America, they distinctly shape the environment for circular innovations.

The integration of geopolitical aspects as a standalone influencing condition, rather than merely extending existing conditions like 'Accidents and Events,' underlines their critical role. This is because geopolitical aspects are deeply ingrained in the region's context, continuously influencing circular economy efforts beyond occasional or external events. Their presence and impact are far-reaching, affecting multiple building blocks of the circular innovation system.

Choosing Scenario 3 allows for a focused examination of how geopolitical realities specifically influence the foundational elements of the circular innovation system, enabling the development of more targeted and contextually appropriate strategies. This approach ensures that the C-TIS (LA) framework remains responsive and adaptable to the unique challenges and opportunities presented by the geopolitical landscape in Latin America. By treating these aspects as a new influencing condition, the framework gains a nuanced tool for navigating the complex interplay between politics and innovation, ensuring strategies are not only effective but also resilient in the face of political and economic fluctuations.

Other Latin American Characteristics

Beyond the informal sector and geopolitical aspects, the other significant characteristics of Latin America have been assessed to fit within the existing components of the C-TIS framework. This alignment ensures that these aspects are adequately considered without necessitating the introduction of new building blocks or influencing conditions.

- Socio-Economic Disparities: The region's high income inequality and significant pockets of poverty are integrated under the influencing condition of Macro-economic and Strategic aspects. This placement recognizes the profound effect of socio-economic factors on the circular innovation landscape, influencing strategic decisions and macroeconomic policies relevant to circular economy initiatives.
- Infrastructure Challenges: As previously discussed in Scenario 2, the deficiencies in waste management infrastructure, underdeveloped transport systems, and uneven communication networks are recognized as part of the broader contextual challenges. Additionally, the deficiencies in waste management infrastructure are aligned with the existing building block of "Reverse Logistics," emphasizing the critical need for improving systems for the collection, recycling, and disposal of materials. Similarly, the lack of financial infrastructure is addressed under the influencing condition of Natural, Human, and Financial Resources, highlighting the importance of financial support and resources in facilitating circular economy practices.
- Consumer Behavior and Knowledge: The considerations related to consumer attitudes, awareness, and behavior towards circular innovations are incorporated into the "Customer" building block. This inclusion reflects the importance of understanding and influencing consumer preferences and behaviors to promote the adoption of circular products and services.
- Systemic Challenges: Various systemic challenges in Latin America, including policy inefficiencies, high bureaucracy, and corruption, are recognized as part of the broader contextual challenges addressed by Scenario 2. Policy inefficiencies are considered under the influencing condition "Environmental and Strategic Aspects," addressing the need for more effective and supportive policy frameworks for circular innovations.

The decision to address these Latin American characteristics without creating additional elements was driven by an evaluation to determine if they warranted inclusion under Scenarios 3 and 4. Ultimately, it was determined that these aspects are appropriately addressed by existing influencing conditions, building blocks, and/or the context of Scenario 2. This approach ensures a comprehensive and coherent framework that is capable of accommodating the complexities of the region while leveraging existing structures to address identified challenges and opportunities effectively.

Overall, the adaptation of the circular TIS framework (C-TIS) to the Latin American context (C-TIS (LA)) emerged from a combination of Scenarios 2, 3, and 4. This adaptation involved recognizing and integrating the unique challenges of Latin America as a new contextual layer, which diverges from the original TIS framework's assumptions. Additionally, this process included the incorporation of the new building block of the "Informal Sector" and the new influencing condition of "Geopolitical Aspects." These changes ensure that the adapted framework effectively addresses the distinctive dynamics and barriers to circular innovation in the Latin American context, providing a robust structure for fostering sustainable development in the region.

4.3 C-TIS (LA)

In this section, the completed C-TIS (LA) framework is presented. This framework results from the integration of adaptations on circularity with the specific context of Latin America, as discussed in the previous sections. The C-TIS (LA) framework effectively addresses the unique challenges and opportunities for circular innovation in the region. Next, the components of the framework will be outlined and explained in detail.

Building Block 1: Product Performance and Quality

- Circular Design: It involves creating products intended for reuse, repair, or recycling at the end of their life cycle (Shankar, 2023). It emphasizes the use of durable materials, designs that facilitate disassembly, and ease of repair. This approach is critical in minimizing waste and enhancing resource efficiency throughout the product's life cycle.
- Perceived Performance and Quality: In circular innovation, it focuses on ensuring that circular products are competitive in quality and performance with traditional products (Engelen, 2023). It involves understanding and addressing consumer preferences, highlighting the environmental and economic benefits of circular products. The goal is to ensure that circular products are perceived as being of equal or superior quality compared to their non-circular counterparts.
- Circular Product Service System (CPSS): This concept integrates products and services in a manner that maximizes customer value while ensuring environmental and economic efficiency (Warns, 2023). Key strategies within CPSS include enhancing operational efficiency, extending product longevity, intensifying product usage, and substituting traditional product systems with more sustainable alternatives. CPSS is integral to minimizing environmental impact and optimizing resource use in circular innovation.

Building Block 2: Product Price

- Economic Viability: It underscores the importance of considering the long-term financial feasibility of circular innovations (Shankar, 2023). This encompasses not just the initial cost of production but also factors like development costs, financing availability, and market demand. It is critical for ensuring that circular innovations are not only environmentally sustainable but also economically viable in the long term.
- Price Transparency: involves understanding the 'True Price' of products and services in CI (Warns, 2023). This concept includes negative externalities, such as economic, social, and environmental impacts. Acknowledging these aspects helps build customer trust and promotes an informed understanding of the environmental and social implications of their purchases.
- Competitive Pricing: is crucial in ensuring that circular products are competitively priced compared to traditional, linearly produced products (Engelen, 2023). While circular products might involve higher costs in some aspects, new business models in CI, such as sharing platforms or product-service systems, can offset these costs, making circular products more accessible and reducing the relative price for consumers.

Building Block 3: Circular Production System

- 3R(s) Capabilities: It emphasizes the importance of the 3R(s) - reduce, reuse, and recycle. Companies with strong capabilities in at least the 3R(s) can effectively minimize waste and

maximize resource value, contributing to sustainable circular practices. Although extensive literature mentions a multitude of R-related concepts, the adoption of a more extensive set of Rs often leads to complexity and confusion, particularly in non-industrialized contexts. In Latin America, a focus on the essential 3Rs is more practical and aligned with the region's socio-economic environment (Pablo Paño Yáñez, 2021).

- Scalability: It involves the capacity to produce large quantities of products efficiently, aligning with environmental, logistical, and economic efficiency (Warns, 2023). The system's performance is benchmarked against single-use alternatives, and its success is tied to its ability to scale while maintaining its circularity principles.

- Flexibility and Adaptability: It highlights the importance of a production system's ability to adapt to new technologies and market conditions (Shankar, 2023). Businesses that demonstrate flexibility and adaptability are better positioned to adopt and sustain circular practices over time, thereby remaining competitive and responsive to the evolving demands of circular innovation. Flexibility in production systems also enables companies to navigate the challenges and opportunities presented by circularity, such as material sourcing, manufacturing processes, and product lifecycle management.

Building Block 4: Complementary Products and Services

- Collaborative Ecosystem: This aspect emphasizes the necessity for collaboration between different industries and sectors to share knowledge, resources, and develop innovative circular solutions (Shankar, 2023). It is vital to establish a supportive ecosystem of products and services, encompassing infrastructure and network support for effective circular innovation. Collaboration fosters the creation and accessibility of circular products and services in the market.

- Proximity Optimization: The importance of proximity in the context of complementary products and services is highlighted due to the need for efficient reverse logistics (Warns, 2023). The environmental impact of transport distances in logistics can significantly affect the environmental performance of circular solutions. Ensuring that complementary services and products are in close proximity is crucial to mitigate environmental impact and support the diffusion of circular practices.

- Lifecycle Services: The requirement for comprehensive services throughout the product lifecycle, from development to recycling, is essential (Engelen, 2023). The complexity of circular supply chains necessitates a broad range of services to maximize resource utilization efficiency and manage the end-of-life of products effectively. The lack of available, compatible, or affordable complementary products and services can significantly hinder large-scale diffusion of circular innovations .

Building Block 5: Network Formation and Coordination

- Strong Network: Essential for circular economy, involving robust collaboration among manufacturers, suppliers, and distributors to ensure the availability and accessibility of circular products and services (Shankar, 2023). It facilitates knowledge sharing and the development of new solutions.

- Interconnected Network: Focuses on the network's complexity in the circular economy, emphasizing the importance of local connectedness, bidirectional connections for reverse streams, and proximity of service providers (Warns, 2023). It's crucial for efficiently managing reverse logistics and effective resource circulation.

- Clear Roles and Shared Goals: Highlights the necessity of well-defined roles and coordinated actions among actors involved in developing, producing, distributing, and managing circular products (Engelen, 2023). Coordination, which can be informal or formal, involves collaboration and a shared vision. The absence of adequate actor types and coordination can significantly impede the adoption of circular innovations.

Building Block 6: Customers

- Customer Awareness and Engagement: Emphasizes the importance of increasing customer awareness and knowledge about the circular economy and its benefits (Shankar, 2023). This is vital for creating demand for circular products and services and overcoming barriers to their adoption. Educating customers about the advantages and processes of circularity can lead to more informed choices and a shift in consumer behavior towards sustainability.

- Willingness to Pay and Use: Highlights the necessity for customers to recognize the value of circular innovations and be willing to pay for and use them (Warns, 2023). This aspect is crucial in circular innovation, where the product's convenience, competitive pricing, and strong environmental claims play a significant role in influencing customer decisions. The willingness to pay and use is a key factor in determining the success and widespread adoption of circular innovations. This is especially relevant in the Latin American context, where consumers' readiness to pay additional costs for sustainable products is often constrained by immediate economic pressures. In many Latin American countries, the urgency of financial stability, and realities may lead to prioritizing short-term economic needs over the long-term benefits of sustainability, influencing spending behaviors on circular innovations (Andrea Cantú et al., 2021).

- Customer Integration: Focuses on the integration of customers in the circular economy, not just as end-users but as active participants (Engelen, 2023). This involves ensuring that customers use products properly, do not misuse them, and dispose of them appropriately at the end of their useful life. Proper customer integration helps close resource loops and is essential for the overall success of circular innovation.

Building Block 7: Innovation-specific Institutions

- Regulatory Alignment and Stability: It focuses on the alignment of regulatory frameworks, environmental laws, waste disposal regulations, and overall legal systems with circular economy principles (Shankar, 2023). Stability in these institutions is vital for facilitating the diffusion of circular innovations. The absence or misalignment of supportive regulations creates significant barriers, emphasizing the need for regulatory frameworks that favor sustainable and circular innovations (Warns, 2023).

- Standardization and Legitimacy: Addresses the need for standardizing circular products and services and their indicators (Shankar, 2023). This ensures compatibility among various circular solutions, facilitating their recycling or reuse. It also covers the role of institutions in creating legitimacy for circular innovations, which involves intervening in areas like material pricing, infrastructure development, and public education to support circularity (Engelen, 2023).

- Supportive Policy Infrastructure: Focuses on the development of robust policies that support the circular economy, including subsidies for circular businesses and initiatives (Shankar, 2023). It highlights the need for emerging robust policies that create a supportive environment for circular innovation and help overcome barriers to adoption.

Building Block 8: Reverse Logistics

- Collection and Inspection: It focuses on the initial stages of handling returned or end-of-life products (Engelen, 2023). It involves the collection of products from end-users and transporting them to a central location, such as a retailer collection center or a drop-off point. The critical aspect here is the inspection process, where products are assessed based on their performance and appearance. This stage determines the eligibility of products for return and aims to filter out unwanted items, ensuring only suitable products enter the RL process. Effective collection and inspection are crucial for maintaining the efficiency and integrity of the reverse logistics system.

- Product Recovery Management: It encompasses various activities associated with the handling of products after collection and inspection (Engelen, 2023). It includes the sorting of products for different forms of recovery management like reuse, repair, upgrade, remanufacturing, or disposal processes. The decisions made during this stage are vital for achieving optimal value recovery and minimizing costs. Product recovery management is a complex process due to the potential variability in the quantity and quality of returned products, making it a labor-intensive activity compared to standard manufacturing processes. Efficient management of this stage is essential for the overall effectiveness of the reverse logistics system.

- Waste Management: It deals with the management of products that are not suitable for direct reuse or recovery. This stage involves processes like disposal, landfilling, and incineration (Engelen, 2023). Effective waste management within RL is crucial for minimizing the environmental impact and ensuring that materials are disposed of in an environmentally responsible manner. This subblock is an integral part of the RL system, as it handles the final stage of the product life cycle, ensuring that waste is managed efficiently and sustainably.

Building Block 9: Informal Sector

- Informal Waste Management: This sub-block acknowledges the comprehensive role of the informal sector in waste management, encompassing a wide array of activities beyond collecting, sorting, and recycling. It stresses the critical need to recognize the contributions of all individuals and groups within the informal sector to circular economy practices, whether or not there is a direct engagement with them. This recognition is vital for understanding the full landscape of waste management and its implications for circular innovation. Actively engaging with informal sector participants can significantly enhance resource recovery and streamline waste management processes. Equally important, however, is acknowledging the sector's impact passively; understanding that even in the absence of direct collaboration, the informal sector's activities profoundly influence the circular innovation system's waste management dynamics. This dual approach ensures a holistic strategy that leverages the strengths of the informal sector while addressing potential challenges it presents to circular innovations.

- Informal Competition: Highlights the informal sector's competitive and complementary presence within the market. It underscores the necessity of understanding informal market dynamics to develop strategies that ensure formal circular innovations are competitive. This sub-block points to the need for both recognizing the presence of informal competitors and designing circular products and services that are adaptable and appealing to a diverse consumer base.

- Informal Complementary Products and Services: Focuses on the informal sector's role in offering products and services that either complement or supplement formal circular innovation efforts. It advocates for the active incorporation of informal contributions into circular processes and acknowledges their existence at various lifecycle stages of circular products and services. This approach seeks to uncover new value chains and enhance sustainability through a comprehensive integration of informal sector activities into formal circular innovation strategies.

Influencing Condition 1: Knowledge and Awareness of Technology

- Circular Technological Knowledge: It emphasizes the necessity of both fundamental and applied technological knowledge in the context of circular innovation (Engelen, 2023). Fundamental knowledge pertains to understanding the technological principles involved in various components of the Technological Innovation System (TIS), such as product development, production processes, and the integration of complementary products and services. Applied technological knowledge is crucial for the actual development, production, repair, maintenance, and enhancement of these components. A lack of knowledge and awareness in these areas can significantly impede the formation of various TIS building blocks, as it affects the ability of actors to effectively implement circular economy principles and technologies in their operations.
- Circular Innovation Demonstration: It underscores the importance of large-scale demonstration projects in fostering the adoption of circular practices (Shankar, 2023).Such projects serve as impactful examples that encourage and speed up the implementation of circularity through different sectors. They are instrumental in overcoming challenges such as skepticism about the effectiveness of circular solutions and insufficient understanding of the advantages of circularity. Demonstrations on a large scale can effectively illustrate the practical application and benefits of circular practices, thus encouraging broader adoption and understanding of the principles and potential impact of circular innovation.

Influencing Condition 2: Knowledge and Awareness of Application and Market

- Market Structure and Dynamics: It focuses on the need for comprehensive understanding of the market structure and dynamics in the context of circular economy (Warns, 2023). Awareness of how the innovation can be applied and insight into the market dynamics, along with the involvement of relevant social stakeholders, is critical for establishing networks. The complexity of networks in circular and reuse innovations makes this knowledge even more crucial. A lack of awareness about the market structure and the inability to identify the roles of different social actors hampers the formation of effective networks, impeding large-scale diffusion of circular innovations. Understanding market dynamics also involves recognizing the interplay of factors like competition, customer preferences, and supply-demand relationships, which are pivotal for the successful implementation and growth of circular practices.
- Return Predictability: It highlights the importance of predictability in the returns on investment for circular businesses (Shankar, 2023). Given the innovative characteristics of circular products and services, market demand can be uncertain, posing challenges in attracting investors and securing financing. It is vital for circular businesses to evaluate and articulate the long-term economic viability of their innovations, ensuring that they can attract necessary financial resources for sustainable operation and growth. Achieving predictability in returns involves understanding market trends, customer preferences, and aligning business models with these insights to create more stable and predictable revenue streams.

- Information Symmetry: It underscores the significance of balanced information flow between different parties involved in circular economy transactions (Shankar, 2023). Asymmetric information, where one party possesses more information than the other, can be a substantial barrier to the adoption of circular practices. Ensuring that consumers and other stakeholders have access to accurate and comprehensive information about the benefits and characteristics of circular products and services is critical. This symmetry in information helps in building trust, reducing uncertainty, and encouraging the adoption of circular practices by alleviating misconceptions about the quality and performance of circular products.

Influencing Condition 3: Natural, Human and Financial Resources

- Resource Availability: It focuses on the necessity of having readily accessible natural, human and financial resources for circular innovation (Engelen, 2023). It is specially important resources like raw and secondary materials that can be acquired individually by organizations or through associations. The availability of these resources, especially high-quality secondary materials, is fundamental to facilitate a circular economy. Current production systems often face challenges in manufacturing sufficient circular products due to a lack of these materials. Therefore, ensuring the availability of resources is essential for effectively implementing circular practices.

- Resource Flow Optimization: It is about the efficient utilization of resources at every stage of the product life cycle (Shankar, 2023). This encompasses all types of resources, including materials and financial resources. Optimizing resource flow is crucial in circular innovation to minimize waste generation and maximize resource efficiency. By effectively managing resource flows, circular initiatives can significantly contribute to a more sustainable and resource-efficient economy.

- Human Resources Development: It pertains to equipping individuals with the necessary knowledge and competencies for circular innovation (Engelen, 2023). This may involve various educational programs, courses, and on-the-job training. The rise in labor demand, particularly for skills in repair and sustainable practices, is a direct consequence of the transition towards a circular economy. Therefore, investing in human resource development is essential for organizations to adapt to this transition, especially as the market structure evolves and new skill sets become increasingly valuable.

Influencing Condition 4: Competition

- Market Positioning: To ensure the success of circular products and services, it's crucial to strategically position them within the market (Shankar, 2023). This strategy involves gaining deep insights into the desires of the target audience, developing a compelling value proposition, and effectively communicating the unique advantages of adopting circularity. Proper market positioning helps circular businesses to differentiate their offerings and appeal to their intended audience, thereby gaining a competitive edge in the market.

- Conventional Competition: Circular businesses often face stiff competition from traditional businesses that have not yet adopted circular practices(Shankar, 2023). This competition can pose significant challenges in gaining market share and achieving profitability. Circular businesses need to navigate this landscape by highlighting the distinct advantages of their circular products and services, including environmental benefits and sustainable practices, to stand out in a predominantly linear market (Shankar, 2023).

- Circular Competition: In addition to competing with traditional products, circular businesses also contend with other circular offerings (Engelen, 2023). This form of competition involves differentiating between various circular solutions, each utilizing new technologies, components, and production systems. The challenge here is to effectively position and market circular solutions amidst a diverse range of circular options, ensuring they meet customer needs and preferences. This competition is influenced by factors like the availability of secondary resources, with innovation systems focusing on different aspects of circularity, such as recycling or product lifespan extension.

Influencing Condition 5: Macro-economic and Strategic Aspects

- Systemic Economic Integration: The circular economy, being a complex system, requires a systemic perspective for success (Shankar, 2023). This perspective acknowledges the interconnections of various actors and factors within the economy and emphasizes the need for collaboration and cooperation to effectively implement circular principles. A systemic approach considers the broader economic and ecological implications of circular practices, fostering a holistic understanding of how individual actions impact the larger system.

- Economic Conditions: The overall economic conditions, including factors like economic growth, recessions, income inequality, and poverty levels, significantly influence the development and adoption of circular innovations (Shankar, 2023). Economic growth periods can provide favorable conditions for investment and innovation in circular practices, while economic downturns or recessions can pose challenges in securing necessary financing. Moreover, issues such as income disparity and the prevalence of poverty are critical factors that shape market readiness and consumer capacity to engage with circular economy solutions. This highlights the importance of understanding and adapting to these multifaceted economic realities to ensure the viability and success of circular initiatives (Shankar, 2023).

Influencing Condition 6: Socio-cultural Aspects

- Norms and Values Alignment: The alignment of norms and values with the principles of the circular economy is essential (Warns, 2023). This includes fostering environmental wins, social wins, and economic wins among supply chain actors and customers. If these circular economy norms and values are not adequately integrated into the socio-cultural context, the formation of the Technological Innovation System (TIS) is hindered. The socio-cultural aspects encompass norms, values, methods, habits, and behaviors that are less formalized than laws and regulations but are crucial in shaping the transition towards a circular economy.

- Cultural Preferences and Resistance: Cultural preferences for traditional ownership models and resistance to change pose significant barriers to circular innovation (Shankar, 2023). Overcoming these challenges requires addressing restricted consumer awareness, minimal engagement, and reluctance to alter established consumer habits and business practices. This involves understanding and influencing cultural aspects, such as values, mindsets, behaviors, capabilities, and competencies, to foster a CE-oriented culture.

- Societal Awareness and Perception: It plays a pivotal role in the adoption of circular practices. It is crucial for consumers to be aware of the benefits of circularity and make informed decisions (Shankar, 2023). However, challenges exist due to the lack of information and knowledge about circularity among consumers, leading to misconceptions about the quality and performance of circular products and hindering the circular transition.

Addressing these issues is vital for enhancing customer engagement in the value chain and promoting more sustainable behaviors.

Influencing Condition 7: Accidents and Events

- Internal Factors: Internal disruptions within a company, such as manufacturing errors or product failures, can significantly impact the development and implementation of circular practices (Shankar, 2023). These internal factors can disrupt production and supply chains, challenging the company's ability to adopt circular practices effectively. Addressing these internal factors is crucial for maintaining the integrity of circular innovation processes.
- External Factors: Events external to the company or the Technological Innovation System (TIS), such as natural disasters, can have profound effects on circular innovation (Engelen, 2023). These external factors can disrupt supply chains and create material shortages, influencing the transition towards circularity.
- Resilience and Adaptability: The ability to recover from shocks and stresses, whether internal or external, is critical for organizations adopting circular practices (Shankar, 2023). Resilience and adaptability enable companies to withstand disruptions and continue their progress towards circular innovation. This includes the capacity to adapt to changing political circumstances, market conditions, and unforeseen events, ensuring the sustainability and success of circular innovation efforts.

Influencing Condition 8: Environmental and Strategic Aspects

- Institutional Policies: They play a pivotal role in the transition to a CE (Warns, 2023). These policies can either enable or obstruct circular and reuse innovations. The presence or absence of supportive policies significantly influences the economic choices of organizations, shaping the overall landscape for CE innovations. Institutional policies, including laws and regulations, determine the framework within which circular practices can develop and thrive.
- Governmental Support: It is crucial for stimulating and sustaining CE innovations, manifesting through various mechanisms such as public policies, subsidies, and directives (Warns, 2023). Governments play a key role in creating a conducive environment for circular practices by offering financial and regulatory backing. This support can range from providing funding for research and development to establishing legal frameworks that favor circular and sustainable practices over traditional linear models.
- Strategic Sustainability Vision: A strategic vision focused on sustainability is essential for driving the circular transition (Warns, 2023). This vision should encompass a long-term perspective, incorporating environmental considerations into national and international strategies. The alignment of macroeconomic developments with strategic policies for key industries, emphasizing environmental sustainability, is critical for fostering niche development, scaling circular innovations, and ensuring effective network formation within the CE.

