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Strengthening competitiveness, science, technology, and innovation system in the department of Amazonas: A management analysis and intervention proposals

Enrique Herrera León[1*], Luz Ángela Ramos Bautista[2], Mercedes Rodríguez Camargo[3]

[1,2]*Cosmos Educational and Scientific Corporation, Colombia.*
[3]*Augustinian University, Colombia.*

Corresponding author: Enrique Herrera León (*Email: ehltrabajo2018@gmail.com*)

Abstract

This study analyzes the challenges facing the Competitiveness, Science, Technology, and Innovation System (SCSTI) in the Department of Amazonas, Colombia. Drawing on a review of specialized literature and diverse secondary sources, it identifies key factors underlying these challenges, as well as their most visible consequences: low levels of competitiveness and an underdeveloped scientific and technological output. In response, the study proposes a comprehensive strategy focused on implementing coordinated agendas, strengthening local capacities, and promoting mechanisms that facilitate knowledge transfer and application. These measures aim to stimulate increased investment in Scientific, Technological, and Innovative Activities (STIAs) and to improve the management of projects financed through royalty funds, thereby contributing to the region's sustainable development. Ultimately, this work seeks to inform the design of public policy and to serve as a foundation for collaboration among key stakeholders in consolidating the SCSTI ecosystem in the Colombian Amazon.

Keywords: Amazon, Competitiveness, Human capital, Innovation, Knowledge spillover.

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1. Introduction

In contemporary contexts, Science, Technology, and Innovation (STI) are widely recognized as fundamental pillars for socioeconomic development and competitiveness in the 21st century. In Colombia, the transformations triggered by economic liberalization in the 1990s—together with the adoption of neoliberal policies—necessitated a redefinition of development strategies. These changes placed increased emphasis on integration into international markets, process quality, and large-scale production.

In response, public policies have been implemented and institutional frameworks established to strengthen productivity and innovation at both the national and regional levels. For territories to achieve meaningful and effective integration into an increasingly competitive global environment, it is imperative to move beyond traditional comparative advantages and convert them into sustainable competitive advantages.

Despite notable progress at the national level, significant regional disparities in STI persist. The Department of Amazonas, endowed with vast natural and cultural diversity, faces considerable limitations in managing its Competitiveness, Science, Technology, and Innovation System (SCSTI). The department has yet to successfully coordinate actors and resources around a shared vision [1]. This institutional weakness is evident in lagging competitiveness indicators and scientific and technological output that remains in its early stages of development.

Several factors contribute to this scenario, including weak coordination among entities within the system and insufficiently trained human capital for knowledge management and transfer [2]. As a result, investment levels in Scientific, Technological, and Innovative Activities (STIAs) remain low, and the productive sector exhibits limited technological sophistication.

Addressing the management limitations of the SCSTI in Amazonas is essential for advancing toward sustainable and equitable regional development. Strengthening this system would not only yield economic and social benefits but also create opportunities to harness the region's biodiversity and natural resources in responsible and innovative ways.

Key steps in this process include improving the management of STI projects and increasing investment in STIAs—critical actions for enhancing competitiveness, fostering the generation of relevant knowledge, and addressing local needs in both social and productive domains [3].

This study aims to contribute to a deeper understanding of these challenges and to offer strategic guidance for designing more effective responses. Its central objective is to analyze the management limitations of the SCSTI in the Department of Amazonas and based on this analysis, propose a comprehensive strategy for system strengthening.

To achieve this goal, the study begins with a characterization of the current state of the system across its various subsystems—productive, technological, scientific, financial, and facilitative. This diagnostic approach helps to identify the root causes and consequences of its limited management capacity, using established problem analysis tools. On this basis, a strategic alternative is proposed, focused on the coordination of agendas, development of local capacities, and promotion of mechanisms for knowledge transfer and utilization. Finally, the study outlines the methodology for implementing this proposal, including a description of core activities and the expected outcomes.