Influencing Condition 9: Transportation and Digital Infrastructure

- Transportation Infrastructure: It focuses on the development, maintenance, and efficiency of transportation networks, including roads, railways, ports, and urban transport systems. It addresses the challenges posed by geographic and logistical factors, which impact the

ability to efficiently transport goods and resources. Effective transportation infrastructure is crucial for the smooth operation of circular economy practices, enabling the movement of raw materials, products, and waste.

- Communication Infrastructure: It deals with the availability and quality of telecommunication services, including mobile and internet access. It highlights the importance of reliable communication networks for supporting digital platforms and services that facilitate circular economy activities. Efficient communication infrastructure is essential for coordinating activities, sharing information, and engaging stakeholders in the circular economy.

- Data Infrastructure: It emphasizes the infrastructure needed for effective data management and real-time information sharing (Engelen, 2023). It includes capabilities for monitoring, tracking, and analyzing product performance and usage data. A robust data infrastructure supports data-driven technologies such as AI, IoT, and blockchain, which are crucial for optimizing manufacturing, distribution, and reverse logistics processes. Effective data infrastructure enables strategic decision-making and enhances resource efficiency in circular economy practices.

Influencing Condition 10: Geopolitical Aspects

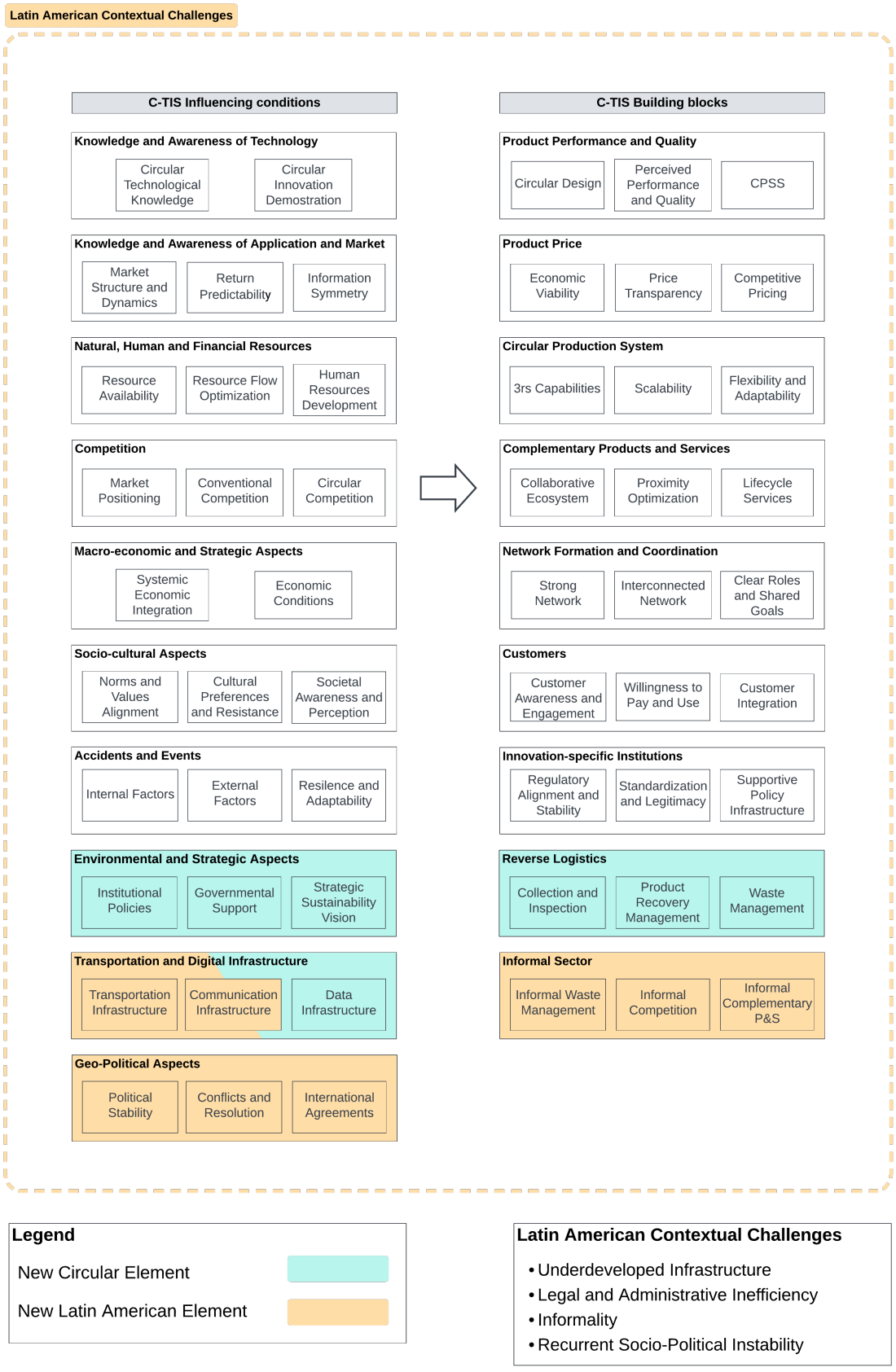
- Political Stability: Dedicated to assessing the governance and political climate's steadiness. It focuses on how the continuity and predictability of political institutions and policies support or hinder the implementation of circular innovations. Political stability is crucial for long-term planning and investment in sustainable development, creating an environment where circular economy innovations can flourish.

- Conflicts and Resolutions: Focuses on the impact of internal and external conflicts on the socioeconomic landscape, highlighting how these conflicts can disrupt the progress towards a circular economy. It examines both the presence of conflicts and the effectiveness of governmental and international efforts to resolve them. Effective conflict resolution is vital for maintaining or restoring stability, ensuring that resources and attention can be devoted to advancing circular economy goals rather than being diverted by instability or unrest.

- International Agreements: Addresses how international dynamics, shaped by relationships and treaties, influence the circular economy. It examines the role of diplomatic engagements and international cooperation in facilitating or hindering circular economy practices. It considers how positive international relationships and constructive agreements can support sustainability goals, while also acknowledging the challenges that may arise from complex international treaties and negotiations.

Figure 11 shows the graphic representation of the integrated C-TIS (LA) framework.

Figure 11: Integrated C-TIS (LA) framework



Legend

New Circular Element

New Latin American Element

Latin American Contextual Challenges

- Underdeveloped Infrastructure
- Legal and Administrative Inefficiency
- Informality
- Recurrent Socio-Political Instability

5 Framework Application

In this chapter, the newly adapted C-TIS (LA) framework will be applied through two case studies of circular innovations in Latin America. The aim is to assess the practical relevance and effectiveness of the framework in real-world scenarios. The selected case studies focus on the recycling of mining tires in Chile and organic composting in Peru, representing diverse sectors within the circular economy.

For each case study, the state of the framework's building blocks will be assessed and the corresponding influencing conditions identified. Additionally, participants' definitions and strategies of circular economy will be discussed to understand their approach and mindset towards circular practices.It is important to note that only Case 1 presented a niche strategy, while Case 2 had not implemented any niche strategies at the time of the study.

Following the individual analysis of each case study, the results will be compared to identify common themes, differences, and overarching insights. This comparative analysis aims to reveal broader trends and lessons applicable across different sectors and contexts within Latin America.

Finally, insights from expert interviews will be presented, providing additional depth and perspective on the implementation of circular economy initiatives in the region. These expert views will offer valuable context and support the findings from the case studies, enriching the overall understanding of the adapted C-TIS (LA) framework's applicability and impact.

5.1 Case Study 1: Recycling of Mining Tires in Chile

5.1.1 Background and Description

The first case study focuses on a company in Chile that recycles large-scale mining tires through a thermal process known as Pyrolysis or Thermolysis. This innovative method involves shredding the tires and heating them in an oxygen-free reactor, preventing combustion and instead melting the material. The process produces three primary products: steel, which is separated from the rubber before entering the reactor, liquid and gaseous fuels, and a special form of carbon black known as recovered Carbon Black (rCB). This rCB can replace traditional or petrochemical carbon black in various applications.

The interviewee, who blends technical and commercial responsibilities, highlighted the company's commitment to the circular economy. The company defines the circular economy as a system where waste from a production chain is reintegrated into the same chain as raw materials. This straightforward definition effectively conveys the essence of circularity, avoiding the need for lengthy explanations during meetings with clients and investors.

Founded on the principles of the circular economy, the company initially faced a relatively new concept in Chile. However, the significance of these principles has grown, largely due to new laws related to extended producer responsibility. These regulations prioritize the recycling of tires, making it not just beneficial but mandatory. This legal framework supports the company's business model and reinforces the importance of their circular practices within the local regulatory environment.

This background provides a comprehensive understanding of the company's innovative approach to recycling mining tires and its alignment with circular economy principles, setting the stage for further analysis using the C-TIS (LA) framework.

5.1.2 Building Blocks

In this case study, barriers and affected building blocks of the innovation were identified. The analysis revealed that several building blocks are either incomplete or missing, leading to specific barriers in the implementation and scaling of the circular innovation. It is important to note that the building blocks not explicitly described were considered complete by the interviewee.

B.B.3 Circular Production System

The Circular Production System block is hindered by the absence of the **Scalability** sub-block. The innovation is unable to scale without making it unviable and unprofitable, and therefore, at its current state, cannot be effectively implemented. The process for recycling mining tires through pyrolysis faces significant challenges in scaling up to larger, more efficient operations. The lack of scalable infrastructure and technology means there is no capacity to produce large quantities efficiently, which is critical for economic and environmental viability. This absence of scalability results in significant limitations in expanding operations to meet broader market demands, making it difficult to achieve the necessary production volumes for economic sustainability.

B.B.5 Network Formation and Coordination

In the case study, the Network Formation and Coordination block is incomplete because the **Interconnected Network** sub-block lacks the necessary advancement. The network for circular economy activities, including the transportation of resources and services, is underdeveloped and lacks the necessary local connectedness and bidirectional connections, crucial for efficient resource circulation and reverse logistics. While there are some existing networks, they are not fully established to support the specific needs of circular innovations. This incomplete network results in inefficiencies in the transportation and distribution of materials, making the logistics of collecting and delivering recycled materials complex and costly.

B.B.6 Customers

The Customers block is incomplete due to both the Willingness to Pay and Use and Customer Awareness and Engagement sub-blocks being insufficiently matured.

- **Willingness to Pay and Use**: In Latin America, customers are primarily driven by price rather than environmental benefits. The willingness to pay for sustainable products is limited by economic constraints, leading to a preference for cheaper alternatives. While there is a willingness to use circular products, the price must be right for customers to choose them over traditional options. This economic prioritization results in a slow adoption rate for circular products, hindering their market penetration.

- **Customer Awareness and Engagement**: The lack of customer awareness and knowledge about the circular economy and its benefits is a significant barrier. Customers often lack the information necessary to understand the advantages of circular products, which affects their confidence and willingness to engage with these innovations. This lack of awareness leads to lower demand and support for circular products, further complicating market adoption. Although some efforts are made to educate customers, they are not sufficient to make a substantial impact.

B.B.7 Innovation-specific Institutions

The Innovation-specific Institutions block is incomplete due to issues in both Regulatory Alignment and Stability and Standardization and Legitimacy sub-blocks.

- **Regulatory Alignment and Stability**: This block is incomplete due to a lack of regulatory alignment despite some regulatory stability. The absence of supportive regulations for circular economy principles creates significant barriers. Misalignment in waste regulations and the lack of supportive laws result in increased costs and complexities for companies trying to implement circular practices, as they must navigate a fragmented and often contradictory legal landscape. While some stability in regulations exists, the alignment with circular economy principles is missing, hindering broader adoption.

- **Standardization and Legitimacy**: While there are existing standards for traditional products, new circular products often lack complete standardization and legitimacy. This creates confusion and hesitancy among customers and regulatory bodies. The absence of well-defined standards and institutional recognition for new circular products results in market resistance and slower adoption rates. Some standards exist, but they are not fully established or widely accepted, making it difficult to establish legitimacy.

B.B.9 Informal Sector

The entire building block of the informal sector is not applicable in this case. Specifically, the mining tire recycling industry does not engage with the informal sector at all. Mining tires come from the formal sector, and the recycling of these tires is strictly regulated. Due to the extended producer responsibility laws in Chile, tires are considered a priority product, making their recycling mandatory. This prioritization contributes to a more formal and regulated approach to tire disposal and recycling. Consequently, the mining tire recycling industry operates through formal channels, ensuring that the disposal and recycling processes are handled in an organized and regulated manner. Even though the informal sector is crucial in waste management in Latin America, it is notably absent in this specific sector.

Table 9 shows the discussed building blocks and sub-blocks.

Table 9: Building Blocks and Barriers from Case 1

Building Block	Sub-Block	Barrier	Translated Quote
Circular Production System	Scalability	The process for recycling mining tires through pyrolysis faces significant challenges in scaling up to larger, more efficient operations.	"One of the challenges [...] in the global tire pyrolysis industry is scaling the process. [...] Pyrolysis plants are smaller, a plant of, say, 10,000 tons is already a considerable size, and it is not as efficient."

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Table 9 continued from previous page

Building Block	Sub-Block	Barrier	Translated Quote
Network Formation and Coordination	Interconnected Network	The network for circular economy activities is inefficient, lacking the necessary local connectedness and bidirectional connections crucial for efficient resource circulation and reverse logistics.	"[I]n [...] Chile, which is a very long but not very wide country, logistics involve linear routes from north to south, and that complicates things. [...] Your materials [...] are very dispersed. [...] to collect [...] materials in the south, [...] it is easier to access a region of Chile through Argentina [...] due to the geography. The Andes are very difficult to cross."
Customers	Customer Awareness and Engagement	There is a significant lack of customer awareness and understanding regarding the benefits and processes of circular economy products, leading to low confidence and engagement with these products.	"The issue with customers is partly about whether they have the knowledge or know about the product [...]. That lack of confidence significantly affects the willingness to use it. [...] Sometimes customers want to use the product, but they [already] have long-term supply contracts [...] with traditional companies."
	Willingness to Pay and Use	Consumers in Latin America prioritize cost over sustainability, showing a low willingness to pay for circular innovations unless they are cheaper than traditional products.	"[...] as long as it is cheaper than the original product. [...] in Latin America, [...] people do not move much for how clean or green the product is, it's about price."
Innovation-specific Institutions	Regulatory Alignment and Stability	The lack of alignment in regulatory frameworks and inconsistent environmental laws and waste disposal regulations significantly hinder the adoption and diffusion of circular economy innovations.	"[...] in the regulation of waste, if I have a process that generates waste, by law, that product will be considered waste and not raw material. Many laws also increase costs because they require you to treat that product as waste and hire companies specializing in transporting or mitigating it. [...] under Chilean law we still fall into the category of incineration, and by definition, we are not incineration."
	Standardization and Legitimacy	The absence of standardized norms and the struggle to gain legitimacy for new circular products, like recovered carbon black, make it challenging to achieve widespread acceptance and integration in the market.	" The original product, carbon black, has defined ASTM standards, but the recovered carbon black does not have all the standards approved. [...] [It] is [...] complex when presenting the product to a customer. I tell them [...] I have this new product similar to the old one [...], [but] they follow the old standards [...] and I have to explain that they are not the same."

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Table 9 continued from previous page

Building Block	Sub-Block	Barrier	Translated Quote
Informal Sector	Informal Waste Management, Informal Competition and Informal Complementary Products and Services	The Informal Sector building block doesn't apply in this particular case as the mining tire recycling industry operates exclusively within formal, regulated channels. Mining tires are sourced from the formal sector and their recycling is strictly regulated under Chile's extended producer responsibility laws.	"In the rubber industry, I do not see [...] informal sector involvement. [...] Mining tires, when no longer used by the mining operation, are stored in collection yards. [...] The system for tire collection is much more organized. There is a whole system in place to figure out what to do [with the tires]. It is not like they are just discarded carelessly, [...] which is why the system exists."

5.1.3 Influencing Conditions

In this case study, the influencing conditions have been evaluated to understand their impact on the innovation and its scalability. The analysis identified several influencing conditions that are either fully or partially affecting the implementation and diffusion of circular innovation.

I.C.1 Knowledge and Awareness of Technology

This influencing condition emphasizes the necessity of having both fundamental and applied technological knowledge in the context of circular innovation.

Circular Technological Knowledge: The pyrolysis process has technological inefficiencies and limitations, which makes it difficult to achieve economies of scale compared to traditional methods. Externally, regulatory bodies lack the necessary technological knowledge, leading to misunderstandings and misclassifications. This condition is fully affecting the innovation due to significant gaps in knowledge that hinder large-scale implementation. The specific building blocks being affected are Circular Production System (Scalability) and Innovation-specific Institutions (Regulatory Alignment and Stability).

I.C.3 Natural, Human and Financial Resources

This condition addresses the availability and management of various resources necessary for implementing circular innovations.

- **Resource Availability:** The resources, including raw materials and financial resources, are dispersed and difficult to access. The high Capital Expenditure (CAPEX) required for the technology necessitates significant financial backing, which is hard to secure due to conservative financial institutions and the perceived high risk of new products. This condition is fully affecting the innovation due to substantial financial barriers and resource distribution challenges. The specific building block being affected is Network Formation and Coordination (Interconnected Network).
- **Resource Flow Optimization:** Proper management and distribution of resources are crucial for addressing the logistical challenges of extensive networks with limited infrastructure. Without a well-planned logistics strategy that considers the dispersed location of extraction sites and the distribution of customers, significant inefficiencies arise. These inefficiencies result in long and costly transports, inefficient use of resources, and ultimately difficulties in maintaining an effective interconnected network. This condition is fully affecting the innovation due to major logistical inefficiencies. The specific building blocks being affected is Network Formation and Coordination (Interconnected Network).

I.C.6 Socio-cultural Aspects

This condition focuses on the societal and cultural factors influencing the adoption of circular innovations.

- **Societal Awareness and Perception:** The insufficient dissemination and understanding of the environmental and sustainability benefits of circular products create a significant barrier to customer engagement. The lack of adequate and effective awareness of the tangible and real benefits of these products prevents customers from feeling motivated to adopt these more sustainable alternatives. This condition is fully affecting the innovation due to a significant lack of societal awareness and perception. The specific building block being affected is Customers (Customer Awareness and Engagement).
- **Cultural Preferences and Resistance:** Resistance to paying more for circular products is influenced by a strong cultural preference for lower-cost products. This focus on price over environmental benefits creates a significant obstacle for the adoption of circular innovations. This condition is partially affecting the innovation due to substantial resistance based on economic considerations rather than inherent opposition to circular products. The specific building block being affected is Customers (Willingness to Pay and Use).

I.C.8 Environmental and Strategic Aspects

This condition includes the role of policies and governmental support in fostering or hindering circular innovations.

- **Institutional Policies:** The lack of proper recognition and understanding of the specificities of circular technologies, particularly regarding pyrolysis, leads to misclassification and inappropriate regulation. Additionally, the development of standards has not kept pace with technological innovation. Establishing these standards involves complex politics, requiring consensus among various stakeholders, each with different interests. This condition is partially affecting the innovation due to significant regulatory misalignments. The specific building block being affected is Innovation-specific Institutions (Standardization and Legitimacy).
- **Governmental Support:** There is a lack of governmental support in the form of official recognition, incentives, or subsidies for emerging circular economy technologies. This affects the regulations on waste treatment and the classification of technologies and materials, further hindering the adoption and scaling of circular innovations. This condition is partially affecting the innovation due to limited governmental support. The specific building block being affected is Innovation-specific Institutions (Regulatory Alignment and Stability).

I.C.9 Transportation and Digital Infrastructure

This condition addresses the state of transportation networks and their impact on circular economy practices.

Transportation Infrastructure: The transportation infrastructure, including roads, railways, ports, and urban transport systems, is generally underdeveloped, poorly maintained, and inadequate to meet current demands. Geographic challenges such as the Andes Mountains and frequent landslides further exacerbate these issues, leading to significant barriers in efficiently transporting goods and resources. This condition is fully affecting the innovation due to severe

infrastructural inadequacies. The specific building block being affected is Network Formation and Coordination (Interconnected Network).

Table 10 shows the discussed influencing conditions and their impact on the innovation.

Table 10: Influencing Conditions from Case 1

Influencing Condition	**Affected Building Block(s)**	**Description in Context**	**Translated Quote**
Knowledge and Awareness of Technology: Circular Technological Knowledge	Circular Production System (Scalability) and Innovation-specific Institutions (Regulatory Alignment and Stability)	The pyrolysis process has technological inefficiencies and limitations, which makes it difficult to achieve economies of scale compared to traditional methods. Externally, regulatory bodies lack the necessary technological knowledge, leading to misunderstandings and misclassifications.	"[T]echnologically, the process [...] is more difficult to scale [...] and it is not as efficient." "[...] when we talked about pyrolysis or thermolysis, it was confused with incineration. [...] Sometimes the person in charge doesn't know."
Natural, Human and Financial Resources Resource Availability	Network Formation and Coordination (Interconnected Network)	The resources, including raw materials and financial resources, are dispersed and difficult to access. The high capital expenditure (Capex) required for the technology necessitates significant financial backing, which is hard to secure due to conservative financial institutions and the perceived high risk of new products.	"[...] when you have a very large country [...] [y]our materials [...] can be very expensive to accumulate and are very dispersed." " If you go to the bank with a new product, the bank will be reluctant to lend you money because [...] there is a lot of risk. [...] Chilean banking is quite conservative, [...] they are quite risk-averse."
Natural, Human and Financial Resources Resource Flow Optimization	Network Formation and Coordination (Interconnected Network)	The current system faces challenges in logistics and the reverse supply chain due to geographical and infrastructural limitations, impacting the efficiency of resource collection and distribution.	"In Chile, logistics involve linear routes from north to south, and that complicates things. [...] Your materials are very dispersed. [...] The Andean mountains are very difficult to cross."
Socio-cultural Aspects Natural Cultural Preferences and Resistance	Customers (Willingness to Pay and Use)	There is a significant cultural preference for traditional, established products and practices, primarily driven by economic considerations. This resistance to change makes it challenging to introduce innovative circular solutions	"In Latin America, people do not move much for how clean or green the product is, it's about price."
Socio-cultural Aspects Natural Societal Awareness and Perception	Customers (Customer Awareness and Engagement)	There is a lack of widespread societal awareness and understanding of the benefits of circular economy practices. Efforts to educate the public on these benefits have been insufficient in substantially changing consumer behavior.	"The issue with customers is partly about whether they have the knowledge or know about the product. That lack of confidence significantly affects the willingness to use it."

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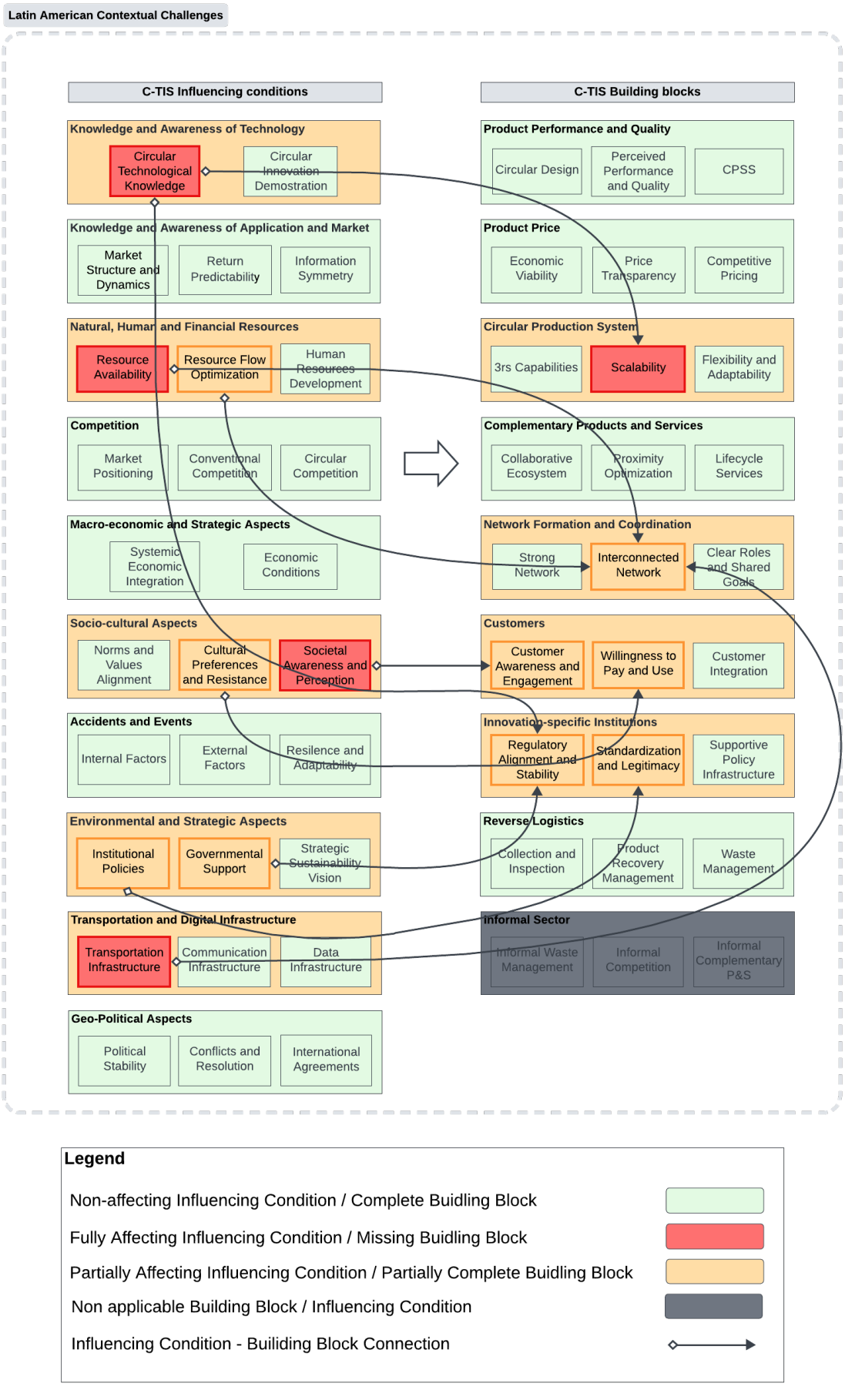
Table 10 continued from previous page

Influencing Condition	**Affected Building Block(s)**	**Description in Context**	**Translated Quote**
Environmental and Strategic Aspects Institutional Policies	Innovation-specific Institutions (Standardization and Legitimacy)	The lack of proper recognition and understanding of the specificities of circular technologies, leads to misclassification and erroneous regulation. Additionally, the development of standards has not kept pace with technological innovation. Establishing these standards involves complex politics, requiring consensus among various stakeholders, each with different interests.	"For us specifically, when we talked about pyrolysis or thermolysis, it was confused with incineration [...] under Chilean law, we fall into the category of incineration, but by definition, we are not incineration."
Environmental and Strategic Aspects Governmental Support	Innovation-specific Institutions (Regulatory Alignment and Stability)	Government support is insufficient in terms of providing formal recognition, incentives, or subsidies for new circular economy technologies. This shortfall impacts regulations concerning waste management and the categorization of technologies and materials.	"Governmental support [...] affect[s] regulations on waste treatment or the classification of technology or what is considered raw material or waste."
Transportation and Digital Infrastructure Transportation Infrastructure	Network Formation and Coordination (Interconnected Network)	The transportation infrastructure in the region is generally underdeveloped and poorly maintained, with significant geographic challenges such as vast distances and difficult terrain. This inadequacy hinders the efficient movement of goods and resources, essential for circular economy practices.	"Countries are very large [...] this affects logistics, and in the circular economy, logistics is key [...] your raw materials can be very dispersed. [...] the roads are not well developed."

Figure 12 provides the graphical representation of the model application for Case 1, identifying the relevant influencing conditions and building blocks.

It is important to note that in this case, the interviewee highlighted the use of a niche strategy specifically aimed at addressing the challenges of regulatory alignment and standardization. This strategy involves the company's active participation in committees where relevant laws and standards are discussed, as well as efforts to educate policymakers on emerging technologies and circular innovations. By engaging in this advocacy, the company seeks to influence policy development and create a more favorable regulatory environment for circular practices. This niche strategy will be further developed and integrated into the framework in Chapter 6, as "Policy Advocacy".

Figure 12: Framework Application to Case Study 1



5.2 Case Study 2: Compost Production in Peru

5.2.1 Case Background and Description

The second case study focuses on a company in Peru that produces compost from fruit residues and other organic waste. This innovative process involves collecting organic waste materials, such as fruit residues, and converting them into high-quality compost. The composting process not only helps in managing waste effectively but also produces a valuable product that can enrich soil fertility.

The case had two participants, who combine technical and business knowledge to drive the company forward. They define the circular economy as a process where waste is transformed into new resources, allowing continuous reuse and minimizing environmental impact. This definition reflects the company's practical approach to circular economy principles, aiming to create a system where waste management is not only about reducing disposal costs but also about contributing to environmental improvement and social responsibility. The participants noted that, in Peru, there is still a cultural gap in fully embracing circular economy practices, particularly regarding corporate social responsibility and the willingness to invest in sustainable solutions.

This background provides a comprehensive understanding of the company's innovative approach to compost production and its alignment with circular economy principles, setting the stage for further analysis using the C-TIS (LA) framework.

5.2.2 Building Blocks

In this case study, barriers and affected building blocks of the innovation were identified. The analysis revealed that several building blocks are either incomplete or missing, leading to specific barriers in the implementation and scaling of the circular innovation. Similarly as in the previous case, it is important to note that the building blocks not explicitly described were considered complete by the interviewee.

B.B.2 Product Price

The Product Price block is incomplete due to issues with **Competitive Pricing**: The company struggles to offer competitively priced compost products. They face competition from informal fertilizers and compost products that significantly lower their quality to reduce costs. This makes it difficult for the company to compete on price without compromising the quality of their compost, which is crucial for maintaining their market position and customer trust.

B.B.6 Customers

The Customers block is incomplete due to both the **Willingness to Pay and Use** and **Customer Awareness and Engagement** sub-blocks being insufficiently matured.

- **Willingness to Pay and Use**: Many customers prioritize price over quality and environmental benefits, especially in informal retail channels. This economic prioritization limits the adoption of higher-quality, more expensive circular products, making it difficult for the company to penetrate the market effectively.
- **Customer Awareness and Engagement**: There is a significant disparity in customer awareness and knowledge about the benefits of high-quality compost. While knowledgeable farmers demand quality and perform rigorous checks, the majority of retail customers,

particularly in informal channels, lack awareness and prioritize lower prices over product quality. This lack of awareness hinders the company's ability to educate the market and build a strong customer base for their high-quality compost products.

B.B.7 Innovation-specific Institutions

The Innovation-specific Institutions block is incomplete due to issues in both the **Regulatory Alignment and Stability** and **Supportive Policy Infrastructure** sub-blocks.

- **Regulatory Alignment and Stability**: The regulatory environment is highly fragmented and inconsistent. Companies face significant bureaucratic hurdles and high costs to obtain necessary permits. The lack of clear and supportive regulations for circular economy practices creates barriers that discourage formal business operations and investment.
- **Supportive Policy Infrastructure**: There is a notable absence of policies that support circular innovations. The current legal framework imposes heavy demands on companies trying to operate formally, without providing the necessary support or incentives. This creates an environment where businesses are penalized rather than encouraged to adopt sustainable practices, further complicating their operations and growth prospects.

Table 11 shows the discussed building blocks and sub-blocks.

Table 11: Building Blocks and Barriers from Case 2

Building Block	**Sub-Block**	**Barrier**	**Translated Quote**
Product Price	Competitive Pricing	The company's compost products struggle to compete in price with informal fertilizers that lower their quality to reduce costs, making it difficult to offer competitively priced products without compromising quality.	"I can't compete with the informal fertilizer maker who mixes it with soil and sand and adds water and all sorts of waste. [...] I can sell you [...] compost [and] you'll find in it [...] organic waste like fruits and vegetables."
Customers	Customer Awareness and Engagement	There is a significant lack of customer knowledge and awareness regarding the quality and benefits of compost products. This leads to a substantial portion of the market being uninformed about the advantages of using high-quality compost, thus hindering the adoption of sustainable practices.	"[T]he retail channel, where knowledge doesn't matter [and only] 10% is interested in quality products "
	Willingness to Pay and Use	Many customers, particularly in the retail market, prioritize low prices over quality. Economic pressures lead them to choose cheaper alternatives, even if these are of inferior quality, reflecting a low willingness to pay for sustainable, high-quality compost products.	"The gardener doesn't care if you sell him garbage as long as it's cheap [...] This is 90% of those gardeners."

Continued on next page

Table 11 continued from previous page

Building Block	Sub-Block	Barrier	Translated Quote
Innovation-specific Institutions	Regulatory Alignment and Stability	Unclear, conflicting, and overly stringent regulatory requirements, combined with bureaucratic delays and high costs, create significant obstacles to obtaining necessary permits, leading to operational uncertainty and high risks for the company.	"We started the formal paperwork process, initially submitting papers to the ministry of Environment, who then told us that the entity responsible for authorizing and supervising compost production is SENACE. SENACE said they only oversee established plants or municipal waste, not products like ours. This back-and-forth lasted several weeks."
	Supportive Policy Infrastructure	The lack of supportive infrastructure and incentives for circular economy initiatives discourages formal activities and innovation, leaving companies without necessary governmental support or facilitation to operate sustainably and legally.	"There is no office or government body promoting circular economy initiatives. Instead of creating virtuous cycles, the law [...] makes it impossible to act without passing through all their filters [...] The state should be promoting and assisting these initiatives instead of penalizing them with heavy regulations."

5.2.3 Influencing Conditions

In this case study, the influencing conditions have been evaluated to understand their impact on the innovation and its scalability. The analysis identified several influencing conditions that are either fully or partially affecting the implementation and diffusion of circular innovation.

I.C.4 Competition

This influencing condition addresses the impact of market competition on the adoption of circular innovations.

Conventional Competition: The company faces intense competition from cheaper, lower-quality non-organic fertilizers and informal compost, making it difficult to compete on price alone. This condition is partially affecting the innovation, as the company can still differentiate its product based on quality, but struggles with price competitiveness. The specific building block being affected is Product Price (Competitive Pricing).

I.C.6 Socio-cultural Aspects

This condition focuses on the societal and cultural factors influencing the adoption of circular innovations.

- **Cultural Preferences and Resistance:** Cultural preferences for cheaper products and resistance to paying more for higher-quality, environmentally beneficial options hinder the adoption of compost. This condition is partially affecting the innovation, as the cultural resistance is significant but not insurmountable with increased awareness and education. The specific building block being affected is Customers (Willingness to Pay and Use).
- **Societal Awareness and Perception:** There is a lack of awareness among consumers about the benefits of compost and the circular economy, leading to lower demand and engagement with these products. This condition is fully affecting the innovation due to

a significant lack of societal awareness and perception. The specific building block being affected is Customers (Customer Awareness and Engagement).

I.C.7 Accidents and Events

This condition addresses the impact of unforeseen events on the adoption and implementation of circular innovations.

External Factors: Natural events like El Niño have caused economic uncertainties, leading customers to revert to cheaper, non-compost fertilizers. This condition is partially affecting the innovation, as while El Niño and similar events create significant disruptions, they do not completely halt the adoption of compost. The specific building block being affected is Customers (Willingness to Pay and Use).

I.C.8 Environmental and Strategic Aspects

This condition includes the role of policies and governmental support in fostering or hindering circular innovations.

- **Institutional Policies:** The complex and burdensome regulatory environment creates barriers for obtaining necessary licenses, hindering the company's ability to operate formally. This condition is fully affecting the innovation due to significant regulatory misalignments and the challenging bureaucratic process. The specific building block being affected is Innovation-specific Institutions (Supportive Policy Infrastructure).
- **Governmental Support:** There is insufficient governmental support to aid in obtaining necessary licenses, making it difficult for the company to compete formally. This condition is fully affecting the innovation due to limited governmental support and lack of incentives. The specific building block being affected is Innovation-specific Institutions (Regulatory Alignment and Stability).

I.C.10 Geopolitical Aspects

This condition addresses the impact of political factors on the adoption and implementation of circular innovations.

Political Stability: Political instability creates economic uncertainties, affecting customers' willingness to invest in higher-quality compost products. This condition is partially affecting the innovation, as political instability introduces economic unpredictability but does not entirely prevent market engagement with compost. The specific building block being affected is Customers (Willingness to Pay and Use).

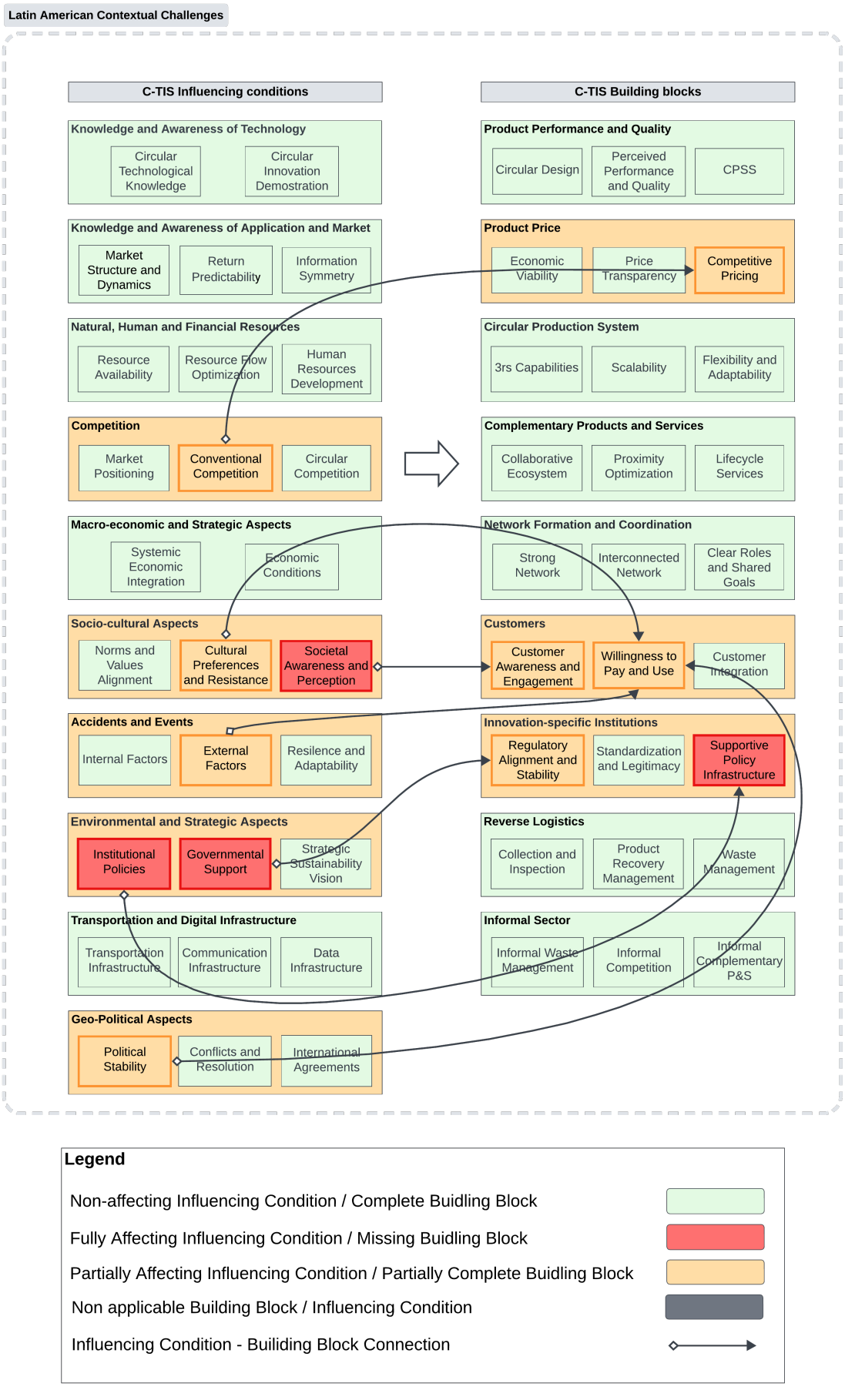
Table 12 shows the discussed influencing conditions and their impact on the innovation.

Table 12: Influencing Conditions from Case 2

Influencing Condition	**Affected Building Block(s)**	**Description in Context**	**Translated Quote**
Competition: Conventional Competition	Product Price (Competitive Pricing)	The company faces intense competition from cheaper, lower-quality non-organic fertilizers and informal compost, making it difficult to compete on price alone.	"I can't compete with the maneur seller who just mixes it with dirt and adds water. [...] So it's difficult; if I add 10% sand to a ton of compost, it increases the weight a lot."
Socio-cultural Aspects: Cultural Preferences and Resistance	Customers (Willingness to Pay and Use)	Cultural preferences for cheaper products and resistance to paying more for higher-quality, environmentally beneficial options hinder the adoption of compost.	"The gardener who buys it doesn't care if you sell them trash, as long as it's cheap."
Socio-cultural Aspects: Societal Awareness and Perception	Customers (Customer Awareness and Engagement)	There is a lack of awareness among consumers about the benefits of compost and the circular economy, leading to lower demand and engagement with these products	"There are two types of farmers: the knowledgeable and the unknowledgeable. [Only] the knowledgeable one will ask for analyses, will inspect, will sample and analyze the sample."
Accidents and Events: External Factors	Customers (Willingness to Pay and Use)	Natural events like El Niño have caused economic uncertainties, leading customers to revert to cheaper, non-compost fertilizers.	"Some have said [that], due to the climate, El Niño, [...] they will not continue putting more money into cultivation."
Environmental and Strategic Aspects: Institutional Policies	Innovation-specific Institutions (Supportive Policy Infrastructure)	The complex and burdensome regulatory environment creates barriers for obtaining necessary licenses, hindering the company's ability to operate formally.	"The level of requirements is such that they ask for traceability, you practically have to have a laboratory, a professional, and a series of things [...] The bureaucracy and laws can be perverse for an activity that is beneficial for all parties."
Environmental and Strategic Aspects: Governmental Support	Institutions (Regulatory Alignment and Stability)	There is insufficient governmental support to aid in obtaining necessary licenses, making it difficult for the company to compete formally.	"There is no office for promoting these virtuous circles. The law says you can't do anything unless you pass through [certain] filters, so you don't have a anything to hang onto. The state doesn't help".
Geopolitical Aspects: Political Stability	Customers (Willingness to Pay and Use)	Political instability creates economic uncertainties, affecting customers' willingness to invest in higher-quality compost products.	"Some have said [that], due to [...] politics, they will not continue putting more money into cultivation."

Figure 13 provides the graphical representation of the model application for Case 2, identifying the relevant influencing conditions and building blocks.

Figure 13: Framework Application to Case Study 2



5.3 Case Studies Comparison

In this section, the two case studies of circular economy initiatives in Latin America are compared to highlight commonalities and differences. The first case study involves a Chilean company that recycles large-scale mining tires through a thermal process known as Pyrolysis or Thermolysis. This method emphasizes industrial waste management by converting mining tires into reusable materials such as steel, liquid and gaseous fuels, and recovered carbon black.

The second case study centers on a Peruvian company producing compost from fruit residues and other organic waste. This process not only manages organic waste but also produces valuable compost for agricultural use, highlighting a more community-focused approach to the circular economy.

Despite these differences, both cases aim to reduce waste and promote sustainability, demonstrating the diverse applications of circular economy principles across different industries and countries in Latin America. The following section will compare the circular economy definitions, barriers, building blocks, influencing conditions and strategies obtained from these case studies.

CE definition

The mining tire recycling case defines the circular economy as a system where waste from a production chain is reintegrated into the same chain as raw materials. This definition focuses on minimizing waste and promoting efficiency within the same production process, reflecting an industrial perspective in a regulated sector. In contrast, the compost production case views the circular economy as transforming waste into new resources, allowing continuous reuse and minimizing environmental impact. This approach emphasizes environmental improvement and social responsibility, focusing on the benefits of compost for soil fertility and agricultural sustainability.

Both definitions aim to reduce waste and promote resource efficiency, but their focus and implications differ. The mining tire recycling definition is more industrially focused, emphasizing the closed-loop system within a single production chain, which aligns with the highly regulated nature of the industry. On the other hand, the compost production definition highlights broader environmental and community benefits, such as improving soil health and reducing reliance on chemical fertilizers. This reflects the agricultural context of the case, where the circular economy is seen as a means to enhance sustainability and social responsibility. While both companies are committed to circular practices, their definitions illustrate the different priorities and contexts of their respective industries.

Barriers

The analysis of barriers in both case studies reveals how missing or incomplete building blocks impact the implementation and scaling of circular innovations.

In the mining tire recycling case, several key barriers emerged. The first is the challenge of scaling the pyrolysis process, which faces significant technological inefficiencies and limitations. This barrier is linked to the incomplete Scalability sub-block within the Circular Production System building block. The second barrier is the inefficiency in the transportation and distribution of recycled materials, due to an underdeveloped network lacking local connectedness and bidirectional connections. This barrier stems from the incomplete Interconnected Network sub-block within the Network Formation and Coordination building block. Additionally, customer-related barriers include a lack of awareness and understanding of circular products and a low willingness to pay for sustainable products, primarily due to economic constraints. These barriers are tied

to the incomplete Customer Awareness and Engagement and Willingness to Pay and Use sub-blocks within the Customers building block. The regulatory environment also poses barriers, with misaligned and inconsistent regulations and a lack of standardization and legitimacy for new circular products, affecting the Regulatory Alignment and Stability and Standardization and Legitimacy sub-blocks within the Innovation-specific Institutions building block.

In the compost production case, competitive pricing presents a significant barrier. The company struggles to offer competitively priced compost products due to competition from informal fertilizers that lower their quality to reduce costs. This barrier is linked to the incomplete Competitive Pricing sub-block within the Product Price building block. Customer-related barriers include a lack of awareness and knowledge about the benefits of high-quality compost and a low willingness to pay for sustainable products, driven by economic pressures and a preference for cheaper alternatives. These barriers are tied to the incomplete Customer Awareness and Engagement and Willingness to Pay and Use sub-blocks within the Customers building block. Regulatory and policy barriers also exist, with unclear, conflicting, and stringent requirements creating operational uncertainty and high risks for the company. These barriers stem from the incomplete Regulatory Alignment and Stability and Supportive Policy Infrastructure sub-blocks within the Innovation-specific Institutions building block.

Comparing the barriers between the two cases, several common themes emerge. Both cases face significant customer-related barriers due to low awareness and willingness to pay for sustainable products, driven by economic constraints and cultural preferences for cheaper alternatives. Additionally, both cases struggle with regulatory and policy barriers, including misaligned regulations and a lack of supportive infrastructure and incentives. However, the specific barriers and their impacts vary due to the different contexts of the industries. The mining tire recycling case faces unique technological and logistical challenges related to scaling and network efficiency, while the compost production case struggles more with competitive pricing and the informal sector's influence.

Building Blocks

In the comparison of the building blocks, distinct differences and notable similarities emerge between the two case studies, highlighting the unique challenges and shared difficulties in implementing circular innovations.