2. Theoretical Framework and Literature Review

A thorough understanding of the fundamental concepts related to Science, Technology, and Innovation (STI), as well as regional competitiveness, is essential for analyzing the dynamics of the Competitiveness, Science, Technology, and Innovation System (SCSTI). These conceptual frameworks not only elucidate the interactions among policies, actors, and indicators that shape Colombia's innovation ecosystem, but also provide analytical tools for identifying persistent gaps across specific territories.

In this regard, once the theoretical foundations of STI are established—along with its measurement through instruments such as the Departmental Competitiveness Index (IDC)—it becomes necessary to contextualize the analysis within the specific case of the Department of Amazonas. Despite its rich cultural and environmental diversity, this region faces significant challenges in terms of scientific output, investment in innovation activities, and the development of technological capacities. These limitations highlight the urgent need to design and implement strategies that strengthen SCSTI and foster more equitable and sustainable regional development.

2.1. Key Concepts

To understand the functioning of the Competitiveness, Science, Technology, and Innovation System (SCSTI), it is essential to clarify several closely related concepts. Science, Technology, and Innovation (STI) refers to a set of organized activities aimed at generating knowledge, applying it to the development of new products, processes, or services, and substantially improving those that already exist.

In the Colombian context, the National Science, Technology, and Innovation System (SNCTI)—established by Law 1286 of 2009 and later regulated by Law 1753 of 2015—is conceived as an open system that brings together policies, programs, methodologies, and a range of public, private, and hybrid actors. The current legal framework seeks to enhance the country's scientific and technological capabilities by promoting decentralization and granting a more active role to regional entities.

Regional competitiveness, defined as a territory's capacity to increase productivity and improve the well-being of its population, is measured in Colombia through the Departmental Competitiveness Index (IDC). This index incorporates multiple dimensions, ranging from institutional strength and infrastructure to market performance, education, health, and environmental sustainability. It also evaluates elements such as efficiency, sophistication, and innovation. These indicators serve to identify the strengths and weaknesses of each region and are critical for informed public policy decision-making.

Regarding innovation, it is important to highlight the concept of knowledge spillover, which refers to the circulation and appropriation of knowledge across various settings and among diverse actors [4]. This exchange fosters the generation of new ideas while promoting innovation and strengthening collective capacities. In this vein, the quadruple helix model [5] posits that the dynamism and effectiveness of innovation are driven by interaction among universities, businesses, the state, and civil society. The more these sectors engage through co-action, the more effectively they can address complex challenges.

2.2. Context of the Amazon in Science, Technology, and Innovation (STI)

The challenges faced by the Department of Amazonas in the field of Science, Technology, and Innovation (STI) are evident. According to the 2018 Departmental Competitiveness Index (IDC), the department ranked 24th out of 32, with a score of 3.64. This result places it significantly below the national average and the levels attained by departments with intermediate performance. Such a position is largely attributable to the absence of reliable and consistent data, as well as to structural weaknesses in key areas such as markets, innovation, business dynamics, and institutions.

Regarding scientific and technological production, progress has been limited. Between 2007 and 2016, the Colombian Observatory of Science and Technology (OCyT) and Publindex recorded only seven publications in indexed journals, representing a mere 0.18% at the national level. This low level of visibility stands in stark contrast to the existence of local knowledge that remains unsystematized in academic databases, thereby underscoring the need to strengthen mechanisms of documentation and dissemination [3]. In terms of investment in R&D and Innovation (RDI), although a growing national trend was observed between 2000 and 2018, in Amazonas a substantial effort is still required for such investments to generate a tangible impact on regional development.

The concentration of research in departments such as Bogotá and Antioquia further exacerbates inequalities. In peripheral territories such as Amazonas, research groups are scarce and technological capacities remain limited, thereby constraining the potential for scientific development.