Circular Production System: In the mining tire recycling case, the Circular Production System block is hindered primarily by the absence of the Scalability sub-block. The pyrolysis process for recycling mining tires faces significant technological inefficiencies and limitations, making it challenging to scale up operations efficiently. This limitation affects the economic viability and broader market reach of the innovation. In contrast, the compost production case did not specifically identify scalability as a missing or incomplete sub-block, suggesting that their production system might not face the same technological barriers to scaling. The compost production system is technologically advanced and effective. However, scalability is hindered primarily by difficulties in penetrating the market of larger companies due to the expensive and complex certification process required. This issue is evident in the large stock of compost that cannot be sold without proper certification.

Network Formation and Coordination: For the mining tire recycling case, the Network Formation and Coordination block is incomplete due to the lack of an Interconnected Network. The geographical challenges and the inefficient logistics of collecting and distributing materials in Chile result in significant operational inefficiencies. The compost production case, on the

other hand, benefits from having providers and consumers of compost located closer together, making it easier to form a connected network. This proximity facilitates more efficient logistics and coordination within the compost production sector.

Customers: The Customers block in both cases is incomplete due to deficiencies in Customer Awareness and Engagement and Willingness to Pay and Use sub-blocks. In the mining tire recycling case, customers lack sufficient awareness and understanding of the benefits and processes of circular economy products, leading to low engagement. Additionally, consumers prioritize cost over sustainability, showing a low willingness to pay for circular innovations. Similarly, in the compost production case, many customers, particularly in the retail market, prioritize low prices over quality and lack awareness about the benefits of high-quality compost. Both cases highlight the need for increased customer education and engagement to drive demand for sustainable products.

Innovation-specific Institutions: Both cases face significant challenges within the Innovation-specific Institutions block. In the mining tire recycling case, issues stem from a lack of Regulatory Alignment and Stability and Standardization and Legitimacy. The absence of supportive regulations and standards creates significant barriers to the adoption and market acceptance of new circular products. Similarly, the compost production case identifies the incomplete Regulatory Alignment and Stability sub-block and the lack of a Supportive Policy Infrastructure. The complex and burdensome regulatory environment and the absence of supportive policies hinder the company's ability to operate formally and compete effectively.

Informal Sector: The mining tire recycling case does not engage with the Informal Sector block, as the industry operates exclusively within formal, regulated channels. In contrast, the compost production case acknowledges and includes the influence of the informal sector extensively. Informal competition from unregulated fertilizers and compost products creates significant pricing pressures, and the informal nature of many organic waste suppliers complicates efforts to establish formal, regulated operations. The compost sector is so intertwined with the informal sector that its influence is always included or acknowledged, ensuring the block is neither incomplete nor missing. This stark difference underscores the varied impact of the informal sector on circular innovations across different industries and contexts.

Influencing Conditions

Comparing the influencing conditions impacting the circular innovations in both case studies reveals how various socio-cultural, economic, and strategic factors either fully or partially affect the adoption and scalability of circular practices.

Knowledge and Awareness of Technology: In the mining tire recycling case, the influencing condition of Knowledge and Awareness of Technology fully affects the innovation due to significant gaps in technological knowledge and regulatory understanding. The pyrolysis process faces misunderstandings and misclassifications by regulatory bodies, leading to barriers in large-scale implementation. In contrast, the compost production case does not explicitly mention significant technological knowledge gaps or regulatory misunderstandings. The technical norms for compost production are well established and understood within the company, indicating that the influencing condition of Knowledge and Awareness of Technology is less critical.

Natural, Human, and Financial Resources: The resource availability condition fully affects the mining tire recycling innovation due to dispersed raw materials and the high capital expenditure required for the pyrolysis process. Logistical challenges and conservative financial

institutions add to the complexity of securing necessary resources. Conversely, in the compost production case, resource availability is not explicitly highlighted as a significant barrier. The organic waste needed for composting is more readily accessible and comes from a variety of sources, such as agricultural fields and companies. Although both Peru and Chile face geographical challenges, the abundance of closer, accessible resources for compost production mitigates these difficulties.

Socio-cultural Aspects: In the mining tire recycling case, socio-cultural aspects fully affect the innovation due to a lack of societal awareness and understanding of circular economy benefits. Customers prioritize price over sustainability, leading to resistance in adopting circular products. In the compost production case, socio-cultural aspects partially affect the innovation. Cultural preferences for cheaper products and a lack of awareness about the benefits of compost hinder market penetration.

Accidents and Events: Accidents and events have a significant impact on the compost production case but are less relevant to the mining tire recycling case. Natural events in the region, i.e., El Niño, cause economic uncertainties that lead customers to revert to cheaper, non-compost fertilizers. This condition fully affects the compost innovation due to the direct impact of climate and natural phenomena on agricultural sectors. In contrast, the recycling of mining tires is less susceptible to such natural events, making this influencing condition less significant in the first case.

Environmental and Strategic Aspects: Environmental and strategic aspects partially affect the mining tire recycling innovation due to regulatory misalignments and inadequate governmental support. The lack of proper recognition and understanding of pyrolysis leads to significant regulatory hurdles. In the compost production case, these aspects fully affect the innovation. The regulatory environment is complex and burdensome, creating significant obstacles for obtaining necessary licenses. The lack of governmental support and incentives further complicates the situation, making it difficult for the company to operate formally and sustainably.

Geopolitical Aspects: Geopolitical aspects are not explicitly mentioned as a significant barrier in the mining tire recycling case. In contrast, in the compost production case, political instability partially affects the innovation. Economic uncertainties caused by political factors lead customers to revert to cheaper, non-compost fertilizers, affecting the company's market engagement. This difference could be attributed to Peru experiencing more political chaos compared to the relatively stable political environment in Chile at this moment in time.

Transportation and Digital Infrastructure: These kinds of infrastructure are not explicitly mentioned as a significant barrier in the compost production case. In contrast, in the mining tire recycling case, transportation infrastructure fully affects the innovation. Inefficient and underdeveloped infrastructure in Chile combined with geographical challenges directly affect the efficiency transport of goods and materials from and to the company.

The comparative analysis of the two case studies reveals the multifaceted nature of implementing circular economy principles across different sectors and geographical contexts. The mining tire recycling case in Chile and the compost production case in Peru both provide valuable insights into the practical challenges and barriers faced by circular innovations.

Integrating the definitions from both cases, the circular economy can be understood as a system that continuously transforms waste into valuable resources, emphasizing sustainable practices throughout production and consumption cycles. This integrated definition highlights the goals of

minimizing environmental impact, enhancing resource efficiency, and promoting socio-economic benefits through regulatory alignment, technological innovation, and societal engagement.

The comparison of barriers from both case studies revealed several overlapping issues that affect the implementation and scaling of circular innovations. By combining similar barriers identified in each case, a more generalized list of barriers was created. This consolidated list highlights common challenges faced by circular economy initiatives, providing a comprehensive understanding of the obstacles that need to be addressed. The barriers combined came from the following sub-blocks: Customer Awareness and Engagement, Willingness to Pay and Use, and Regulatory Alignment and Stability.

- Significant challenges in scaling up circular production processes efficiently.
- Inefficiencies in the transportation and distribution network for circular economy activities, lacking local connectedness and bidirectional connections.
- Significant lack of customer awareness and understanding regarding the benefits and processes of circular economy products.
- Low willingness to pay for sustainable products, with consumers prioritizing cost over sustainability.
- Lack of alignment in regulatory frameworks and inconsistent environmental laws and waste disposal regulations significantly hinder the adoption and diffusion of circular economy innovations.
- Unclear, conflicting, and overly stringent regulatory requirements create significant obstacles to obtaining necessary permits.
- Absence of standardized norms and the struggle to gain legitimacy for new circular products make it challenging to achieve widespread acceptance and integration in the market.
- Competitive pricing challenges for circular products.
- Lack of supportive infrastructure and incentives for circular economy initiatives, discouraging formal activities and innovation.

In reflecting on the framework, interviewees provided valuable insights that highlighted both the completeness and areas where additional considerations were necessary. In the mining tire recycling case, interviewees emphasized the critical role of reverse logistics in circular innovations and pointed out that the informal sector was not relevant in this context, though it is crucial in other sectors, particularly in plastic recycling. A significant addition from this case was the recognition of transportation infrastructure and geographical challenges as major barriers in the region. This feedback directly influenced the development of the "Transportation and Digital Infrastructure" influencing condition, specifically the transportation infrastructure subcondition. On the other hand, the compost production case reinforced the idea that geopolitical aspects significantly influence the diffusion of innovative circular practices. Unlike the recycling of mining tires case, it also underscored the vital role of the informal sector in agriculture, from affecting competitive pricing to being an essential part of the supply chain. These reflections led to adjustments and enhancements in the framework to better address the unique challenges identified by the interviewees.

5.4 Expert insights

5.4.1 Expert 1

The first expert interviewed is a senior consultant from Mexico specializing in environmental and CE practices. They hold a managerial position in a company that processes waste and also provides consultancy services focused on environmental sustainability and circular economy strategies. With a legal background and specialized education in energy law and renewable energy, and 10 years of experience, they bring a comprehensive understanding of regulatory frameworks and sustainable practices to his roles.

Definition of CE and Latin American Perspective

The expert defines the CE as an enabler of sustainable development. It involves integrating circular practices into the entire lifecycle of products and services, starting from design to end-of-life management. This includes using renewable resources, designing for longevity and reparability, and implementing comprehensive waste management strategies.

In their opinion, in Latin America, the understanding and implementation of the CE are still in nascent stages. The concept is often narrowly interpreted as synonymous with waste management and recycling, overlooking critical aspects such as product design and resource efficiency. Legislative and regulatory frameworks in the region frequently lack the depth and specificity required to support comprehensive circular practices. There is a significant gap in knowledge among policymakers and industry stakeholders, leading to inadequate and poorly adapted regulations. Additionally, the informal recycling sector is a significant part of the waste management system in Latin America. This sector, comprising independent waste pickers and informal recycling businesses, plays a crucial role in managing and recycling waste, despite operating outside formal regulatory frameworks.

Barriers to CE

According to the expert, these are the most significant barriers for the adoption of CE:

- **Regulatory and Legislative Barriers:** Policymakers lack basic knowledge of the circular economy, resulting in superficial laws that focus primarily on waste management. This lack of depth in legislation fails to incentivize the integration of circular principles throughout the product lifecycle.
- **Economic and Financial Barriers:** Limited financial support and incentives for SMEs to adopt circular practices lead to high costs and financial risks, deterring businesses from investing in circular innovations.
- **Market and Consumer Barriers:** A lack of consumer awareness and appreciation of circular products, combined with the influence of commercial marketing that promotes linear consumption patterns, makes it difficult to create demand for circular products and penetrate the market.
- **Technological and Operational Barriers:** Challenges in scaling circular innovations while remaining competitive, coupled with limited availability of sustainable suppliers, result in operational inefficiencies and higher costs in implementing circular practices.

Strategies

Similarly, these are some strategies they highlighted as crucial for overcoming barriers and promoting CE:

1. **Institutional Support:**
    - Develop clear and comprehensive regulations that support circular practices.
    - Ensure effective enforcement mechanisms to hold businesses accountable.
2. **Organizational Changes:**
    - Appoint dedicated roles for sustainability and circular economy within companies.
    - Foster internal communication and alignment on circular goals.
3. **Market Strategies:**
    - Communicate transparently about the benefits and circular nature of products.
    - Engage consumers through education and marketing strategies that emphasize sustainability.
4. **Technological Adoption:**
    - Incorporate innovation and technology in circular practices.
    - Use digital tools (e.g., digital product passports) to enhance transparency and traceability.

Opinion on the Framework

The expert finds the model relevant and well-suited for the Latin American context, given the unique regulatory, economic, and market dynamics in the region. The framework's thorough approach, considering various stages of the product lifecycle and different types of barriers, aligns with the complex nature of implementing circular practices. However, thye emphasized the need to adapt the model to different types of businesses (e.g., traditional companies versus startups) and sectors to increase its applicability and effectiveness.

Other Insights from Expert 1:

Consumer Influence: The expert highlighted the significant impact of consumer behavior and media influence on the adoption of circular products. Companies like Samsung and Apple often create a perception of obsolescence, encouraging frequent purchases of new products. Leveraging influencers to promote circular products can effectively reach a broad audience and change consumption patterns.

Proximity and Local Sourcing: The expert emphasized the importance of local sourcing in the circular economy. Reducing transportation distances minimizes environmental impact and enhances product circularity. Local suppliers that comply with sustainability standards can support the overall lifecycle of circular products, although finding such suppliers can be challenging.

5.4.2 Expert 2

The second expert interviewed is a senior consultant in Peru specializing in CE practices, particularly within the agricultural sector. They are involved in promoting circular agriculture and providing support to businesses aiming to adopt sustainable practices. With 14 years of significant experience in both the Peruvian and Colombian markets, he brings a deep understanding of the challenges and opportunities associated with implementing circular economy initiatives in Latin America.

Definition of Circular Economy and Latin American Perspective

This expert defines the CE as a holistic approach to sustainable development that goes beyond recycling. It involves rethinking and redesigning production and consumption processes to minimize waste and maximize resource efficiency, encompassing the entire lifecycle of products and services.

In Latin America, the concept of the circular economy is often limited to recycling, with a significant gap in understanding its broader implications. There is a need for greater dissemination and education about circular economy principles. Government policies frequently do not align with practical implementation, creating significant barriers for businesses. Additionally, the informal sector plays a crucial role in waste management and recycling. This sector, comprising independent waste pickers and informal recycling businesses, operates alongside formal systems but often lacks the support and recognition needed to enhance their contributions to the circular economy.

Barriers to CE

According to the second expert, these are the most significant barriers for the adoption of CE:

- **Regulatory and Legislative Barriers:** Policymakers have intentions to promote the circular economy but often fail to create coherent and practical regulations. There is a disconnect between policy objectives and actual implementation, leading to bureaucratic hurdles and inconsistent enforcement.
- **Economic and Financial Barriers:** High costs and lack of financial support hinder the ability of entrepreneurs to scale circular economy projects. Young entrepreneurs, in particular, struggle to find the necessary resources to develop and expand their initiatives.

Strategies

Similarly, these are some strategies they highlighted as crucial for overcoming barriers and promoting CE:

1. **Institutional Support:**
    - Develop clear and practical regulations that align with circular economy goals.
    - Provide financial incentives and support to help SMEs adopt circular practices.
2. **Funding and Support:**
    - Participate in competitive funding opportunities to gain government support and legitimacy.
    - Utilize existing governmental and non-governmental programs designed to support circular economy projects.

Opinion on the Framework

The expert finds the model relevant and potentially effective for the Latin American context, particularly in identifying and addressing the barriers to implementing circular economy practices. He acknowledges that the framework needs to be adapted to different types of businesses and sectors to ensure its applicability and effectiveness. The emphasis on understanding specific market dynamics and regulatory environments is crucial for its successful implementation.

Other Insights

Consumer Influence: The expert emphasized the importance of consumer education in promoting circular economy practices. Misconceptions about circularity being limited to recycling need to be addressed through comprehensive awareness campaigns.

Agriculture Circularity: The expert mentioned that agricultural circularity is still in its early stages in Peru. Efforts are being made to promote circular practices, but there is a significant need for better understanding and implementation.

Competitive Funding: Participating in competitive funding opportunities, such as those offered by government councils, can provide crucial support and validation for circular economy projects. These opportunities can also facilitate the regulatory approval process.

Proximity and Local Sourcing: Local sourcing and reducing transportation distances are essential for enhancing the circularity of products. The expert highlighted the need for a functional and structured supply chain that supports sustainable practices.

5.4.3 Synthesis

Both experts define the circular economy as a comprehensive approach to sustainable development that extends beyond mere recycling. It encompasses the entire lifecycle of products and services, from design to end-of-life management, with an emphasis on minimizing waste and maximizing resource efficiency. However, in Latin America, the concept of the circular economy is predominantly viewed through the lens of waste management and recycling. This narrow interpretation, while not ideal, reflects the current practical understanding and implementation in the region. Effective CE strategies must consider this reality, incorporating the broader principles of resource efficiency, product longevity, and comprehensive waste management.

Therefore, an integrated, more relevant definition for Latin America would be:

> "The circular economy in Latin America involves rethinking and redesigning production and consumption processes to minimize waste and maximize resource efficiency, with a strong focus on waste management and recycling, encompassing the entire lifecycle of products and services."

From the perspectives of both experts, the following integrated list of barriers to the adoption of CE in Latin America has been identified:

- Regulatory and Legislative Barriers: Policymakers often lack the necessary knowledge and create superficial regulations that fail to support comprehensive circular practices, leading to bureaucratic hurdles and inconsistent enforcement.
- Economic and Financial Barriers: High costs and insufficient financial support deter businesses, particularly SMEs, from investing in circular innovations and scaling their projects.
- Market and Consumer Barriers: Limited consumer awareness and appreciation for circular products, combined with the influence of marketing promoting linear consumption patterns, make market penetration challenging.
- Technological and Operational Barriers: Difficulties in scaling circular innovations and a lack of sustainable suppliers result in operational inefficiencies and higher implementation costs.

Similarly, this is the list of strategies to overcome barries and promote CE from the perspective of both experts:

- Institutional Support:
  - Develop clear and practical regulations that align with circular economy goals.
  - Ensure effective enforcement mechanisms to hold businesses accountable.
- Funding and Support:
  - Provide financial incentives and support to help SMEs adopt circular practices.
  - Participate in competitive funding opportunities to gain government support and legitimacy.
- Organizational Changes:
  - Appoint dedicated roles for sustainability and circular economy within companies.
  - Foster internal communication and alignment on circular goals.
- Market Strategies:
  - Communicate transparently about the benefits and circular nature of products.
  - Engage consumers through education and marketing strategies that emphasize sustainability.
- Technological Adoption:
  - Incorporate innovation and technology in circular practices.
  - Use digital tools (e.g., digital product passports) to enhance transparency and traceability.

Both experts recognize the significant value of the proposed framework for circular economy practices. They acknowledge its relevance and potential effectiveness in the Latin American context, particularly in identifying and addressing barriers to CE implementation. This validation is crucial as it underscores the framework's adaptability to different business types and sectors, enhancing its applicability and effectiveness.

Consumer education emerged as a critical factor from both experts' perspectives. Misconceptions about circularity being limited to recycling need to be addressed through comprehensive awareness campaigns. This insight reinforces the necessity to incorporate consumer education strategies within the framework, aligning with broader circular economy principles.

Both experts also highlighted the importance of local sourcing and proximity in minimizing environmental impact and enhancing product circularity. This supports the inclusion of transportation infrastructure and logistics as part of the new influencing conditions in the model, validating the adaptation of the model to the Latin American context.

Moreover, the informal sector's role in waste management and recycling is particularly significant in Latin America. Both experts underscored its importance, which reinforces the decision to include the informal sector as a new building block in the model. Recognizing its critical role in the Latin American context ensures that the model addresses the region's unique challenges and leverages existing practices for effective CE implementation.

The insights obtained from these expert interviews will be instrumental in the subsequent analysis. These perspectives will be compared with the findings from the research to assess how they reinforce or contradict the established conclusions. This comparison will provide a deeper understanding of the applicability and robustness of the research outcomes, and will help identify areas where further investigation or adjustment may be necessary.

6 Strategy Development

In this chapter, the focus will be on identifying and developing strategies for overcoming the barriers to CIs as identified through the application of the C-TIS (LA) framework. By examining the connections between influencing conditions and building blocks that result in specific barriers, we will devise strategies aimed at addressing these challenges.

The framework is designed to facilitate the large-scale diffusion of CIs during their introductory stage. Hence, the strategies developed will primarily be niche strategies. As noted by Ortt and Kamp (2022), niche strategies represent viable approaches for introducing radically new innovations. In a previous paper, Ortt, Langley, and Pals (2013) provided a comprehensive list of generic niche strategies that will serve as the foundation for developing targeted strategies for the barriers identified in each case study.

List of Generic Niche Strategies by Ortt et al. (2013)

1. Demo, experiment, and develop niche strategy: Demonstrating and developing the product in controlled settings to enhance quality and performance.
2. Top niche strategy: Targeting high-end market segments with specialized products.
3. Subsidized niche strategy: Leveraging subsidies to offset high costs and encourage adoption.
4. Redesign niche strategy: Simplifying the product to reduce costs and increase accessibility.
5. Dedicated system or stand-alone niche strategy: Creating dedicated systems or standalone products when complementary services are lacking.
6. Hybridization or adaptor niche strategy: Combining new products with existing ones to utilize complementary services.
7. Educate niche strategy: Educating suppliers and customers to increase product knowledge and acceptance.
8. Geographic niche strategy: Targeting geographic areas with favorable conditions for product adoption.
9. Lead user niche strategy: Collaborating with lead users to co-develop and refine the product.
10. Explore multiple markets niche strategy: Exploring various customer applications to identify new market opportunities.

Following the identification and development of these strategies, a comparative analysis will be conducted to examine the commonalities and differences between the strategies developed for each case study. Additionally, these strategies will be compared with those identified in the literature review and expert interviews to determine whether the C-TIS (LA) framework reveals new insights or corroborates existing strategies.

This structured approach aims to provide a comprehensive understanding of effective niche strategies for overcoming barriers to the large-scale diffusion of CIs in the Latin American context.

6.1 Niche Strategies for Case 1

In this section, we present the niche strategies developed for overcoming the barriers identified in Case 1. Each barrier is analyzed with respect to the influencing conditions that affect the corresponding building blocks, and the appropriate niche strategies are proposed.

1. The process for recycling mining tires through pyrolysis faces significant challenges in scaling up to larger, more efficient operations.

   Influencing Conditions:

   - Circular Technological Knowledge: The pyrolysis process has technological inefficiencies and limitations.
   - Resource Availability: The high CAPEX required for the technology necessitates significant financial backing.

   Niche Strategies:

   - Demo, Experiment, and Develop Niche Strategy: To address the technological inefficiencies, the company can demonstrate the pyrolysis process in a controlled environment, experiment with the technology, and further develop it to improve its efficiency. Collaboration with academia or industry partners can enhance this strategy.
   - Subsidized Niche Strategy: To overcome the high financial barriers, the company can seek subsidies or financial support from the government or other organizations that recognize the societal relevance of mining tire recycling and are willing to invest in its development.

2. The network for circular economy activities is inefficient, lacking the necessary local connectedness and bidirectional connections crucial for efficient resource circulation and reverse logistics.

   Influencing Conditions:

   - Resource Availability: Dispersed resources, including raw materials, impact the efficiency of resource circulation and reverse logistics.
   - Resource Flow Optimization: Geographical and infrastructural limitations affect the efficiency of resource collection and distribution.
   - Transportation Infrastructure: Underdeveloped and poorly maintained transportation infrastructure hinders the efficient movement of goods and resources.

   Niche Strategy:

   - Geographic Niche Strategy: The company can set up operations near a hub of mining activities to shorten supply chains and reduce logistical inefficiencies. By locating closer to the source of raw materials, the company can optimize resource flows and mitigate transportation challenges.

3. Consumers in Latin America prioritize cost over sustainability, showing a low willingness to pay for circular innovations unless they are cheaper than traditional products.

Influencing Condition:

- Cultural Preference and Resistance: There is a significant cultural preference for traditional, established products and practices, primarily driven by economic considerations.

Niche Strategy:

- Educate Niche Strategy: The company can focus on educating customers about the benefits of circular products, highlighting their long-term value and environmental impact. Awareness campaigns, eco-labeling, and customer engagement activities can help shift consumer preferences towards sustainable products. By increasing awareness and understanding, the company can address both the low willingness to pay and the lack of customer engagement barriers simultaneously.

4. There is a significant lack of customer awareness and understanding regarding the benefits and processes of circular economy products, leading to low confidence and engagement with these products.

Influencing Condition:

- Social Awareness and Perception: There is a lack of widespread societal awareness and understanding of the benefits of circular economy practices.

Niche Strategy:

- Educate Niche Strategy: The company can focus on educating customers about the benefits of circular products, highlighting their long-term value and environmental impact. Awareness campaigns, eco-labeling, and customer engagement activities can help shift consumer preferences towards sustainable products. By increasing awareness and understanding, the company can address both the low willingness to pay and the lack of customer engagement barriers simultaneously.

5. The lack of alignment in regulatory frameworks and inconsistent environmental laws and waste disposal regulations significantly hinder the adoption and diffusion of circular economy innovations.

Influencing Conditions:

- Circular Technological Knowledge: Lack of knowledge from regulatory bodies leads to misunderstandings and misclassifications.
- Institutional Policies: The lack of proper recognition and understanding of circular technologies leads to misclassification and erroneous regulation.

Niche Strategy:

- Policy Advocacy Strategy: The company can engage with regulatory bodies and participate in policy-making committees to educate policymakers about the specifics of circular technologies. By advocating for clearer and more supportive regulations, the company can help align the regulatory framework with the needs of circular innovations. This strategy inherently includes aspects of the educate niche strategy to ensure policymakers are well-informed.

6. The absence of standardized norms and the struggle to gain legitimacy for new circular products, like recovered carbon black, make it challenging to achieve widespread acceptance and integration in the market.

   Influencing Condition:

   - Governmental Support: Insufficient government support impacts the development of standards and the recognition of circular products.

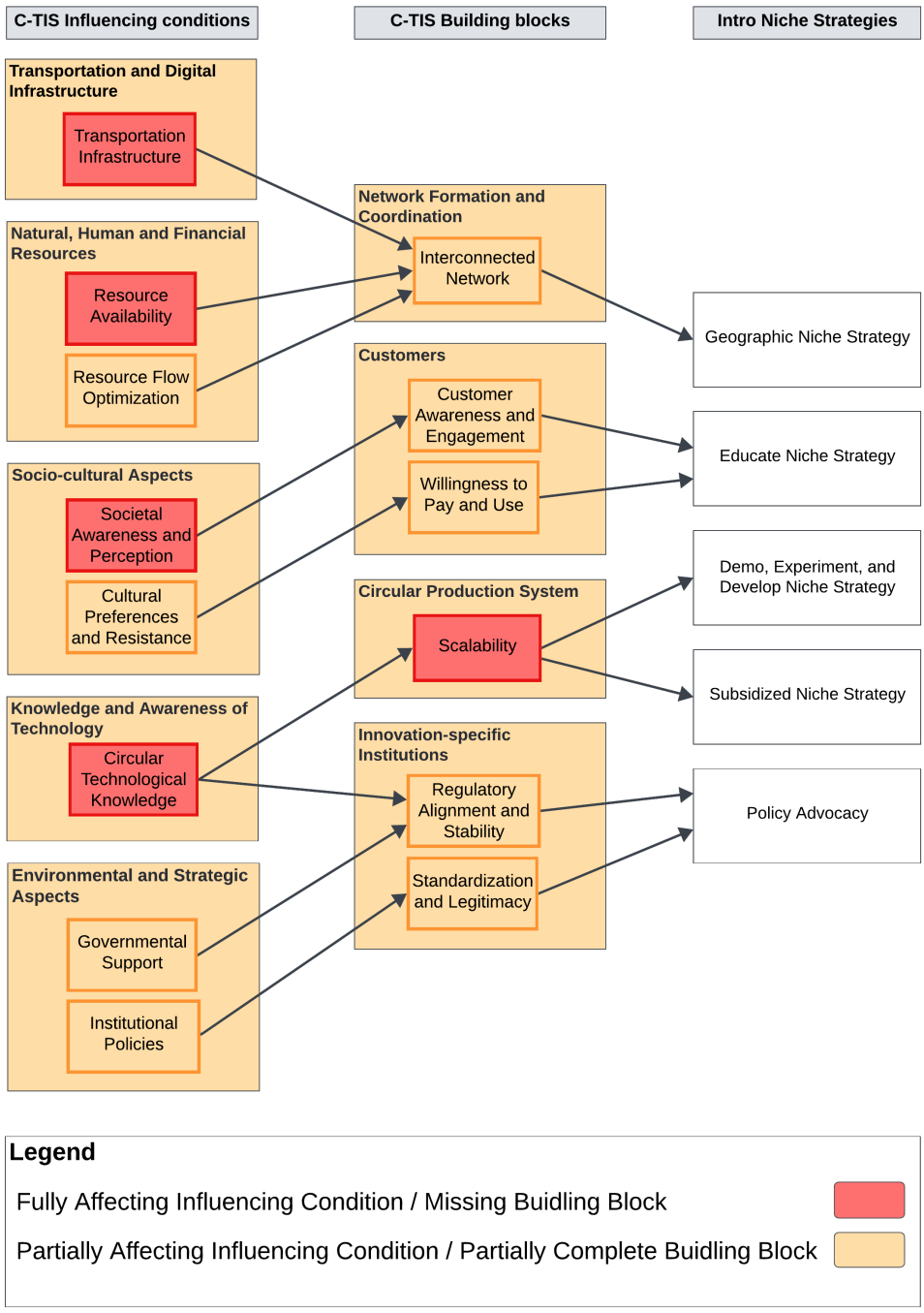
   Niche Strategy:

   - Policy Advocacy Strategy: The company can engage with regulatory bodies and participate in policy-making committees to educate policymakers about the specifics of circular technologies. Additionally, by collaborating with universities or external laboratories, the company can validate their products and work towards establishing standardized norms. Demonstrating the product's effectiveness through third-party validation can help gain legitimacy and market acceptance.

These niche strategies, derived from the influencing conditions affecting the building blocks, provide targeted approaches to overcoming the barriers identified in Case 1. The application of these strategies aims to facilitate the large-scale diffusion of circular innovations by addressing the specific challenges encountered in the introduction stage.

Figure 14 illustrates how the niche strategies result from identifying which influencing conditions affect specific building blocks.

Figure 14: Niche Strategies Case 1



6.2 Niche Strategies from Case 2

In this section, we present the niche strategies developed for overcoming the barriers identified in Case 2. Each barrier is analyzed with respect to the influencing conditions that affect the corresponding building blocks, and the appropriate niche strategies are proposed.

1. The company's compost products struggle to compete in price with informal fertilizers that lower their quality to reduce costs, making it difficult to offer competitively priced products without compromising quality.

Influencing Conditions:

- Conventional Competition: The intense competition from cheaper, lower-quality non-organic fertilizers and informal compost.

Niche Strategies:

- Educate Strategy: Educating customers about the risks of low-quality, unregulated products and the benefits of high-quality, sustainable compost products can help shift consumer preferences. Awareness campaigns and eco-labeling can increase customer confidence and willingness to pay for superior products.
- Top Niche Strategy: Targeting a niche market of customers who prioritize quality and sustainability over price. By focusing on this specific segment, the company can initially charge a premium for their high-quality products and build a loyal customer base.

2. Many customers, particularly in the retail market, prioritize low prices over quality. Economic pressures lead them to choose cheaper alternatives, even if these are of inferior quality, reflecting a low willingness to pay for sustainable, high-quality compost products.

Influencing Conditions:

- Cultural Preferences and Resistance: Resistance to paying more for environmentally beneficial options.
- External Factors: Economic uncertainties caused by natural events like El Niño.
- Political Stability: Political instability affecting economic conditions and customer spending.

Niche Strategies:

- Educate Strategy: Conducting comprehensive education campaigns to inform customers about the environmental and quality benefits of compost products. This strategy includes awareness campaigns, eco-labeling, and customer engagement activities to increase the willingness to pay for sustainable products.
- Top Niche Strategy: Focusing on a niche market of consumers who value quality and sustainability, allowing the company to charge a premium and build a reputation for high-quality compost products. This strategy also helps retain paying customers during times of economic or political instability.

3. There is a significant lack of customer knowledge and awareness regarding the quality and benefits of compost products. This leads to a substantial portion of the market being uninformed about the advantages of using high-quality compost, thus hindering the adoption of sustainable practices.

Influencing Condition:

- Societal Awareness and Perception: Insufficient awareness and understanding of the benefits of compost and the circular economy among consumers.

Niche Strategies:

- Educate Strategy: Conducting comprehensive education campaigns to inform customers about the environmental and quality benefits of compost products. This strategy includes awareness campaigns, eco-labeling, and customer engagement activities to increase the willingness to pay for sustainable products.

- Top Niche Strategy: Focusing on a niche market of consumers who value quality and sustainability, allowing the company to charge a premium and build a reputation for high-quality compost products.

4. Unclear, conflicting, and overly stringent regulatory requirements, combined with bureaucratic delays and high costs, create significant obstacles to obtaining necessary permits, leading to operational uncertainty and high risks for the company.

   Influencing Condition:

   - Institutional Policies: The complex and burdensome regulatory environment hinders the company's ability to operate formally.

   Niche Strategy:

   - Policy Advocacy Strategy: The company can engage with regulatory bodies and participate in policy-making committees to advocate for clearer, more supportive regulations. By educating policymakers about the specific needs and benefits of compost products, the company can help shape a more favorable regulatory environment.

5. The lack of supportive infrastructure and incentives for circular economy initiatives discourages formal activities and innovation, leaving companies without necessary governmental support or facilitation to operate sustainably and legally.

   Influencing Condition:

   - Governmental Support: Insufficient governmental support impacts the company's ability to compete formally.

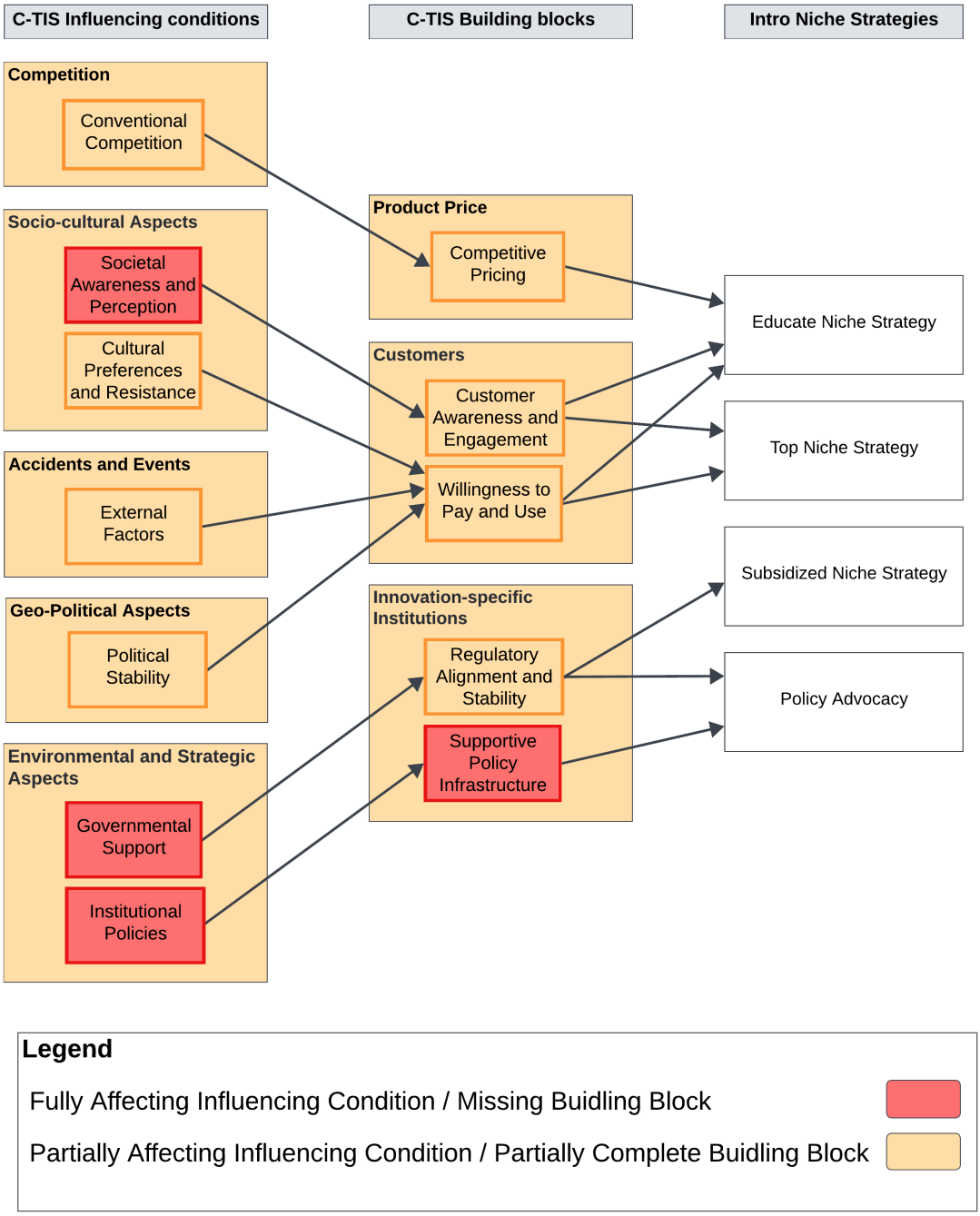
   Niche Strategies:

   - Policy Advocacy Strategy: Engaging with government officials and policymakers to advocate for increased support and incentives for circular economy initiatives. This can include lobbying for subsidies, tax breaks, or other financial incentives that make it easier for companies to adopt and implement circular practices.
   - Subsidized Niche Strategy: Seeking subsidies or financial support from the government or other organizations to offset the costs associated with adopting circular economy practices. This strategy can help make the company's products more competitively priced and sustainable in the long term.

These niche strategies, derived from the influencing conditions affecting the building blocks, provide targeted approaches to overcoming the barriers identified in Case 2. The application of these strategies aims to facilitate the large-scale diffusion of circular innovations by addressing the specific challenges encountered in the introduction stage.

Figure 15 illustrates how the niche strategies result from identifying which influencing conditions affect specific building blocks.

Figure 15: Niche Strategies Case 2



6.3 Strategy comparison

Comparison of the Case Strategies

In this section, we compare the niche strategies developed from the framework for Case 1 and Case 2, identifying similarities and differences and compiling a comprehensive list of niche strategies applicable to circular innovations in Latin America.

Both cases exhibited some common barriers, resulting in similar niche strategies. For example, the educate strategy emerged as crucial in both cases. In Case 1, this strategy addressed

the barriers related to consumers prioritizing cost over sustainability and the lack of customer awareness and understanding. Similarly, in Case 2, the educate strategy tackled the issues of customers prioritizing low prices over quality and the lack of customer knowledge and awareness regarding compost products. The educate strategy involves implementing awareness campaigns, eco-labeling, and customer engagement activities to shift consumer preferences towards sustainable products.

Another common strategy is the top niche strategy. In Case 2, this strategy was employed to target a niche market of consumers who value quality and sustainability, thereby addressing the barriers of intense competition from cheaper, lower-quality products and economic pressures leading customers to choose cheaper alternatives.

The policy advocacy strategy was also used in both cases. In Case 1, this strategy addressed barriers related to the lack of alignment in regulatory frameworks and inconsistent environmental laws, as well as the absence of standardized norms and struggles to gain legitimacy for new circular products. In Case 2, policy advocacy was essential to overcome the challenges of overly stringent regulatory requirements and the lack of supportive infrastructure and incentives for circular economy initiatives. This strategy involves engaging with regulatory bodies, participating in policy-making committees, and educating policymakers to align the regulatory framework with the needs of circular innovations.

Each case also presented unique barriers that required specific niche strategies. For instance, in Case 1, the demo, experiment, and develop niche strategy was necessary to address the technological inefficiencies in the pyrolysis process. This strategy involves demonstrating the process in a controlled environment, experimenting with the technology, and further developing it to improve efficiency. Additionally, the subsidized niche strategy was employed to overcome the high financial barriers to scaling up the technology, seeking subsidies or financial support from the government or other organizations.

In Case 2, the subsidized niche strategy was also used to tackle the lack of supportive infrastructure and incentives for circular economy initiatives. By seeking subsidies or financial support, the company could make its products more competitively priced and sustainable in the long term.

Combining the strategies from both cases, we have the following comprehensive list of niche strategies for circular innovations in Latin America:

1. Educate Strategy
2. Top Niche Strategy
3. Policy Advocacy Strategy
4. Demo, Experiment, and Develop Niche Strategy
5. Subsidized Niche Strategy
6. Geographic Niche Strategy

Comparison with Literature Review and Expert Interviews

Next, we compare these niche strategies with the strategies identified in the literature review and expert interviews to see commonalities and differences.

The literature review identified several strategies, including education and awareness, legislative support, integration of the informal sector, technological innovation, financial incentives, collaborative networks, public policies and governance, and supporting social equity. The educate strategy aligns well with the education and awareness strategy from the literature, highlighting the importance of shifting consumer preferences towards sustainable products through awareness campaigns and eco-labeling.

The policy advocacy strategy aligns with the legislative support strategy, emphasizing the need to engage with regulatory bodies and advocate for clearer, more supportive regulations. The subsidized niche strategy corresponds with financial incentives, as both approaches involve seeking subsidies or financial support to make circular products more competitively priced and sustainable.

Some strategies from the literature review, such as the integration of the informal sector and supporting social equity, were not directly addressed in the niche strategies but remain relevant for future research. The focus on technological innovation in the literature partially aligns with the demo, experiment, and develop niche strategy, which involves improving technological efficiency through controlled demonstrations and experiments.

The expert interviews emphasized institutional support, funding and support, organizational changes, market strategies, and technological adoption. The policy advocacy strategy aligns with the need for institutional support and the development of clear and practical regulations. The subsidized niche strategy corresponds with funding and support, as both involve seeking financial assistance to overcome high initial costs.

The emphasis on market strategies and engaging consumers through education in the expert interviews aligns with the educate strategy. The demo, experiment, and develop niche strategy also partially aligns with the technological adoption strategy, focusing on improving technological efficiency and innovation.

By identifying these niche strategies and comparing them with existing strategies in the literature and expert interviews, this research provides a targeted approach for overcoming barriers to the large-scale diffusion of circular innovations in Latin America. The comprehensive list of niche strategies can serve as a valuable guide for companies and policymakers aiming to promote circular economy practices in the region.

7 Discussion

The discussion chapter delves into the interpretation and implications of the findings from this study on CE practices in Latin America. It begins by examining how the results align with or challenge existing research, highlighting their theoretical significance. Practical implications are then considered, focusing on how these findings can inform policy-making, strategic planning, and industry practices. The chapter also underscores the scientific contributions of the study, including new insights and advancements in methodology and theory.

A critical component of the discussion is exploring alternative perspectives on CE practices in Latin America, taking into account socio-economic and cultural contexts. Furthermore, the influence of global CE trends on Latin American practices is analyzed, providing a broader context for the study's findings.

7.1 Interpretation of the Results

CE and CI Latin American Definitions

The interpretation of results begins with a discussion on the definition of CE, followed by the application of the CI concept to this definition.

The first insights into the definition of CE came from the literature review, which highlighted various definitions emphasizing sustainability, resource efficiency, and lifecycle thinking. In the Latin American context, unique socio-economic and cultural dimensions significantly shape CE. The informal sector is crucial in waste management and recycling, necessitating its recognition and inclusion in CE strategies.

From the literature, the technocentric definition by Kumar et al. (2019) was found to be the most fitting. This definition describes CE as an economic system aimed at closing product life cycles through resource reuse, recycling, and recovery. It aligns particularly well with the Latin American nuances of waste management and the integration of the informal sector. This alignment addresses one of the key research questions concerning the appropriate definition of CE in this context.

Further insights were gained from the empirical assessment through case studies and expert interviews. The mining tire recycling case defined CE as a system where waste from a production chain is reintegrated into the same chain as raw materials. In contrast, the compost production case viewed CE as transforming waste into new resources, emphasizing environmental improvement and social responsibility.

The expert interviews provided a comprehensive definition, viewing CE as a system that involves rethinking and redesigning production and consumption processes to minimize waste and maximize resource efficiency. This definition emphasizes the importance of waste management and recycling, extending across the entire lifecycle of products and services.

Barriers to CI diffusion in Latin America

In the exploration of barriers to CIs diffusion within the Latin American context, the primary focus is on the barriers identified through the application of the adapted framework in the case studies. These case studies provide a detailed view of the specific challenges faced by different sectors in implementing circular economy practices.

Mining Tire Recycling Case:

1. The challenge of scaling the pyrolysis process faces significant technological inefficiencies and limitations. This barrier is linked to the incomplete Scalability sub-block within the Circular Production System building block.
2. Inefficiencies in the transportation and distribution of recycled materials due to an underdeveloped network lacking local connectedness and bidirectional connections. This barrier stems from the incomplete Interconnected Network sub-block within the Network Formation and Coordination building block.
3. A lack of awareness and understanding of circular products among customers, tied to the incomplete Customer Awareness and Engagement sub-block within the Customers building block.
4. A low willingness to pay for sustainable products due to economic constraints, associated with the Willingness to Pay and Use sub-block within the Customers building block.
5. Misaligned and inconsistent regulations affecting the Regulatory Alignment and Stability sub-block within the Innovation-specific Institutions building block.
6. A lack of standardization and legitimacy for new circular products, impacting the Standardization and Legitimacy sub-block within the Innovation-specific Institutions building block.

Compost Production Case:

1. The company struggles to offer competitively priced compost products due to competition from informal fertilizers that lower quality to reduce costs. This barrier is linked to the Competitive Pricing sub-block within the Product Price building block.
2. A lack of awareness and knowledge about the benefits of high-quality compost among customers, associated with the Customer Awareness and Engagement sub-block within the Customers building block.
3. Economic pressures lead to a low willingness to pay for sustainable products, driven by a preference for cheaper alternatives, tied to the Willingness to Pay and Use sub-block within the Customers building block.
4. Conflicting and overly stringent regulatory requirements, combined with bureaucratic delays and high costs, create significant obstacles to obtaining necessary permits. This barrier is linked to the Regulatory Alignment and Stability sub-block within the Innovation-specific Institutions building block.
5. The absence of supportive infrastructure and incentives for circular economy initiatives discourages formal activities and innovation. This barrier stems from the Supportive Policy Infrastructure sub-block within the Innovation-specific Institutions building block.

These barriers show that the primary obstacles identified through the case studies resonate with the broader challenges discussed in existing literature and by experts. This comparison reinforces the validity of the case study findings and emphasizes the pervasive nature of these barriers across different contexts in Latin America.

Circular and Latin American adaptation of the TIS framework

One of the key objectives of this research was to adapt the Technological Innovation Systems (TIS) framework to better fit the context of circular innovation in Latin America. This adaptation process was meticulously carried out by analyzing and comparing three prior circular adaptations: those by Shankar (2023), Warns (2023), and Engelen (2023).

Initially, the decision to divide the building blocks and influencing conditions into sub-blocks and sub-conditions was inspired by Shankar (2023)'s approach. This decision aimed to provide a detailed and nuanced framework capable of addressing specific aspects of circular innovation. To tailor the framework to the Latin American context, regional characteristics were identified and integrated. Key challenges such as infrastructure deficiencies, legal and administrative inefficiency, informality, and recurrent socio-political instability were critical in shaping the adapted framework.

The resulting framework, labeled C-TIS (LA), or Circular TIS for the Latin American context, encapsulates the comprehensive adaptation process. It addresses both circularity and regional-specific challenges, making it uniquely suited to promote circular innovations in Latin America.

The C-TIS (LA) framework not only integrates regional characteristics but also aligns with the broader principles of circular economy and innovation systems. It provides a tailored approach to addressing barriers and leveraging opportunities for circular innovation in Latin America. Highlighting the importance of infrastructure development, regulatory alignment, and the integration of informal sectors. Serving as a model for other regions with similar challenges, demonstrating the value of context-specific adaptations in achieving sustainable development goals.