This context underscores the urgent need to design strategies aimed at strengthening local capacities while simultaneously promoting greater coordination among the various actors of the Regional STI System [6].

3. Methodology

This study adopted a research approach that combined descriptive and propositional dimensions. First, the descriptive component entailed an analysis of the status of the Competitiveness, Science, Technology, and Innovation System (SCSTI) in the Department of Amazonas, with particular attention to its components, dynamics, and limitations. Second, the propositional component involved the design and formulation of a comprehensive strategy aimed at strengthening this System through specific actions, methodologies, and anticipated outcomes.

The analysis was grounded in a detailed review of specialized technical documents. These were complemented by contributions drawn from academic literature and a variety of secondary sources of recognized value, thereby enabling the articulation of a broad, rigorous, and well-contextualized perspective. This combination of references ensured the robustness of the analytical framework and provided a consistent foundation for the proposed strategy.

The core of this study consisted of technical documents, from which the central aspects of the problem were identified, along with the methodologies proposed and the expected results. Complementary to this, secondary sources of a statistical and institutional nature were consulted, including reports from the National Administrative Department of Statistics (DANE), the Colombian Observatory of Science and Technology (OCyT), Publindex, the National Planning Department (DNP), the Economic Commission for Latin America and the Caribbean (ECLAC), the Inter-American Development Bank (IDB), the Amazonas Chamber of Commerce, and various CONPES documents.

The use of these materials facilitated the contextualization of the analysis and provided a solid basis for understanding the functioning of the STI system and its relationship with regional competitiveness.

To analyze the problem, the “problem tree” methodology was employed, a tool that enables the decomposition of a central issue into its causes and effects. In this way, it was possible to determine that the core problem was the limited management capacity of the SCSTI in the Department of Amazonas. Moreover, the main causes of this problem were identified as the lack of coordination among the institutions comprising the system and the insufficient preparation of personnel responsible for management processes and knowledge transfer [2]. In addition, several associated effects were noted, including low levels of investment in RDI and an institutional apparatus characterized by limited effectiveness. This methodological approach thus enabled the structuring of the problem from a clearer basis, subsequently facilitating the identification of possible solutions.

The design of the proposed strategy was organized around three main pillars: the implementation of articulated agendas, the strengthening of local capacities, and the promotion of mechanisms of knowledge spillover [4]. Accordingly, the design sought to address the need for a systemic approach that goes beyond the mere correction of failures and instead emphasizes the consolidation of a strong and sustainable innovation ecosystem [7]. Such an ecosystem must be underpinned by cooperation among stakeholders and the generation of social capital [8-10]. In this regard, the proposed strategy draws upon experiences and best practices in innovation management and regional development, adapting them to the particular conditions of the Amazonian context [2] thereby ensuring their effectiveness and maximizing their impact at multiple levels.

4. Implementation of Integrated Agendas, Training Processes, and Knowledge Spillover Tools

The proposal to strengthen the SCSTI in the Department of Amazonas was structured around three major lines of action, which complement one another and converge into a comprehensive strategy. Each of these lines establishes objectives and methodologies specifically adapted to the regional context, as well as concrete outputs designed to address the weaknesses identified in the management of the SCSTI.

Rather than isolated actions, this approach constitutes an effort to construct a coherent framework capable of overcoming current limitations while opening new opportunities for innovation and development in the territory. The central aim is for these lines of action to serve as the pillars of a sustained process of institutional strengthening and local

capacity-building, enabling the articulation of diverse actors around a shared development project grounded in knowledge [11].

4.1 Action 1: Implementation of Integrated Competitiveness Agendas

The first line of action focuses on the development and implementation of integrated departmental competitiveness agendas, conceived as a mechanism to articulate the institutions comprising the SCSTI in Amazonas and to provide coherence to the various regional plans concerning competitiveness, science, technology, and innovation [12]. The aim is to overcome the historical fragmentation that has characterized the system's management while simultaneously establishing a common framework of action capable of engaging the sectors represented within the quadruple helix.