Strategies to overcome barriers to CI diffusion

Next, we discuss the niche strategies developed for overcoming the barriers identified in the case studies. Each barrier is analyzed with respect to the influencing conditions that affect the corresponding building blocks, and the implications of the proposed niche strategies are explored. These strategies are tailored to address the specific challenges encountered during the introduction and early diffusion stages of circular innovations.

Case 1: Recycling Mining Tires through Pyrolysis

The challenge of scaling the pyrolysis process is a significant barrier in the recycling of mining tires. This barrier is primarily caused by limitations in circular technological knowledge and resource availability. To address these challenges, a Demo, Experiment, and Develop Niche Strategy can be employed. By collaborating with academia and industry partners, the company can refine and demonstrate the pyrolysis technology in controlled environments. This approach not only helps in technological advancement but also builds credibility among stakeholders, potentially attracting investors and regulatory support. Additionally, a Subsidized Niche Strategy can be utilized to mitigate high capital expenditure barriers. Seeking financial support from governmental and non-governmental organizations highlights the importance of public-private partnerships and underscores the need for supportive policy frameworks.

Inefficiencies in the network for circular economy activities pose another significant barrier, affecting resource availability, resource flow optimization, and transportation infrastructure. Implementing a Geographic Niche Strategy can address these issues by establishing operations near mining hubs. This proximity can reduce logistical inefficiencies, improve resource flow, and

mitigate transportation challenges, thus enhancing overall operational efficiency and fostering better collaboration within the supply chain.

Customer willingness and awareness are critical factors influencing the adoption of circular products. The Educate Niche Strategy is vital in this context. Educating customers about the long-term benefits and environmental impacts of circular products can shift consumer preferences towards sustainability. Awareness campaigns and eco-labeling efforts are essential to increase market acceptance and demand for circular products, addressing both the low willingness to pay and the lack of customer engagement barriers simultaneously.

Regulatory alignment and standardization are also crucial for the diffusion of circular economy innovations. The lack of alignment in regulatory frameworks and inconsistent environmental laws can be tackled through a Policy Advocacy Strategy. By engaging with regulatory bodies and participating in policy-making committees, the company can educate policymakers about circular technologies and advocate for clearer and more supportive regulations. This strategy inherently includes aspects of the educate niche strategy to ensure policymakers are well-informed. Additionally, the absence of standardized norms can be addressed by collaborating with universities or external laboratories to validate products and work towards establishing standardized norms, thus gaining legitimacy and market acceptance.

Case 2: Compost Production in Peru

The compost production case in Peru faces significant barriers in competitive pricing due to intense competition from cheaper, lower-quality non-organic fertilizers. To address this, an Educate Strategy can be employed to inform consumers about the risks associated with low-quality, informal fertilizers and the benefits of high-quality compost. Additionally, a Top Niche Strategy can target a market segment that prioritizes high-quality, sustainable products, allowing the company to maintain premium pricing and establish credibility.

Similarly, the barrier of low willingness to pay for sustainable compost products, driven by cultural preferences and economic pressures, can be tackled using the same strategies. Educating consumers about the benefits of compost and circular economy principles is crucial for increasing demand and engagement. By focusing on market segments that value sustainability, the company can navigate economic pressures and build a loyal customer base willing to invest in high-quality compost products.

A significant lack of customer knowledge and awareness about the benefits of compost products can also be addressed through an Educate Strategy. Increasing societal awareness through targeted campaigns can shift consumer behavior towards sustainable practices. Additionally, targeting a top niche market that appreciates high-quality, environmentally beneficial products helps in building a strong customer base.

Regulatory and policy barriers in the compost production case, such as unclear and overly stringent regulatory requirements, can be mitigated through a Policy Advocacy Strategy. Engaging with policymakers to streamline regulatory processes and reduce bureaucratic delays helps create a supportive environment for circular economy initiatives. This strategy emphasizes the need for aligning regulations with industry needs and facilitating formal operations. Furthermore, the lack of supportive infrastructure and incentives can be addressed by seeking government support and subsidies, promoting sustainable operations and innovation.

The frequent recurrence of education and policy advocacy strategies underscores their critical

role in promoting circularity in Latin America. Education is a fundamental strategy for overcoming multiple barriers, as it raises awareness and understanding of circular products among consumers and policymakers. This strategy's prominence in both case studies, as well as in the literature and expert interviews, highlights its pivotal role in the region.

Policy advocacy is equally essential for creating a supportive regulatory environment. Engaging with regulatory bodies to advocate for clearer and more supportive regulations is crucial for aligning the regulatory framework with the needs of circular innovations. This strategy is particularly relevant in addressing barriers related to regulatory alignment and standardization.

The implications of these strategies extend beyond the individual cases. The emphasis on niche strategies tailored to specific barriers highlights the importance of addressing the unique challenges faced by circular innovations in their early stages. These findings underscore the necessity for frameworks like C-TIS (LA), designed to facilitate the introduction and early diffusion of circular innovations, ensuring they achieve large-scale impact in the region.

Furthermore, comparing these strategies with those identified in the literature and expert interviews reveals a broader trend. While education and policy advocacy are common across different contexts, other strategies such as legislative support, technological innovation, and financial incentives also play significant roles. The literature and expert interviews emphasize the need for comprehensive approaches that include both consumer engagement and regulatory support, reinforcing the importance of creating an enabling environment for circular innovations.

In summary, the niche strategies developed in this study provide targeted approaches to overcoming barriers to circular innovation diffusion. By addressing the specific challenges identified in the case studies, these strategies offer valuable insights into promoting circularity in Latin America. The emphasis on education and policy advocacy highlights the crucial role of raising awareness and creating supportive regulatory frameworks, ensuring that circular innovations can achieve large-scale impact and contribute to sustainable development in the region.

7.2 Practical Implications

The findings from this study have several practical implications for policymakers, industry stakeholders, and practitioners involved in the promotion and implementation of circular economy (CE) practices in Latin America. By understanding the specific barriers and identifying effective strategies to overcome them, this research provides a comprehensive roadmap for facilitating the diffusion of circular innovations (CIs) in the region.

Policy-Making and Regulatory Frameworks

- Developing Supportive Regulatory Frameworks: The study highlights the need for clear, consistent, and supportive regulatory frameworks that facilitate the adoption of CIs. Policymakers should engage directly with industry stakeholders to understand their needs and challenges. Specific actions could include the creation of multi-stakeholder committees that include industry representatives, policymakers, and experts from academia to collaboratively develop regulations that are both supportive of circular practices and sensitive to the unique socio-economic conditions of Latin America. Given the region's diverse regulatory environments, it may be beneficial to start with pilot regulatory initiatives, gradually scaling up as these frameworks are refined.
- Providing Financial Incentives and Subsidies: Governments should consider implementing targeted financial incentives, such as tax breaks, grants, or low-interest loans, for companies adopting circular innovations. These financial supports are particularly crucial for

small and medium-sized enterprises (SMEs), which often face significant capital expenditure barriers. For example, a targeted subsidy program could be established to support companies in the early stages of adopting technologies like pyrolysis in the mining sector or composting in agriculture. However, the feasibility of these programs depends heavily on the fiscal capacity of the respective governments and the political will to prioritize sustainability over immediate economic gains.

Industry Practices and Strategic Planning

- Prioritizing Consumer Education Campaigns: Companies should launch comprehensive educational campaigns aimed at raising awareness about the benefits of circular products among consumers. These campaigns could leverage social media, partnerships with educational institutions, and collaborations with NGOs to reach a broad audience. For instance, a campaign might include workshops and webinars that focus on the long-term environmental and financial benefits of adopting circular products. However, given the diversity of consumer awareness and education levels across Latin America, these campaigns should be tailored to different demographic and socio-economic groups to ensure maximum impact.
- Fostering Collaboration for Technological Development: Collaboration between businesses, academia, and government research institutes is essential to enhance the efficiency and scalability of circular technologies. Establishing public-private partnerships (PPPs) could facilitate shared investment in research and development (RD), leading to more robust and scalable solutions. For example, a PPP could focus on developing and scaling up reverse logistics systems for waste management in urban areas. The feasibility of such collaborations, however, may be challenged by the varying levels of trust and collaboration readiness among these stakeholders in different Latin American countries.
- Implementing Niche Strategies: Businesses should consider adopting niche strategies that address specific barriers identified in this research. For instance, targeting high-income consumers who prioritize sustainability can help companies maintain premium pricing and establish market credibility. Companies could also explore geographic niche strategies by focusing on urban areas where infrastructure and consumer awareness are more developed. However, the feasibility of these strategies may vary depending on the local market conditions and consumer behavior in different regions.

Infrastructure Development

- Investing in Transportation and Digital Infrastructure: The study underscores the critical need for improved transportation and digital infrastructure to support CE activities. Governments and private sector stakeholders should prioritize investments in developing robust infrastructure that facilitates efficient resource circulation and reverse logistics. For example, enhancing transportation networks in rural areas can help overcome logistical challenges in waste collection and recycling. Additionally, improving digital infrastructure could support the development of platforms that connect waste producers with recyclers, optimizing the supply chain. However, these infrastructure investments require significant financial resources and long-term planning, which may be challenging in regions with limited public funds or political instability.

Stakeholder Engagement

- Building Strong Collaborative Networks: The successful implementation of CE practices requires strong, collaborative networks between public and private sectors. Stakeholders

should prioritize creating platforms for regular dialogue and collaboration, such as industry forums or sustainability roundtables. These platforms can help address regulatory alignment and customer awareness barriers by fostering a shared understanding of the benefits and challenges of CE. For example, a regional CE forum could be established where stakeholders from different countries share best practices and collaborate on cross-border initiatives. The feasibility of such networks depends on the willingness of stakeholders to engage in open dialogue and the presence of facilitators who can bridge gaps between different sectors.

Utilization of the Adapted Framework

- Applying the C-TIS (LA) Framework: The adapted C-TIS (LA) framework developed in this study provides a practical tool for systematically identifying barriers to circular innovations and developing tailored strategies to overcome them. Stakeholders can use this framework to conduct detailed analyses of their specific contexts, allowing for more effective and context-specific interventions. For instance, a company could use the framework to identify the most pressing barriers in its operations, such as regulatory challenges or consumer awareness gaps, and develop targeted strategies to address these issues. However, the complexity of the framework may require training and capacity-building efforts to ensure that stakeholders can effectively apply it in their decision-making processes.

Feasibility Considerations

While the recommendations provided in this study offer actionable strategies for promoting CE in Latin America, their feasibility varies depending on the specific context of each country and sector. Factors such as economic conditions, political stability, and cultural attitudes towards sustainability will significantly influence the implementation of these recommendations. Therefore, it is crucial for stakeholders to critically assess the local context and adapt these strategies accordingly. Continuous monitoring and iterative refinement of the strategies will be necessary to ensure their effectiveness and sustainability in the long term.

7.3 Scientific Contribution

This research makes several significant contributions to the scientific understanding of circular economy practices and the diffusion of circular innovations in Latin America. The study extends existing theoretical frameworks and provides new insights that enhance our understanding of the unique challenges and opportunities in this region.

Adaptation of the TIS Framework:

The adaptation of the Technological Innovation Systems (TIS) framework to the specific context of circular innovations in Latin America is a major scientific contribution. The C-TIS (LA) framework incorporates regional characteristics such as infrastructure deficiencies, legal and administrative inefficiency, informality, and socio-political instability. It reinforces the use of the building block Reverse Logistics and the influencing conditions Environmental and Strategic Aspects, and Data Infrastructure, which were included in previous circular adaptations. Additionally, it contributes with the newly added building block Informal Sector, highlighting its importance in Latin America and in circularity, especially in waste management. Furthermore, the framework introduces the influencing conditions Transportation Infrastructure and Geopolitical Aspects, which are critical for understanding and promoting circular innovations in the region. This tailored framework provides a more accurate and relevant tool for analyzing and promoting circular innovations in Latin America.

Identification of Context-Specific Barriers:

The study identifies and categorizes specific barriers to the diffusion of circular innovations in Latin America. By providing detailed case studies and an integrated list of generalized barriers, the research offers a comprehensive understanding of the challenges faced by different sectors, especially in Chile and Peru. These barriers contribute as empirical evidence of how obstacles present themselves in certain sectors in Latin America, with some of them reinforcing theoretical barriers previously identified as important for the region. This identification is crucial for developing targeted strategies and policy interventions.

Development of Niche Strategies:

The derivation and conceptualization of niche strategies using the adapted TIS framework is another significant contribution. These strategies are tailored to address the specific barriers identified in the case studies in Chile and Peru, providing practical approaches for facilitating the introduction and early diffusion of circular innovations. The study highlights the importance of education, policy advocacy, and technological development in overcoming these barriers. Ultimately, it presents niche strategies for the introduction stage of circular innovations in Latin America, an aspect that has not been adequately represented in the scientific literature so far.

Comparison with Existing Strategies:

By comparing the strategies derived from the C-TIS (LA) framework with those identified in the literature and expert interviews, the study offers a broader perspective on the effectiveness of different approaches. This comparison underscores the unique contributions of the TIS-derived strategies and highlights the need for context-specific adaptations to address regional challenges effectively.

Integration of Socio-Economic and Cultural Contexts:

The research emphasizes the importance of considering socio-economic and cultural contexts in the promotion of circular economy practices. The integration of these contexts into the adapted framework and the identification of relevant barriers and strategies provide valuable insights for both researchers and practitioners. Specifically, by including realities such as the informal sector and issues like geopolitical and economic instability, the research creates a more complete picture of the situation in the region. This approach provides a better understanding of the barriers, their underlying causes, and possible strategies to address them effectively.

In summary, this study advances the scientific understanding of circular economy practices in Latin America by providing a tailored theoretical framework, identifying context-specific barriers, and developing practical strategies for overcoming these challenges. These contributions are valuable for guiding future research and informing policy and practice in the promotion of circular innovations in the region.

7.4 Alternative View of Circularity in Latin America

The research highlights that indigenous and local communities in Latin America possess unique and valuable perspectives on CE. These perspectives are deeply embedded in community well-being, sustainability, and harmony with nature, often prioritizing these values over economic profit. This contrasts with the more prevalent business and technology-driven models of CE, which emphasize resource efficiency and economic returns.

Indigenous and local practices offer a holistic approach to CE, integrating sustainable resource management, communal benefit, and long-term ecological balance. These practices are not merely historical; they are actively employed in various regions today, emphasizing reuse, repair, and reduced consumption (Circle Economy, 2023; Paño Yañez, 2021). The integration of these perspectives can enrich mainstream CE strategies by providing alternative methods for achieving sustainability that align with local cultural and societal values.

The C-TIS (LA), adapted in this study, may not be entirely suitable for analyzing circular innovations in indigenous and local settings. The C-TIS (LA) framework's focus on economic profit and technological advancement does not align with the goals and success metrics in these communities, which are more centered on ecological balance and community well-being.

For instance, the agricultural practices of the Natabuela community in Ecuador, as well as the entrepreneurial activities of Kiwicha women through the community enterprise Warmikuna NATABUELA, emphasize equity, resilience, and transparency (Almeida Guzmán et al., 2023). These practices highlight the inherent circularity within the community economies of indigenous peoples and their application of CE principles. These examples demonstrate that a framework prioritizing economic outcomes might overlook critical aspects of circularity in these contexts.

Integrating principles from indigenous and local practices into mainstream CE strategies could significantly enhance sustainability efforts. Indigenous knowledge systems offer valuable insights into resource management, ecological sustainability, and community resilience. By incorporating these principles, mainstream CE strategies could adopt a more inclusive and holistic approach that prioritizes environmental health and social equity alongside economic development.

The concept of Buen Vivir, which emphasizes harmony with nature, community well-being, and social equity, aligns closely with CE principles and challenges the dominant development paradigm (Chuji et al., 2019). Emphasizing these values could lead to more sustainable and equitable circular practices.

Given this new view of CE, some of the definitions and discourses discussed in the literature review, initially deemed out of scope for this research, find relevance here. For example, the "Reformist Circular Society" discourse proposed by Calisto Friant et al. (2020), which focuses on social justice and participatory governance while addressing the resource nexus, aligns with these indigenous perspectives. The definition by Grafström and Aasma (2021) fits within this discourse, portraying CE as a regenerative economy that separates technological and biological cycles, valuing systemic change that incorporates social dimensions. This approach could be highly relevant in contexts where environmental justice is a significant concern, especially in regions affected by green colonialism and exploitation by the Global North.

Future research should explore how indigenous and local perspectives can inform and reshape existing CE models. Developing new frameworks or adapting existing ones to better capture the values and success metrics relevant to these communities is crucial. This research could lead to a more comprehensive understanding of CE that includes diverse cultural and societal values, ultimately fostering more sustainable and equitable circular practices.

In summary, the alternative perspectives on CE found in indigenous and local communities in Latin America present a valuable opportunity to enrich and expand mainstream CE strategies. These perspectives prioritize ecological sustainability and social equity, offering a holistic approach that can complement and enhance current CE models. Future research should continue to explore these perspectives, integrating them into broader CE frameworks to achieve more

inclusive and effective sustainability outcomes.

7.5 The Global Circular Economy and Its Impact in Latin America

The global trends in CE and sustainability often have profound and complex impacts on developing regions like Latin America. While these trends promote sustainability and environmental stewardship, they can inadvertently perpetuate historical inequalities and create new challenges for the region.

One critical concept that has emerged is "green colonialism," which describes the geographic outsourcing of labor and natural resources from Latin America to sustain the global market, particularly in the context of the energy transition. This phenomenon, rooted in historical North-South imbalances, raises significant environmental justice issues (Dorn, 2022). For instance, Latin America's rich natural resources, such as lithium in the Lithium Triangle, are increasingly in demand for sustainable technologies like batteries and renewable energy storage. However, this demand often comes at a high environmental and social cost. The extraction of lithium in the Salar de Atacama in Chile has led to severe water injustices and socio-environmental conflicts affecting indigenous communities (Jerez et al., 2021). This exemplifies the broader issue where the Global South is exploited under the guise of environmental progress (Zografos & Robbins, 2020).

The global geopolitical environment significantly impacts the practical implementation of circular innovations. This includes the exploitation and pollution of less developed countries by more developed ones through the extraction of raw materials and other environmentally damaging practices. Powerful countries often exert influence to exploit resources in less powerful nations, perpetuating cycles of dependency and environmental degradation. An illustrative example is the controversial agreement allowing China to export its waste to Ecuador. This practice highlights a troubling trend where more developed countries offload their waste, enhancing their sustainability records while exacerbating ecological challenges in recipient countries (Gonzalez, 2024). Such practices not only undermine local environmental standards but also strain the already inadequate waste processing capabilities in Latin America.

These global dynamics have several implications for CE practices in Latin America:

1. Environmental and Social Costs: The exploitation of natural resources for global sustainability initiatives often results in significant environmental degradation and social injustices in Latin America. This underscores the need for a critical evaluation of global sustainability initiatives to ensure they do not disproportionately burden developing regions.

2. Technological and Economic Imbalances: The emphasis on techno-optimistic solutions driven by Euro-North American-centric modernity must be balanced with local realities. Latin America's unique socio-economic and cultural contexts should inform the development and implementation of CE strategies, ensuring they are inclusive and equitable.

3. Policy and International Collaboration: Addressing these challenges requires robust policy frameworks and international collaboration. Policymakers in Latin America must advocate for fair trade agreements that protect the region's environmental and social interests. Greater investment in local waste management infrastructure and technologies that align with CE principles is also crucial. International collaborations should support these efforts, ensuring that sustainability transitions are inclusive and equitable.

Integrating critical sociological perspectives into the TIS framework can provide a deeper understanding of these global dynamics. The strategic and economic influencing conditions within the framework should consider geopolitical factors that enable powerful countries to pollute, thus

making other countries sustainable. This approach absorbs activism into an existing model, enhancing its applicability to the Latin American context.

The impact of global circular economy trends on Latin America is significant, highlighting the need for critical evaluation and inclusive policymaking. By integrating local and indigenous perspectives and ensuring fair global practices, Latin America can navigate these challenges and advance towards a more sustainable and just circular economy. This approach not only benefits the region but also contributes to a more equitable global sustainability movement.

8 Conclusion

In this final chapter, the key elements of the study on CE practices in Latin America are revisited. The conclusion brings together insights from the extensive literature review, the adaptation of the TIS framework to circularity, and the practical application of this framework. By summarizing the findings, the chapter addresses the research questions and discusses the theoretical and practical implications of the research. The study's limitations are also acknowledged, providing a clear evaluation of the constraints and challenges encountered. Finally, reflective thoughts on the broader impact of this research are offered, along with suggestions for future research directions to encourage continued exploration and implementation of CE principles. This chapter aims to highlight the significance of the work and provide a comprehensive overview while setting the stage for ongoing academic and practical advancements in this important field. Finally, identifying gaps in the research, the chapter proposes areas for future investigation to ensure that the conversation about circular economy practices continues to evolve and expand.

8.1 Summary of Findings

SQ1: ***How can we define CE and CIs within the Latin American context?***

The research synthesized insights from the literature review, case studies, and expert interviews to develop definitions of CE and CIs tailored to the Latin American context.

The integrated definition of CE, reflecting the unique socio-economic and cultural dimensions of Latin America, is as follows:

"The circular economy in Latin America involves rethinking and redesigning production and consumption processes to minimize waste and maximize resource efficiency. This approach emphasizes waste management, recycling, and transforming waste into valuable resources throughout the entire lifecycle of products and services. The goal is to achieve sustainability through regulatory alignment, technological innovation, and societal engagement."

This definition emerged from multiple sources. The literature review emphasized sustainability, resource efficiency, and the inclusion of the informal sector. Case study perspectives contributed by focusing on reintegrating waste into production chains and transforming waste into new resources. Additionally, expert interviews highlighted comprehensive waste management and lifecycle considerations, reinforcing the integrated approach.

Building on the CE definition, CIs are defined as:

"Innovations developed to align with the principles of the circular economy, emphasizing waste minimization, resource efficiency, and sustainability through regulatory alignment, technological innovation, and societal engagement."

The CI definition is supported by practical applications observed in the case studies, such as the mining tire recycling initiative and compost production, which demonstrate how CI principles can be applied to achieve waste minimization and resource efficiency.

These definitions provide a tailored understanding of CE and CI for Latin America, reflecting the region's specific needs and opportunities in achieving sustainable development.

SQ2: ***What are the barriers impacting the adoption of CIs in Latin American contexts?***

The primary barriers impacting the adoption of CIs) in Latin American contexts were identified through the case studies, providing real-world examples of challenges encountered under different conditions. These barriers were integrated into a comprehensive list:

- Significant challenges in scaling up circular production processes efficiently.
- Inefficiencies in the transportation and distribution network for CE activities, lacking local connectedness and bidirectional connections.
- Significant lack of customer awareness and understanding regarding the benefits and processes of CE products.
- Low willingness to pay for sustainable products, with consumers prioritizing cost over sustainability.
- Lack of alignment in regulatory frameworks and inconsistent environmental laws and waste disposal regulations significantly hinder the adoption and diffusion of CE innovations.
- Unclear, conflicting, and overly stringent regulatory requirements create significant obstacles to obtaining necessary permits.
- Absence of standardized norms and the struggle to gain legitimacy for new circular products make it challenging to achieve widespread acceptance and integration in the market.
- Competitive pricing challenges for circular products.
- Lack of supportive infrastructure and incentives for CE initiatives, discouraging formal activities and innovation.

These barriers were primarily derived from the specific contexts of the case studies, highlighting the real-world challenges faced in implementing CE practices in Latin America. Notably, some barriers, such as the significant lack of customer awareness and understanding and the low willingness to pay for sustainable products, were repeatedly identified across both case studies, underscoring their pervasive impact.