The starting point involves identifying and characterizing the key actors of the ecosystem [7] including entrepreneurs, academic institutions, public entities, and support organizations. This process entails detailed mapping in the municipalities of Leticia and Puerto Nariño, as well as in the non-municipalized areas, with the purpose of classifying participants according to previously defined grouping variables. Beyond being a technical exercise, this step carries strategic value, as it makes visible those actors who have frequently remained on the margins of decision-making and recognizes civil society as an active agent in the construction of the agenda. In this way, the process fosters shared leadership between the public and private sectors, a necessary condition for reaching consensus around regional development.

Once the characterization has been completed, the next step is to design a value and interaction chain that allows for an understanding of how the different components of the SCSTI interrelate and where strategic value is generated. This exercise materializes in the form of a sociogram that illustrates connections, interdependence, and potential tensions among institutions and sectors. Its usefulness lies in its ability to open pathways for building alliances, anticipating conflicts, and strengthening trust among actors, while also providing key inputs to guide targeted interventions that enhance collaboration and reinforce local capacities around the department's productive priorities.

The final phase of the process consists of strategically aligning the Regional Plan for Competitiveness, Science, Technology, and Innovation (RPSTI) with the existing territorial planning instruments [13]. This requires a diagnostic process that integrates ongoing studies and programs, strengths, weaknesses, opportunities, and threats (SWOT) analysis, and the prioritization of strategic projects based on their impact, feasibility, and sectoral relevance. Building on this analysis, a collective process is promoted to construct a shared vision in which representatives of all social sectors participate. The outcomes are consolidated in a single document that establishes the department's roadmap for competitiveness and STI, in alignment with the 2020–2024 Development Action Plan (DAP) and current national commitments.

The outputs of this action include technical reports on actor characterization, databases systematizing the information collected, sociograms graphically representing inter-institutional relationships, and updated, integrated competitiveness and STI plans. Additionally, a portfolio of prioritized strategic projects is developed, including at least eight project profiles ready for resource mobilization. However, beyond the formal deliverables, the most significant contribution of this action lies in the creation of a participatory space for dialogue and joint planning that strengthens regional governance and lays the foundation for consolidating a more robust and sustainable innovation ecosystem in Amazonas.

4.2 Action 2: Strengthening Regional Science, Technology, and Innovation System

The second line of action in the proposal is oriented toward strengthening human talent, understood as an indispensable condition for enhancing management capacity and knowledge transfer within the SCSTI of Amazonas. It is based on the premise that human capital is the most decisive resource in any innovation process: without well-trained, motivated, and committed individuals, even the greatest institutional or financial efforts ultimately lose their scope and effectiveness [14]. The objective, therefore, goes beyond the transmission of technical knowledge; it seeks to consolidate competencies that enable the creation of a community of practice capable of sustaining the progress achieved over time [15].

Within this framework, the design of a seminar to support and promote innovation is proposed, directed at the strategic sectors of the department. Its purpose is to familiarize participants with the foundations of open innovation, the development of an innovation-oriented culture, and the management of knowledge applied to productive sectors [2, 3]. This training adopts an experiential and participatory format, in which national and international experts guide the connection between theory and the specific realities of the Department of Amazonas. The target audience includes local communities, private sector representatives, and social organizations.

In addition, a diploma program on the formulation and management of STI projects is proposed, delivered in a blended modality (in-person and virtual), with the objective of equipping community members with tools for project design, evaluation, and presentation to access financing resources. The program is structured in three phases: the first, awareness-raising, aims to reinforce participants' motivation and commitment; the second, conceptualization, addresses the technical and regulatory aspects related to the National STI System (SNCTI) and the General Royalties System; and the third, contextualization, provides a space to apply the acquired knowledge to concrete regional cases. This process is expected not only to ensure that participants master project formulation methodologies but also to enable them to adapt these tools to the specific conditions and opportunities of Amazonas.

A third component involves training in knowledge spillover, directed at 30 participants who will receive instruction in tools and methodologies designed to promote the circulation of knowledge throughout the territory. This training combines in-person workshops and virtual sessions with innovative pedagogical strategies. The content revolves around strategic perspectives, knowledge management [2] technology monitoring, project design, and the structuring of research,

development, and innovation initiatives. The aim is for participants to understand how knowledge is shared and appropriated among diverse actors, and how such interaction acts as a driver of productive synergies [3].

Furthermore, specialized training is required to strengthen the competencies of STI managers. This program, directed at individuals who have participated in the previous workshops, seeks to consolidate their skills and prepare them to serve as managers and disseminators of best practices within the territory. These managers will not only be capable of leading innovation initiatives and transferring methodologies but will also provide guidance in project formulation from within the region.

At the conclusion of this line of action, certified and endorsed by a recognized educational institution, it is expected that a community of practice will be established, serving as a model for building networks of trust and collaboration within the Amazonian context. Likewise, the development of a portfolio of ideas and projects, continuously enriched by these communities of practice, will enable the Department of Amazonas to propose and implement competitive and community-driven initiatives in the short and medium term. The entire process must be documented in technical and specialized reports that allow for the identification of progress in local capacities and the achievements attained.

Ultimately, this line of action seeks to place human talent and its strengthening at the very core of the SCSTI. This is made possible through processes of training, capacity-building, and the consolidation of communities of practice that establish the foundations for a permanent and resilient innovation system. In this way, knowledge becomes a lasting driver of progress and regional leadership, equipping Amazonas with the capacity to face future challenges with strength [3].

4.3. Action 3: Specialized Support for the Initiation of Knowledge Spillover

The third line of action in the proposal is oriented toward fostering knowledge spillovers as a strategic channel for the generation, circulation, and appropriation of knowledge in Amazonas. The aim of this line of action is to ensure that knowledge is not confined to institutional academic spaces, but rather disseminated, shared, and transformed into a collective resource that strengthens innovation processes and builds networks of trust across scientific, productive, and institutional domains. In this sense, the support process is gradual: it begins with a diagnosis of the regional ecosystem, continues with the design of strategies to enhance knowledge spillover, and culminates in their implementation.

The first phase consists of an analysis of the ecosystem developed through a co-creation approach with local stakeholders [7]. This requires collective workshops and individual validation sessions in which aspects such as global trends, the competitive diamond, market forces, and political, economic, social, and technological environments are examined. This is not merely a descriptive diagnostic, but rather an exercise to identify opportunities, weaknesses, and threats that shape the territory's innovation capacity. Based on this diagnosis, it becomes possible to anticipate risks and outline mechanisms to leverage available resources while simultaneously promoting the strategic circulation of knowledge.

The second phase involves the construction of a knowledge spillover model [4] tailored to the particularities of the Department of Amazonas. This requires combining documentary review and trend analysis with the identification of the region's competitive factors. Once this exercise is completed, the strategic elements required for the success of the system are selected, and development scenarios are elaborated to anticipate possible trajectories, evaluate alternatives, and choose those that provide the greatest benefits for the region. After defining the desired scenario, strategies are formulated to guide institutions in optimally managing the knowledge within the SCSTI.

The final phase of this line of action is the implementation of the strategies, which must be translated into concrete action guidelines. This stage requires the formulation of projects based on local capacities, the establishment of communities of practice, and the exchange of experiences [15]. Furthermore, it entails the development of a resource management plan, the preparation of collaborative project profiles, and the creation of a participatory technological platform [16]. This platform should include both ongoing and completed projects to consolidate the department's scientific and technological production and to facilitate cooperation among system stakeholders.