Additionally, the barriers identified in the literature review and expert interviews provide further reinforcement to this integrated list. Barriers related to legislative and regulatory challenges, market and consumer barriers, and technological and operational inefficiencies, as identified in these sources, align closely with those found in the case studies, thereby validating and strengthening the findings.

SQ3: ***What modifications are required in the TIS framework to make it suitable for analyzing and addressing the barriers specific to CIs?***

The adaptation of the Technological Innovation Systems (TIS) framework for CIss involved a detailed analysis and integration of elements from three prior adaptations by Shankar (2023), Warns (2023), and Engelen (2023). The primary modifications included:

- Division into Sub-blocks and Sub-conditions: Inspired by Shankar (2023)'s approach, this division aimed to create a more detailed and nuanced framework.
- New Building Blocks and Influencing Conditions: Key elements were selectively integrated to form a comprehensive framework, including:

  - Reverse Logistics from (Engelen (2023) as a new building block, emphasizing the importance of managing reverse flows of materials.
  - Environmental and Strategic Aspects from Warns (2023) as a new influencing condition, highlighting the need for considering environmental impacts and strategic planning.
  - Data Infrastructure from Engelen (2023), initially considered as a standalone influencing condition, was integrated as a sub-condition within a broader category to reflect its contextual relevance.

These modifications ensured that the framework could effectively address the specific barriers to CIs by providing a detailed and context-sensitive analysis tool. The resulting framework, labeled C-TIS, for the circular adaptation, is designed to tackle the unique challenges posed by CE practices, making it suitable for analyzing and addressing the barriers specific to CIs. Tables 7 and 8 (Section 3.4) show all the sub-blocks and sub-conditions that resulted form this partial adaptation.

SQ4: ***How can the TIS framework, already adapted for CIs, be further modified to specifically address the barriers unique to Latin America?***

The Technological Innovation Systems (TIS) framework, after being adapted for CIs, underwent further modifications to address the unique barriers present in the Latin American context. This process involved analyzing regional characteristics and determining the necessary adjustments to the framework. The primary modifications included the following adaptation scenarios:

- Scenario 2: New Context - Addressing regional characteristics that influence various elements of the framework. These include challenges with infrastructure, legal and administrative inefficiencies, informality, and socio-political instability.
- Scenario 3: New Influencing Conditions - Addition of:
  - Transportation and Digital Infrastructure: This influencing condition was developed by integrating the sub-conditions of transportation and communication infrastructure and data infrastructure. This decision was influenced by the significant impact of infrastructure on CIs, as evidenced in Case Study 1.
  - Geo-political Aspects: This new influencing condition addresses the sensitivity of the region to political stability and international influence, ensuring that the framework adequately reflects the socio-political dynamics affecting CIs.
- Scenario 4: New Building Blocks - Inclusion of:
  - Informal Sector: Recognizing the substantial impact of the informal sector on waste management and recycling in Latin America, this new building block was added. This decision was supported by insights from Case Study 2 and expert interviews, highlighting the sector's crucial role in the region.

These modifications resulted in a refined framework, named C-TIS(LA), that effectively addresses the barriers unique to Latin America by incorporating regional characteristics and new elements. This framework is designed to provide a comprehensive analysis tool for CIs within the specific context of Latin America.

Figure 11 (Section 4.3) shows the graphic representation of the C-TIS (LA) framework.

SQ5: ***How can the adapted TIS framework be used to derive and conceptualize effective strategies tailored to overcome the identified barriers to CIs in Latin America?***

The adapted TIS framework, tailored to the specific socio-economic and cultural context of Latin America, proves to be a valuable tool for deriving effective strategies to overcome the identified barriers to Circular Innovations (CIs). By systematically analyzing how various influencing conditions affect the building blocks within the TIS framework, we can conceptualize targeted strategies that address these barriers directly.

For each barrier identified in the case studies, the framework enabled the identification of relevant influencing conditions, such as Circular Technological Knowledge, Resource Availability, Cultural Preferences, Social Awareness, Institutional Policies, and Governmental Support. The connection between these influencing conditions and the incomplete or affected building blocks provided a clear pathway to develop niche strategies tailored to these specific challenges.

Figures 14 (Section 6.1) and 15 (Section 6.2) illustrate how the strategies from the cases were developed by applying the framework.

SQ6: ***How do strategies derived from the adapted TIS framework compare to other theoretical and practical strategies for Latin America?***

The strategies derived from the adapted TIS framework exhibit significant alignment with, yet notable distinctions from, other theoretical and practical strategies for promoting circular economy practices in Latin America. The comparison highlights the unique contributions and complementary aspects of the TIS-derived strategies.

Education and Awareness:

Both the literature review and expert interviews emphasize the critical role of education and awareness in overcoming barriers to circular economy adoption. This aligns with the TIS-derived strategies, which consistently highlight the need for educating consumers, policymakers, and industry stakeholders about the benefits and processes of circular products. The frequent recurrence of educational strategies underscores their foundational importance in shifting consumer behavior and fostering supportive regulatory environments.

Legislative Support and Policy Advocacy:

The literature and expert insights also stress the necessity of clear regulatory frameworks and government incentives to support circular economy practices. The TIS-derived strategies echo this emphasis through policy advocacy strategies aimed at engaging with regulatory bodies, participating in policy-making committees, and advocating for supportive regulations. This alignment underscores the critical need for robust and aligned regulatory frameworks to facilitate the large-scale adoption of circular innovations.

Technological Innovation and Financial Incentives:

While the literature emphasizes investing in R&D and infrastructure for recycling technologies, the TIS framework provides specific strategies such as demo, experiment, and develop, and subsidized niche strategies to address technological and financial barriers. These TIS-derived strategies offer practical approaches to overcoming high capital expenditure and technological inefficiencies, complementing the broader calls for technological innovation and financial incen-

tives found in the literature.

The comprehensive list of strategies that resulted from the case studies are:

- Demo, Experiment, and Develop Niche Strategy
- Subsidized Niche Strategy
- Geographic Niche Strategy
- Educate Niche Strategy
- Top Niche Strategy
- Policy Advocacy Strategy

In summary, the TIS-derived strategies complement and enhance the existing theoretical and practical strategies for circular economy adoption in Latin America. They provide a structured, context-specific approach that aligns with broader strategic themes while offering targeted solutions to specific barriers identified in the case studies. The emphasis on education, policy advocacy, and practical technological solutions ensures that these strategies are both comprehensive and actionable, addressing the unique challenges of promoting circular innovations in the region.

MRQ: *How can the TIS framework be adapted to identify the unique barriers to Circular Innovations in Latin America and what strategies can be derived from this adapted framework to overcome these barriers?*

The TIS framework was adapted to identify the unique barriers to CIs in Latin America by incorporating specific regional characteristics and new elements relevant to the socio-economic and cultural context of the region. This adaptation process involved:

1. Including Regional Characteristics as a New Context of the TIS: Recognizing regional factors such as infrastructure challenges, legal and administrative inefficiencies, informality, and socio-political instability.
2. Identifying Relevant Influencing Conditions and Building Blocks: New building blocks like the informal sector and new influencing conditions like transportation and digital infrastructure, and geo-political aspects were incorporated to address these factors. The framework was further detailed by dividing it into sub-blocks and sub-conditions to provide a context-sensitive analysis tool.
3. Developing a Refined Framework (C-TIS (LA)): This refined framework effectively addresses barriers unique to Latin America by incorporating the identified regional characteristics and new elements.

Using this adapted framework, barriers of circular innovations in Latin America can be identified. Effective strategies can then be derived by systematically analyzing how various influencing conditions affect the building blocks. For each barrier identified, the framework enables the development of niche strategies tailored to these specific challenges. These strategies include educational campaigns, policy advocacy, financial incentives, and other targeted approaches that address the unique barriers to the diffusion and adoption of circular innovations in the region. This systematic approach ensures that the strategies are both comprehensive and actionable, providing a structured methodology to overcome the identified barriers.

8.2 Limitations

While this study provides valuable insights into the promotion of Circular Economy (CE) practices and the diffusion of Circular Innovations (CIs) in Latin America, several limitations need to be acknowledged. Recognizing these limitations is crucial for understanding the scope and applicability of the findings and for identifying areas for future research.

Subjectivity in Qualitative Data:
The reliance on qualitative data, particularly through case studies and expert interviews, inherently involves subjective interpretation. This subjectivity can introduce biases in data collection and analysis, potentially affecting the neutrality of the findings. Although rigorous methods, such as triangulation, were employed to mitigate these biases, the influence of individual perspectives and experiences remains a significant factor. The subjective nature of this data means that the conclusions drawn may reflect the specific contexts and viewpoints of the participants, limiting the transferability of these findings to other contexts.

Participant Biases:
Responses from interviewees might be influenced by their personal experiences, beliefs, or the desire to present themselves or their organizations in a favorable light. This could lead to over- or under-reporting of certain aspects, thereby skewing the data. Despite the use of validation methods, such as cross-referencing responses with available data and including a diverse range of participants, it is challenging to fully eliminate these biases. This limitation suggests that the findings should be interpreted with caution, especially when considering the potential influence of unexamined biases on the results.

Scope of the Literature Review:
The literature review, though comprehensive, was conducted under time constraints and limited access to certain databases and resources. This may have resulted in the exclusion of some relevant studies or perspectives, particularly those published in languages other than English or Spanish, or those from less accessible journals. The potential for missing out on key studies or emerging trends could affect the completeness and accuracy of the theoretical foundation of this research. Future research should aim to expand the scope of the literature review to include a wider range of sources and perspectives, possibly through collaborations or access to broader databases.

Generalizability of Findings:
The case studies were conducted within specific sectors (mining in Chile and agriculture in Peru) and may not fully capture the diversity of industries or geographical contexts within Latin America. While the adapted TIS framework was developed to encompass common characteristics across the region, the validation through only two case studies limits the confidence in its broader applicability. The significant differences observed between these cases—such as the irrelevance of certain building blocks in specific sectors—underscore the necessity for caution when applying the framework to other contexts. This limitation highlights the need for further empirical research across a more diverse set of countries and industries to ensure that the framework can be effectively generalized.

Complexity of the Adapted TIS Framework:
The adaptation of the TIS framework to the specific context of Latin America involved multiple modifications, integrations, and the introduction of new elements. This increased complexity might pose challenges for its practical application, particularly for stakeholders who are not familiar with the theoretical foundations of the TIS framework. The complexity of the framework may also hinder its adoption in real-world scenarios where simplicity and ease of understanding

are critical. To address this, future work could focus on developing user-friendly guidelines or tools that simplify the application of the framework without compromising its analytical power.

Evolving Nature of CE Practices:
Circular Economy practices and innovations are continuously evolving, influenced by rapid technological advancements, changes in regulatory landscapes, and shifting societal attitudes. The findings of this study reflect the current state of CE practices but may become outdated as the field progresses. This limitation suggests that the framework and strategies developed in this research may require periodic updates to remain relevant. Ongoing research and iterative refinements of the framework are recommended to keep pace with the dynamic nature of CE.

Limitations in Data Availability:
The availability and quality of data in Latin America are often inconsistent, with challenges such as incomplete records, limited access to comprehensive datasets, and variability in data collection standards across countries. This limitation may have affected the depth and reliability of the empirical analysis, particularly in terms of capturing the full range of barriers and strategies in different contexts. Future research should consider developing partnerships with local institutions or leveraging new data collection technologies to improve data availability and reliability.

Ethical Considerations:
Ethical considerations, including ensuring participant confidentiality and obtaining informed consent, were paramount throughout the research process. While these measures are essential for maintaining the ethical integrity of the study, they also posed limitations on the scope of data collection and the types of questions that could be explored. For example, certain sensitive topics may not have been fully investigated due to ethical constraints. This limitation suggests that while the research provides valuable insights, there may be areas where further investigation is needed under different ethical frameworks or in different contexts.

Despite these limitations, the study offers significant contributions to the understanding and promotion of circular economy practices in Latin America. By being transparent about these constraints, the research provides a realistic perspective on its findings and sets the stage for future investigations to build upon and refine the insights presented.

8.3 Future Research

To build upon the findings of this study and further advance the understanding and implementation of circular economy practices in Latin America, several key areas for future research have been identified. These recommendations aim to refine the adapted TIS framework, explore new contexts, and address emerging challenges and opportunities within the region. The following sections outline specific areas where additional research and investigation are needed to enhance the effectiveness and applicability of circular innovations across diverse settings.

Case Study Research Across Different Countries and Sectors

The adapted TIS framework was developed by analyzing common characteristics across Latin America, aiming to capture nuances in a broad and encompassing way. In this sense, the framework is generalizable across Latin American countries by providing a broad understanding of circular innovations in the region. It was designed to encompass the shared challenges and opportunities present in different sectors and regions, offering a flexible tool that can be applied to a variety of contexts within Latin America.

However, the validation of this framework was limited to two case studies—one in the mining sector in Chile and the other in the agricultural sector in Peru. While these case studies demonstrated that the framework could effectively address the barriers in these diverse contexts, the differences between them also revealed that the framework's broad application might not capture specific sectoral or regional nuances. This highlights the importance of further research to validate and refine the framework across additional sectors and countries within the region.

To further ensure the robustness and applicability of the model, future research should include additional case studies across different sectors and countries in Latin America. These case studies would provide empirical data that could help refine the framework, making it more precise and tailored to specific contexts. By exploring circular innovations in diverse countries and sectors, it would be possible to identify and address the unique challenges and opportunities that exist in different regions and industries.

For instance, the barriers and strategies relevant to the mining sector in Chile may differ significantly from those pertinent to the agricultural sector in Peru. Similarly, the challenges faced by circular innovations in urban environments might contrast sharply with those in rural settings. Understanding these nuances will allow for the development of more tailored and effective strategies for promoting circular economy practices.

Moreover, while the framework was developed with a focus on common Latin American characteristics, its application has so far been limited to just two case studies. Although these case studies demonstrated that the framework could encompass the barriers identified in different sectors and countries, the significant differences between the cases suggest that further refinement is needed to account for sector-specific and country-specific elements. This suggests that while the framework may be broadly applicable within Latin America, its relevance in different contexts should be carefully evaluated.

Regarding other regions with similarities to Latin America, such as the Caribbean, future research could explore whether the framework can be adapted for use in these areas. However, given that the framework was specifically developed with a Latin American perspective, applying it elsewhere would require careful consideration of regional nuances not covered in the current adaptation.

Informal Sector as a New Innovation Environment

While this study focused on formal circular innovations and the role of the informal sector as an influencing factor, future research could explore the informal sector as the primary environment for circular innovations. This shift in focus would require developing a new theoretical model that acknowledges the unique characteristics and dynamics of informal economies.

Future studies could develop and apply a new theoretical model specifically designed to analyze and address barriers to circular innovations within the informal sector. This model would need to incorporate unique elements and assumptions relevant to informal economies, potentially offering new insights into the diffusion and adoption of circular innovations in Latin America. Understanding informal innovations could inform policymakers on how to better support these sectors, leading to more inclusive and effective circular economy strategies.

By examining how informal practices contribute to sustainability, future research could identify ways to integrate these practices into broader circular economy strategies. Reflecting on the underlying criticism concerning the colonial and imperialist dimensions of adopting Western

models like the TIS, a new model for the informal sector would better capture the complexities of regions like Latin America, where informal economies play a crucial role. This approach would offer a foundation for others to potentially take a radically different approach to studying circular economy.

Interconnected Barriers and Dynamic Models

Throughout this research, and particularly during the case studies, it became evident that barriers, building blocks, and influencing conditions within the TIS framework are interconnected in various ways. Influencing conditions often impact other influencing conditions, building blocks can affect each other, and barriers can directly or indirectly influence multiple barriers. This interconnectedness is also apparent when observing how a single influencing condition can impact more than one building block.

The traditional TIS framework, designed in a static manner, captures a "snapshot" of the innovation's status at a specific point in time without accounting for these dynamic interactions. This static approach does not fully represent the complex and interwoven nature of barriers and conditions that characterize real-world scenarios.

Future research should focus on developing dynamic models that can capture these interactions and provide a more accurate representation of reality. A dynamic approach would consider the temporal aspects of innovation processes and the continuous interplay between different elements. This would involve creating frameworks that can simulate and analyze how changes in one area might ripple through the system, affecting other areas over time.

Such dynamic models would not only enhance our understanding of circular innovations in Latin America but also provide more robust tools for policymakers and practitioners. By acknowledging and analyzing the interconnected nature of barriers and conditions, we can develop more effective strategies to foster the successful adoption and diffusion of circular economy practices.

Other Possible Research Directions

Future research could consider a deeper investigation into stakeholder engagement strategies within the context of CI in Latin America. This could involve examining best practices for involving various stakeholders in the design, implementation, and scaling of CI. Such research could provide valuable insights into how to build stronger, more collaborative networks that support the diffusion of circular practices. Effective stakeholder engagement can address several barriers identified in this study, such as regulatory alignment and customer awareness, by fostering a collaborative environment where different parties work towards common sustainability goals.

Further studies could also explore the development and implementation of circular business models (CBMs) in Latin America. This research should aim to develop a model specifically for overcoming CBM barriers, analyzing these barriers, and developing strategies. By understanding and addressing these barriers, future research can contribute to a comprehensive strategy for the region's transition to a circular economy, tailored to its unique socio-economic and cultural contexts. Circular business models prioritize sustainability and resource efficiency from the design phase through to end-of-life management, helping mitigate barriers related to competitive pricing and market acceptance.

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Appendix A

Building Blocks and Influencing Conditions from the original TIS framework

The following tables show the building blocks and influencing conditions as described by Ortt and Kamp (2022):

TIS Building Blocks

Building Blocks	**Description**
Product Performance and Quality	A product (with all subsystems including hardware and software components) is required with sufficiently good performance and quality (absolutely or relatively compared to other competitive products). Lacking performance or quality can hamper large-scale diffusion.
Product Price	A product (with all subsystems) is required with a reasonable price (absolutely or relatively compared to other competitive products). The price of a product involves financial and non-financial (e.g., time and effort) investments to acquire and use the product. A prohibitively high price can hamper large-scale diffusion.
Production System	A production system that can produce large quantities of products with sufficiently good performance and quality (absolutely or relatively compared to competitive products), is required for large-scale diffusion. A lack of production system can hamper large-scale diffusion.
Complementary Products and Services	Complementary products and services for the development, production, distribution, adoption, use, repair, maintenance, and disposal of an innovation are required. Unavailable, incompatible or too expensive complementary products and services can hamper large-scale diffusion.
Network Formation and Coordination	Required actors and sufficient coordination of their activities to develop, produce, distribute, repair, maintain and dispose of products are required for large-scale diffusion. Coordination can be emergent and implicit (e.g., the market mechanism) or can be formal and explicit (e.g., an industry association). Coordination can involve actual collaboration and a shared vision regarding the innovation and the TIS around it. If types of actors and coordination amongst these actors are needed yet missing, large-scale diffusion can be hampered.
Customers	Customer segments are required for large-scale diffusion. Potential customers with a need for the innovation should be identified. To become actual customers, they should be aware of the product, see its benefits relative to other innovations, and have the knowledge, means, and willingness to acquire and use it. If actual customers are lacking, large-scale diffusion can be hampered.
Innovation-specific Institutions	These institutions refer to formal policies, laws, and regulations either describing norms and requirements regarding the product, production facilities, and complementary products and services or describing how actors (on the supply and demand side of the market) should deal with the product and system around it. Specific institutions can stimulate or hamper large-scale diffusion.

Note. Retrieved from "A technological innovation system framework to formulate niche introduction strategies for companies prior to large-scale diffusion" by J. R. Ortt and L. M. Kamp, 2022, Technological Forecasting and Social Change, p.14.

Conditions Influencing TIS Building Blocks

Influencing Factors	**Description**
Knowledge and Awareness of Technology	This involves both fundamental and applied technological knowledge. Fundamental knowledge refers to the technological principles involved in components of the TIS, like the product, production, and complementary products and services. Applied technological knowledge refers to the knowledge required to develop, produce, repair, maintain, and improve these components. When relevant actors lack knowledge and awareness of technology for their role, this can affect the formation of several TIS building blocks.

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Table A.2 continued from previous page

Influencing Factors	**Description**
Knowledge and Awareness of Application and Market	This refers to knowledge of (1) potential applications, (2) knowledge of the market (structure) and the actors involved in these applications. This knowledge is required for all actors including customers to formulate strategies, articulate product requirements and find or target other actors. When actors lack such knowledge required for their role, this can affect the formation of several TIS building blocks.
Natural, Human and Financial Resources	Resources can refer to natural, human and financial resources. Natural resources refer to raw materials that can be acquired by each organization separately or by associations of organizations. Human resources refer to individuals with the right knowledge and competences. Increasing human resources may involve education programs, courses and training on the job. Financial resources can come from various sources. Lack of natural, human or financial resources can affect the formation of TIS building blocks.
Competition	Competition can refer to competition between products based on old and new technologies but may also refer to competition between different product versions with a new technology. Since different product versions often require different production systems and complementary products and services, competition arises between networks of companies. The combined complex patterns of competition may hamper the formation of TIS building blocks.
Macro-economic and Strategic Aspects	Macro-economic aspects refer to the overriding economic situation, such as a recession or economic growth. Strategic aspects refer to interests of countries which are often reflected in generic institutions and government policies. Macro-economic and strategic aspects can influence the formation of TIS building blocks.
Socio-cultural Aspects	Socio-cultural aspects refer to the norms and values in a particular culture or socio-technical system. These conditions might be less formalized than the laws and rules in the innovation-specific institutions. They include methods and habits, norms and values (“the way to do things”) and may become visible in interest groups or relevant stakeholder groups. Socio-cultural aspects can influence the formation of different TIS building blocks.
Accidents and Events	Accidents and events may emerge both outside a TIS (e.g., wars, political turmoil or natural disasters) or from within a TIS (e.g., accidents with products or in production, emergence of new technologies). Accidents and events can influence the formation of several TIS building blocks.

Note: Retrieved from "A technological innovation system framework to formulate niche introduction strategies for companies prior to large-scale diffusion" by J. R. Ortt and L. M. Kamp, 2022, Technological Forecasting and Social Change, p.15.

Appendix B

Detailed Modifications of the TIS Framework by Shankar for Circular Innovation

Detailed Modifications to TIS Building Blocks and Influencing Conditions:
This part of the appendix provides an in-depth view of the specific adaptations made by Shankar (2023) to each building block and influencing condition within the TIS framework. These modifications emphasize the integration of circular innovation principles.

Shankar (2023)'s modifications to the framework's Building Blocks are as follows:

1. Product Performance and Quality: Shankar (2023) places a distinct emphasis on integrating circular principles into every stage of product design and development. This includes the concepts of "Design for Circularity", emphasizing durable and repairable product design; "Resource Optimization", aiming for efficient use of materials and energy; and "Integrated PSS", combining products and services to extend usability and minimize waste.

2. Product Price: The adaptation involves considering not just initial costs but also the "Long Term Feasibility" and "Total Cost of Ownership" of products. This approach balances economic viability with the environmental benefits of reduced material and production costs over time.

3. Production System: Shankar (2023) underscores the necessity for a shift in production processes towards resource optimization and waste reduction. This includes enhancing "9 R(s) Capabilities" to minimize waste, implementing "Strong Reverse Logistics" for end-of-life product management, and ensuring "Flexibility and Adaptability" in production methods.

4. Complementary Products and Services: The study highlights the importance of a supportive ecosystem for circular innovation. This is achieved through "Collaboration" with industrial partners, creating an "Ecosystem of Products/Services" that are inherently circular, and developing "Industry-Specific Infrastructure" that facilitates circular practices.

5. Network Formation and Coordination: Effective collaboration and coordination among actors across the value chain are crucial. This involves building "Strong Networks", clarifying the "Division of Responsibility", and fostering "Shared Goals" to ensure collective movement towards circular innovation.