Throughout this process, it is essential to produce technical documents that systematize the work undertaken. These should be accompanied by a skills mapping exercise, the establishment of communities of practice, a portfolio of projects, and a resource management plan to guarantee the sustainability of the initiatives. In addition, it is crucial to provide national visibility to this entire dynamic, thereby contributing to the recognition of the Department of Amazonas as an emerging innovation territory.

Beyond the consolidation of formal outputs, the most important outcome of this line of action is the cultivation of an innovation culture rooted in collaboration and trust at the territorial level. In this regard, knowledge spillover serves as a key catalyst, enabling collaboration networks to transcend territorial and disciplinary boundaries by strengthening stakeholders' capacity to innovate collectively.

5. Results and Indicators

The efforts to strengthen the Regional Science, Technology, and Innovation System (SCSTI) in Amazonas reveal this to be a process of gradual transformation, supported by indicators that evaluate the impact of the proposed and implemented actions. The results are articulated around four strategic axes: the increase of investment in research, development, and innovation (RDI) activities; improvements in the management of royalties; the strengthening of human and institutional capital; and the long-term sustainability of the initiatives.

One of the most significant expected advances is the increase in investment in RDI. This can be achieved through the articulation of integrated agendas and the strengthening of local capacities for project design, which requires creating conditions conducive to attracting both national resources (from the General System of Royalties) and international resources. To measure this progress, indicators will include the annual growth of public and private investment in STI, the

number of research, development, and innovation projects financed, and the total amount of resources mobilized. The ultimate goal is for Amazonas to cease being perceived as a lagging department and to consolidate itself as a territory capable of managing and executing projects with regional impact.

In parallel, substantial progress is expected in the management of royalties allocated to STI projects [15]. Training local stakeholders in the use of the Adjusted General Methodology (MGA) and sectoral guidelines will ensure that the initiatives formulated meet the technical and relevance standards required by the Collegiate Body for Administration and Decision (OCAD). Key indicators in this field include an increase in the approval rate of projects, a reduction in the time required for their technical validation, and improvements in the overall quality of submitted proposals. Through these measures, royalties can become a genuine lever for innovation and competitiveness, rather than simply a budgetary execution mechanism.

The strengthening of human and institutional capital constitutes another key result. The proposal projects the training of at least 100 individuals in the formulation and evaluation of STI projects, the training of 30 stakeholders in knowledge spillover, and the preparation of 50 managers as replicators of good practices. Added to this is the goal of structuring at least eight projects ready to undergo financing processes. These achievements transcend numerical targets, representing instead the consolidation of a human capital base endowed with stronger technical competencies and the capacity to sustain and multiply structural changes in the region.

An equally decisive aspect is the creation of networks of trust and inter-institutional collaboration [17]. The establishment of communities of practice and the development of a collaborative technological platform will foster the building of social capital, understood as the foundation upon which collective innovation processes can be generated [8]. In this domain, indicators will be oriented toward measuring the level of interaction among quadruple-helix actors, the durability of the networks created, and the degree of appropriation of the platform as a tool for the exchange of knowledge and experiences [16].

The sustainability and replicability of the proposal are conceived as long-term commitments. The training of local managers will ensure that processes are maintained beyond the initial intervention, while communities of practice and the technological platform will encourage self-organization and the continuity of collective learning [11, 16]. Complementarily, the methodologies and models developed may be adapted to other departments with similar conditions, thus contributing to the decentralization of science, technology, and innovation in Colombia.

Finally, beyond quantitative indicators, the true impact of the proposal lies in transforming the dynamics of the STI ecosystem in Amazonas. The greatest achievement will be the territory's capacity to generate, manage, and leverage knowledge sustainably, positioning human capital and networks of trust as the driving forces of regional development based on innovation and the responsible use of resources [3].

6. Discussion

The discussion that follows seeks to situate the findings of this study within a broader analytical framework, highlighting both its contributions to academic knowledge and the practical and political challenges entailed in its implementation. First, it examines the ways in which the proposal contributes to the existing literature on innovation and regional development, offering an alternative approach to traditional models. It then acknowledges the challenges and limitations that condition its deployment in contexts such as Amazonas, which are shaped by structural constraints and complex institutional dynamics. Finally, it addresses the political and practical implications derived from the study, with the purpose of guiding possible courses of action and public policy aimed at consolidating a more inclusive and sustainable innovation ecosystem.

6.1. Contribution to Literature

The proposal to strengthen the SCSTI in the department of Amazonas—through the articulation of integrated agendas, capacity building, and the promotion of mechanisms for knowledge spillover—constitutes both a significant contribution to public management and an important addition to the debate on regional development and innovation, grounded in concrete experiences and communities of practice [4]. Unlike traditional top-down approaches, which tend to impose directives from the central level without considering territorial particularities, this model advocates a balance between strategic orientation and processes of co-creation with local stakeholders. This hybrid character provides flexibility to adapt to the heterogeneity and structural constraints faced by peripheral territories such as Amazonas.

The emphasis placed on the quadruple helix and on the construction of social capital [8] aligns with theoretical currents that underscore the importance of trust, cooperation, and sustained interaction among academy, government, industry, and civil society in fostering innovation ecosystems [7]. In this regard, it is important to highlight that assigning value to indicators associated with social capital [10] and integrating them into the measurement of outcomes represents a significant methodological advance, as it broadens visibility and monitoring of dimensions that are often relegated to the domain of the intangible. Likewise, the proposal diverges from intervention models focused solely on technological transfer. It recognizes instead that regional development requires both the incorporation of new technologies and the strengthening of endogenous capacities in project formulation, management, and execution. In so doing, it places human capital at the center of transformation, acknowledging that it is people—rather than devices or infrastructure—who ultimately guarantee the sustainability of innovation processes.

Taken as a whole, this initiative not only provides practical tools to guide interventions in contexts characterized by limited institutional capacity but also enriches the academic debate with a methodological framework that integrates problem analysis, strategic foresight, and the collective construction of solutions. Its greatest value lies in proposing a

viable pathway for historically marginalized regions to convert knowledge into a driver of sustainable development, thereby reducing disparities and building a model of innovation that is more inclusive and territorially balanced [3, 13].

6.2. Challenges and Limitations

Implementing a plan of this scale and significance entails a series of challenges that must be identified from the outset to address them and ensure the plan's viability. One of the most critical challenges is resistance to change, which emerges both within institutions and communities. For many years, these actors have adhered to traditional practices, resulting in persistent reluctance to adopt new methodologies of management and innovation. Added to this is institutional fragmentation and the high turnover of public-sector officials, whose appointments often shift according to factors external to the science, technology, and innovation system itself. This situation generates discontinuity in processes, undermining institutional memory regarding community-driven efforts [11] while also hindering the consolidation of capacities and opportunities in the medium and long term.

Another significant challenge lies in the structural infrastructural limitations of the Amazonas region, particularly in relation to digital connectivity and transportation. These conditions not only increase the costs of project implementation but also hinder the execution of training programs and the articulation of collaborative networks among actors within the quadruple helix. For this reason, it becomes necessary to design flexible strategies that adapt to the actual conditions and possibilities of a department such as Amazonas. Here, digital technologies acquire particular importance, as they can provide lightweight virtual tools capable of creatively leveraging the scarce resources available in the territory.

With regard to the limitations of this study, it is important to acknowledge that, although the research was based on a systematically developed project and complemented with secondary sources and academic literature, certain factors constrain the scope of its results. The first limitation concerns the fieldwork, which was restricted to a specific context and timeframe, conditions that limit the extrapolation of findings to broader realities or different dynamics. In this sense, although the empirical evidence supported the testing of the proposed premises, the number of participants and cases analyzed is insufficient to ensure strong statistical representativeness, which reflects the more qualitative and contextualized orientation of the study.