6. Innovation-specific Institutions: Shankar draws attention to the role of regulatory frameworks and environmental laws. This entails working towards a "General Consensus" on circularity, promoting "Standardization" of practices and products, and advocating for "Emerging Robust Policies" that support circular economy transitions.

7. Customers: The adapted framework recognizes the pivotal role of customer behavior and preferences. This includes enhancing "Awareness and Knowledge" about circular options, shifting "Ownership Preferences" towards more sustainable models, and addressing the "Resistance to Change" often encountered in consumer habits.

Similarly, the modification to the Influencing Conditions of the original TIS framework are outlined below:

1. Knowledge and Awareness of Technology: Shankar (2023) points out the need for a deeper understanding of technology specific to circular innovation, expanding the "Limited Scope of Circular Products" and promoting "Large Scale Demonstration" projects to showcase the benefits.

2. Application and Market Dynamics: The adaptation emphasizes understanding market dynamics and applications, addressing "Uncertain Returns", overcoming "Linear Lock-ins", and mitigating "Asymmetric Information" to streamline the market for circular products and services.

3. Natural, Human, and Financial Resources: Shankar (2023) highlights a distinct approach to resource utilization in circular innovation. This focuses on "Resource Flow Optimization", harnessing "Leadership and Team Skills" for innovative practices, and ensuring the "Availability of Finances" for circular projects.

4. Macro-economic and Strategic Aspects: The study underlines the necessity of shifting macro-economic policies and strategic considerations. This involves adopting a "Systemic Perspective", adapting to "Economic Conditions", and formulating "Conducive Regulations" that favor circular innovation.

5. Socio-cultural Aspects: emphasizes the alignment of social and cultural norms with circular principles, which includes enhancing "Literacy and Motivation", fostering "Informed Preferences", and overcoming the "Limited Information and Knowledge" that hampers circular practices.

6. Competition: The unique competitive landscape in circular innovation is highlighted, with a focus on "Market Positioning", navigating "Conventional Competition", and crafting a compelling "Value Proposition" for circular products and services.

7. Accidents and Events: The framework acknowledges the importance of resilience and flexibility. This includes managing "Internal Disruption", understanding "Cascading Effects", and building "Resilience" to maintain continuity in the face of adverse events.

Keywords and Focus Areas:

The tables below detail the Keywords and Focus Areas for the Building Blocks and Influencing Conditions as outlined by Shankar in his adaptation of the TIS framework. These focus areas are consistent with those depicted in the figure of Shankar's framework included in the main text.

Keywords and Focus Areas for Circular Innovation relevant for TIS Building Blocks

Focus Area	**Description**
Design for Circularity	The design of products and services that are designed to be reused, repaired, or recycled at the end of their life. This can be done by using durable materials, designing for disassembly, and making it easy to repair products.
Resource Optimization	The efficient use of resources throughout the product life cycle. This can be done by using recycled materials, reducing waste, and minimizing energy consumption.
Integrated PSS	Product-service systems that combine products and services in a way that minimizes waste and environmental impact. For example, a product-service system could include a product that is rented and then returned to the manufacturer for reuse or remanufacture.
9 R(s) Capabilities	This refers to the nine principles of waste hierarchy. Businesses that have strong 9 R(s) capabilities can minimize waste and maximize the value of resources.

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Table B.1 continued from previous page

Focus Area	**Description**
Strong Reverse Logistics	The efficient collection and disposal of end of life products / materials. Businesses with strong reverse logistics capabilities are able to recover valuable materials and minimize the environmental impact of waste disposal.
Flexibility and Adaptability	The ability to change and adapt to new technologies and market conditions. Businesses that are flexible and adaptable are better able to adopt circular practices and remain competitive in the long term.
Long Term Feasibility	The need to ensure that circular innovation is economically viable in the long term. This includes factors such as the cost of developing and implementing new technologies, the availability of financing, and the potential for market demand.
Total Cost of Ownership	The need to consider the total cost of ownership of circular products and services, including the cost of materials, manufacturing, and disposal. This can help to ensure that circular solutions are actually more sustainable than traditional ones.
Strong Network	The need for strong collaboration between different actors in the value chain, such as manufacturers, suppliers, and distributors. This can help to ensure that circular products and services are available and accessible to consumers.
Division of Responsibility	The need to clearly define the roles and responsibilities of different actors in the circular economy. This can help to avoid conflict and ensure that everyone is working towards the same goals.
Shared Goals	The need for all actors in the circular economy to share the same goals. This can help to ensure that everyone is working towards a common vision and that progress is made.
Collaboration	The need for collaboration between different industries and sectors. This can help to share knowledge and resources and to develop new circular solutions.
Ecosystem of Products / Services	The need to create an ecosystem of products and services that are designed to be circular. This can help to ensure that there is a market for circular products and services and that they are accessible to consumers.
Industry Specific Infrastructure	The need for industry-specific infrastructure that supports circular practices. This is relevant for highly specific industries, where compatibility is key.
General Consensus	The need for a general consensus on the principles of the circular economy. This can help to create a supportive environment for circular innovation and to overcome barriers to adoption.
Standardization	The need for standardization of circular products and services and their indicators. This can help to ensure that they are compatible with each other and that they can be easily recycled or reused.
Emerging Robust Policies	The need for emerging robust policies that support the circular economy. This can include things like supportive regulations to subsidies for circular businesses.
Awareness and Knowledge	The need to raise awareness of the circular economy and its benefits. This can help to create demand for circular products and services and to overcome barriers to adoption.

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Table B.1 continued from previous page

Focus Area	Description
Ownership Preferences	The need to change consumer preferences away from ownership and towards sharing and leasing. This can help to reduce waste and to make circular products and services more accessible to consumers.
Resistance to Change	The need to overcome resistance to change from businesses and consumers. This can be a challenge, but it is essential for the successful transition to a circular economy.

Note: Retrieved from "Exploring the role of niche strategies in overcoming barriers to circular innovation: Exploratory case studies of circular high-tech firms in the Netherlands" by R. Shankar, 2023, TU Delft Education Repository, pp.107-109.

Keywords and Focus Areas for Circular Innovation relevant for TIS Influencing Conditions

Focus Area	Description
Limited Scope of Circular Products	The scope of circular designs remains limited, preventing the full realization of their potential impact. This can be due to a lack of technological know-how, market demand, or regulatory support.
Large Scale Demonstration	The establishment of more large-scale demonstration projects can serve as powerful showcases to inspire and accelerate the adoption of circular practices throughout various industries. This can help to overcome barriers such as uncertainty about the viability of circular solutions and a lack of awareness of the benefits of circularity.
Market Positioning	The market positioning of circular products and services is critical for their success. This includes understanding the needs of target customers, developing a clear value proposition, and effectively communicating the benefits of circularity.
Conventional Competition	Circular businesses face competition from conventional businesses that are not yet adopting circular practices. This can make it difficult to gain market share and achieve profitability.
Value Proposition	The value proposition of circular products and services needs to be clear and compelling in order to attract customers. This includes highlighting the environmental and economic benefits of circularity, as well as the quality and performance of circular products.
Uncertain Returns	The returns on investment for circular businesses can be uncertain, due to the novelty of circular products and services and the lack of clear market demand. This can make it difficult to attract investors and secure financing.
Linear Lock-ins	Linear economic systems are characterized by a ”take, make, dispose” approach to resources. This can make it difficult to adopt circular practices, as businesses and consumers are often locked into linear systems.
Asymmetric Information	Asymmetric information exists when one party to a transaction has more information than the other party. This can be a barrier to the adoption of circular practices, as consumers may be unaware of the benefits of circular products and services.
Resource flow Optimisation	Resource flow optimization is the efficient use of resources throughout the product life cycle. This covers all resources, materials and fiscal resources.
Leadership and Team Skills	Leadership and team skills are essential for the successful implementation of circular innovation. This includes the ability to develop and execute a clear vision for circularity, as well as the ability to build and manage a team of skilled and motivated individuals.
Availability of Finances	The availability of finances is essential for the development and implementation of circular innovation. This can be obtained through a variety of sources, such as government grants, private investment, and crowdfunding.
Systemic Perspective	The circular economy is a complex system that requires a systemic perspective to be successful. This means taking into account the interconnectedness of different actors and factors, and the need for collaboration and cooperation.
Economic Conditions	The economic conditions can have a significant impact on the development and adoption of circular innovation. For example, periods of economic growth can provide opportunities for investment and innovation, while periods of recession can make it more difficult to secure financing.
Conducive Regulations	Conducive regulations can create a supportive environment for the development and adoption of circular innovation. This includes regulations such as corporate responsibility directives and EU Action Plans.

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Table B.2 continued from previous page

Focus Area	**Description**
Literacy and Motivation	The level of literacy and motivation among consumers and businesses can also affect the development and adoption of circular innovation. Consumers who are aware of the benefits of circularity and are motivated to make sustainable choices are more likely to support circular businesses and products. Businesses that are committed to circularity and are willing to invest in the necessary resources are also more likely to be successful.
Informed Preferences	Consumers who have access to accurate information about the environmental and social impacts of their choices are more likely to make informed decisions about the products and services they purchase. This can help to drive demand for circular products and services.
Limited Information and Knowledge	The lack of information and knowledge about circularity can be a barrier to its adoption. This includes information about the benefits of circularity, as well as the challenges and opportunities associated with it.
Internal Disruption	Accidents that occur within a company can disrupt production, supply chains, and other operations. This can have a significant impact on the ability of a company to adopt circular practices.
Cascading Effects	Accidents can have cascading effects, affecting other companies and organizations. This can make it difficult to coordinate efforts to adopt circular practices.
Resilience	Resilience is the ability to recover from shocks and stresses. This is important for companies and organizations that are adopting circular practices, as they will be more likely to be able to withstand disruptions.

Note: Retrieved from "Exploring the role of niche strategies in overcoming barriers to circular innovation: Exploratory case studies of circular high-tech firms in the Netherlands" by R. Shankar, 2023, TU Delft Education Repository, pp.110-113.

Appendix C

Detailed Modifications of the TIS Framework by Warns for Reuse Innovations

In the following tables, detailed descriptions are presented for the adapted R-TIS building blocks and influencing conditions as specified by the author. These tables provide an in-depth look at the modifications and enhancements introduced to align the R-TIS framework more closely with the principles of the circular economy.

Explanation for adapted R-TIS building blocks

Building Block	**Adapted explanation for R-TIS**
Product Performance and Quality	This building block of the R-TIS is the development of a Circular Product Service System (CPSS). More specifically, in Reuse innovation, this is a proposition for reuse. Depending on the circular strategy, technological advancements have a more prominent (e.g., recycling) or less prominent role (e.g., reuse). The CPSS is a promise of good performance, economic and environmental, and quality, in comparison to its competitors.
Product Price	The cost of the CPSS is a building block in the R-TIS. This refers to the financial and non-financial cost (time and effort) of the product, but also its 'True Price'. Examples: transaction costs, switching costs, cost of sales and depreciation. A product should be priced reasonably relative to competition or in absolute terms.
Production System	A well-established Circular production system capable of delivering the CPSS in a substantial quantity. This in a logistically, economically and environmentally efficient way, which deals with return streams, and in case of other CE strategies than Reuse, is able to recycle, repurpose the product, its components or materials. The benchmark here is the single-use alternative. It should prevent any rebound on efficiency by the Circular production system itself, or it will negate the environmental claim of the CPSS. Absence of this hinders large-scale diffusion of Circular and Reuse innovations. Large production systems need large investment and time for setting up.
Complementary Products and Services	The availability and proximity of complementary products and services that aid in the development, production, distribution, adoption, use, repair, maintenance, and disposal of the innovation. Because of the need of reverse logistics for most CE strategies and the increasing effect distance between actors has on the environmental impact of this logistics, proximity is an important mitigator for the environmental performance.
Network Formation and Coordination	The construction of a comprehensive network of actors within the Closed-Loop supply chain. Typically, it refers to the connections between actors, such as suppliers, manufacturers, distributors, complementary product/service providers. This closed-loop supply chain relies more on connectedness (network density), bidirectional connections (e.g., reverse streams), proximity of social actors to one another to facilitate efficient reverse logistics. Social actors share, exchange intermediate products, byproducts, and infrastructure, to create value from the flow of materials and resources in (semi)-closed loops, which is key to the CE. The necessity of the coordination meant by Ort & Kamp is the more relevant with this growing complexity. Collaboration between new actors and incumbents to form strategies and agendas that help to reform the societal context. When coordination between these actors is lacking, such as collaboration and shared vision for the technological innovation and the R-TIS, large-scale diffusion is hindered completely.
Customers	Early identification of a customer segment is still vital. Potential customers, who have a need for the innovation or those who can benefit significantly from using it, should be identified. Essentially, there should be a 'willingness to pay and use'. For circular innovations this is also based on their convenience and a competitive price and environmental claims form a basic requirement. Sensory aspects and appearance are not dependent on the sort of innovation but on its intended use. Learning mechanisms, helping customers to adopt a product or vice versa, are elementary.
Innovation-specific Institutions	Innovation-specific institutions, encompassing formal and informal rules like government policies, laws, standards, and regulations, can either obstruct or facilitate diffusion. Specifically to CE, "legal and regulatory environmental frameworks" should be in place that favour the circular and more sustainable innovations. Stability of the institutions and its support are key.

Note: Retrieved from "Niche strategies for reuse innovations: Niche introduction strategies for large scale diffusion of reuse innovations in the European domestic soft drinks industry" by R.

Warns, 2023, TU Delft Education Repository, p.38.

Explanation for adapted R-TIS influencing conditions

Influencing Condition	**Adapted explanation for R-TIS**
Knowledge and Awareness of Technology	Fundamental and applied technological knowledge. Applied technological knowledge is necessary to develop, produce, repair, maintain, and improve these components. An important nuance is that CE has strategies that rely extensively on technological innovation, such as recycling for sorting, handling and the converting of waste streams, and strategies that are less reliant on technology and more on the innovation of processes between supply chain actors and the consumer; e.g. reverse logistics and industrial symbiosis.
Knowledge of Application and Market	Knowledge of potential applications of the innovation and knowledge of the market structure and the relevant social actors is essential for the formation of a network. It can be stressed that, given the more complex network formation of circular and Reuse innovations, this Influencing Condition is relatively more important than in the case of high-tech innovation. As in the TIS, this knowledge is developed through market analysis, experimentation, learning by doing, learning by using and learning by interaction with the sociotechnical system. A lack of knowledge and awareness of the applications and market indeed impacts all social actors. The absence of this knowledge prevents customers from finding or using the product. It prevents suppliers from targeting the right customers. Moreover, for the rTIS it prevents social actor operating from the same supply chain role to find each other, collaborate and share materials and resources. In all cases, rTIS formation is hampered.
Natural, Human, and Financial Resources	Availability and proximity of resources, including natural, human, and financial resources, is another critical influencing condition.
Competition	Competition forms a significant influencing condition, especially during rTIS formation.
Macro-economic and Strategic Aspects	Macro-economic and strategic aspects significantly influence the rTIS building blocks.
Socio-cultural Aspects	Socio-cultural aspects, including the norms and values held by potential customers and other stakeholders, can also influence the formation of rTIS building blocks. Specific norms of CE and Reuse- environmental wins, social wins, and economic wins- should be supported by the values residing in the supply chain actor and customers or diffusion can be prevented completely.
Accidents and Events	Accidents and events, either within or outside the rTIS, can have a significant impact on the rTIS building blocks.
Environmental and Strategic Aspects	Institutional policies and governmental support encourage transition to CE. Experimentation and learning is a core component of Circular Economy (CE) innovation, encompassing the generation, testing, and refinement of business models. It is driven by public policies and sustainability visions, facilitating niche development and scaling; the network formation.

Note: Retrieved from "Niche strategies for reuse innovations: Niche introduction strategies for large scale diffusion of reuse innovations in the European domestic soft drinks industry" by R. Warns, 2023, TU Delft Education Repository, p.41.

Appendix D

Detailed Modifications of the TIS Framework by Engelen for Circular Innovation

In this appendix, a detailed explanation is provided on how the original TIS framework was modified by Engelen to better suit Circular Innovation.

The development process of the adapted TIS framework in Engelen (2023)'s thesis is a methodical response to identified gaps in the existing model, particularly in its application to circular innovations. Engelen (2023)'s approach began with an acknowledgment of the need for a framework that more effectively captures the complexities and unique characteristics of circular innovations, which differ significantly from traditional technological innovations in their lifecycle processes and systemic implications.

Central to Engelen (2023)'s adaptation process was a comprehensive systematic literature review. This step was crucial in understanding the distinctions between circular and traditional technological innovations, particularly in terms of their unique aspects and challenges. The insights gained from this review not only highlighted the necessity for adaptation but also provided the foundational knowledge required for the subsequent steps in the framework's development.

Following the literature review, Engelen (2023) embarked on defining circular innovation within the context of his research. This definition, which emphasizes resource efficiency, economic implications, and reduced environmental impact, became the cornerstone for the modifications to the TIS framework. By grounding the framework in this tailored definition, Engelen (2023) ensured that the adapted model would align closely with the specific dynamics and requirements of circular innovations. This meticulous process of recognition, review, and definition culminated in a TIS framework that is better suited to analyze and support the diffusion of circular innovations, addressing the previously unmet needs within this field.

The TIS framework underwent substantial modifications in Engelen (2023)'s adaptation, introducing and enhancing building blocks and influencing conditions, which are presented in the following table:

Table D.1: Modifications of building blocks and influencing conditions by Jules Engels

Element	**Description**
Building block 3: Production system	A production system, or multiple small-scale production systems that can produce large quantities of products with sufficiently good performance and quality (absolutely or relatively compared to competitive products), is required for large-scale diffusion. A lack of production system(s) can hamper large-scale diffusion.
Building block 4: Complementary products and services	Complementary products and services for the development, production, distribution, adoption, maintenance, upgrading, (re-)use, repair, refurbish, remanufacturing, repurposing, recycling and recovering of an innovation are required. Unavailable, incompatible or too expensive complementary products and services can hamper large-scale diffusion.
Building block 5: Network formation and coordination	Required actors and sufficient coordination of their activities to develop, produce, distribute, upgrade, maintain, repair, refurbish, remanufacture, repurpose, recycle and recover of products are required for large-scale diffusion. Coordination can be emergent and implicit (e.g., the market mechanism) or can be formal and explicit (e.g., an industry association). Coordination can involve actual collaboration and a shared vision regarding the innovation and the TIS around it. If types of actors and coordination amongst these actors are needed yet missing, large-scale diffusion can be hampered.

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Table D.1 continued from previous page

Element	Description
Building block 6: Customers	Customer segments are required for large-scale diffusion. Potential customers with a need for the innovation should be identified. To become actual customers, they should be aware of the product, see its benefits relative to other innovations, and have the knowledge, means and willingness to acquire, use and dispose of it properly. If actual customers are lacking, large-scale diffusion can be hampered.
Building block 8: Reverse logistics	A reverse logistics system that can effectively move goods from their typical final destination for maintaining and recapturing value via collecting and inspecting for direct reuse, product recovery management (disassembly, service, repair, refurbish, remanufacture, repurpose, recycle), and waste management (disposal, landfill, incineration), is required for large-scale diffusion. A lack of or an inefficient reverse logistic system can hamper large-scale diffusion.
Influencing condition 1: Knowledge and awareness of technology	This involves both fundamental and applied technological knowledge. Fundamental knowledge refers to the technological principles involved in components of the TIS, like the product, production, complementary products and services and reverse logistics. Applied technological knowledge refers to the knowledge required to develop, produce, repair, maintain, improve and recirculate these components. When relevant actors lack knowledge and awareness of technology for their role, this can affect the formation of several TIS building blocks.
Influencing condition 3: Natural, human and financial resources	Resources can refer to natural, human and financial resources. Natural resources refer to raw and secondary materials that can be acquired by each organization separately or by associations of organizations. Human resources refer to individuals with the right knowledge and competences. Increasing human resources may involve education programs, courses and training on the job. Financial resources can come from various sources. Lack of natural, human or financial resources can affect the formation of TIS building blocks.
Influencing condition 8: Data infrastructure	Data infrastructure refers to the infrastructure that facilitates data exchange throughout the TIS networks, like monitoring, tracking, and analyzing product performance and usage data, while enabling TIS actors to share real-time information throughout the TIS. Lacking or incompatible data infrastructure can affect TIS building block formation.

Note: Retrieved from "Overcoming barriers to circular innovations: exploring niche strategies for successful introduction" by J. Engelen, 2023, TU Delft Education Repository, p.82.

The adaptation of the TIS framework in Engelen (2023)'s thesis was motivated by a need to address the distinct characteristics and systemic approach required by circular innovations, particularly in the contexts of production, consumption, and waste management. These modifications were specifically designed to encapsulate the interdependencies inherent in circular systems, recognizing the integral role of each TIS factor in the effective diffusion of circular innovations.

Central to this adaptation was the acknowledgment that circular innovations demand a unique lifecycle process and systemic changes. This necessitated incorporating elements essential to circular innovations, such as reverse logistics and data infrastructure, due to their critical roles in diffusion. The inclusion of these elements was a deliberate move to enhance the framework's relevance and applicability in studying circular innovations, ensuring a comprehensive capture of the range of factors influencing their development and diffusion.

Appendix E

Interview Outline for Case Studies and Experts

In this appendix, the interview outlines for he case studies and the expert interviews are provided.

Interview Outline for Case Study Participants

Introduction
Good morning/afternoon, my name is Renzo Paino and I am conducting a study on circular innovation barriers and its causes. Thank you for participating. My research is centered on understanding the barriers of circular innovations in Latin America and identifying strategies to overcome them.

We'll discuss your company's understanding of circularity, delve into the challenges you've faced, and explore the strategies you've implemented. Please introduce yourself, including your role and experience with circular practices within your company.

General Interview Questions

1. Could you explain your circular innovation and how it relates to circularity?
2. What initially sparked your company's interest in circular innovation?

Main Interview Questions
Circularity Understanding and Application:

1. How do you or your company define and understand the concept of circularity?

Barriers and Challenges:

2. What are the primary barriers to implementing or adopting circular innovations at your company?
3. What are the causes of these barriers?
4. Discuss the strategies you've employed to address these barriers. What has been successful, and what hasn't?

Framework Alignment:

5. What about "Building Block 1"? What is the state of the innovation/company in regard to this? (Repeat for each block)
6. What do you think these barriers are being influenced by? What is causing/influencing these barriers?

Conclusion
Thank you very much for you time and participation in the study. Do you have any inquiries or comments about the study or your contribution? We'll review the interview and may follow up for additional insights. Expect to hear from me in the following days if needed.

Interview Outline for Experts in Circularity

Introduction
Good morning/afternoon, my name is Renzo Paino and I am conducting a study on circular

innovation barriers and its causes. Thank you for participating. My research is centered on understanding the barriers of circular innovations in Latin America and identifying strategies to overcome them. We will discuss your views on circularity and its application in Latin America, and we'll seek your expert feedback on my research framework. Could you start by telling me about your professional journey and your expertise in the field of circular economy?

Main Interview Questions
Definitions and Regional Context:

1. How do you define/understand circular economy, in Latin America, and how does it compare with global trends?

Underlying Causes and Strategies:

2. What barriers do you think are more common in the introduction and diffusion of circular innovations?

3. What underlying causes do you attribute to these barriers in circular innovation adoption?

4. What types of barriers are being implemented to overcome these barriers?

Framework Review:

4. Given your expertise, how would you critique or enhance the proposed framework of our study?

5. What additional elements or considerations should be incorporated into our framework to better address the regional context and are there any elements that are, in your opinion, irrelevant or less important in Latin America?

Conclusion
Thank you very much for you time and participation in the study. Do you have any inquiries or comments about the study or your contribution? We'll review the interview and may follow up for additional insights. Expect to hear from me in the following days if needed.