Moreover, while the incorporation of indicators to measure social capital [8, 10] constitutes an innovative methodological contribution, it also presents significant difficulties in translating into verifiable data such abstract dimensions as trust, cooperation, and collaborative networks. This challenge opens the door to potential oversimplification of a proposal such as the one presented here, yet it also underscores the need to advance the application of mixed method approaches that can more effectively capture the kinds of dynamics described in this document. Similarly, reliance on the information provided by participants entails the possibility of biases or social desirability responses that may limit the objectivity of certain results.

In short, although the approach developed—combining fieldwork with documentary review and academic analysis—enables a rigorous examination of the phenomenon under study, this work could be further complemented with a longitudinal follow-up that would allow for reviewing and evaluating the evolution of such social dynamics over time. Likewise, such an approach would enable the assessment of the sustainability of processes in the long term, providing a foundation for future research.

6.3. Political and Practical Implications

The results of this research are significant both in political and practical terms. From a public policy perspective, there is a clear need to design instruments that transcend actions limited to fostering investment in science and technology, as these must also strengthen the managerial capacities of all actors involved at the regional level. This implies advancing toward more favorable regulatory frameworks that enable enhanced interinstitutional cooperation, guarantee dedicated budgets for human capital development, and support the creation of more robust technological platforms functioning as open knowledge repositories and interactive spaces.

On a practical level, this proposal offers a concrete roadmap to guide and direct the work of government entities, universities, the business sector, and social organizations in pursuit of sustainable outcomes. It is advisable that these actors adopt co-creation mechanisms in which decision-making processes are collectively constructed through dialogue and negotiation, thereby avoiding unilateral impositions from those with greater influence or power. Likewise, investment in continuous training programs and the promotion of knowledge spillover dynamics are essential strategies for consolidating an innovation ecosystem that is dynamic, resilient, and adapted to the specific conditions of the Amazonian department.

Furthermore, the dissemination of advances derived from processes and projects implemented in the field through widely accessible publications is vital to legitimizing such efforts and projecting them internationally. In this way, the prospect of consolidating a knowledge-based development model will increasingly gain traction [3]. Making visible the actions and projects developed within local communities thus serves both as a mechanism for integrating technical and financial cooperation with external stakeholders and as an appropriate avenue for securing support for territories that have historically been marginalized.

In sum, the implications of a proposal such as the one advanced in this study demonstrate that the Amazonas not only confronts challenges stemming from its structural limitations but may also become a living laboratory for territorial innovation—provided that appropriate tools, sufficient budgets, and adequate human capital development are secured [13]. In this manner, science, technology, and knowledge can move beyond being mere aspirations in territories distant from major urban centers to become genuine drivers of social, productive, and economic transformation with long-term sustainable effects.

7. Conclusion

The analysis developed throughout this study provides clear evidence of the urgency of strengthening the System of Competitiveness, Science, Technology, and Innovation (SCSTI) in the Department of Amazonas. Despite the department's vast natural and cultural wealth, it continues to face structural limitations in management, coordination, and capacity-building. These conditions typically manifest in low levels of investment in RDI, an incipient scientific and technological output, and fragmented actions among the actors of the quadruple helix. Such constraints severely limit the territory's potential while simultaneously widening the gap with other regions of the country that possess greater installed capacities.

The proposal advanced in this study constitutes a comprehensive alternative to address the challenges identified, structured around three axes: the construction of integrated agendas, the strengthening of human capital through continuous training processes, and the promotion of mechanisms and dynamics of knowledge spillover as catalysts of innovation [4]. Each of these axes—often implemented in isolation—would yield greater results if pursued in a complementary manner. Together, they would contribute to strengthening regional governance, enhancing capacities for project formulation and management, and strategically linking knowledge among the diverse actors of the science, technology, and innovation ecosystem [7].

The expected outcomes transcend the mere fulfillment of quantitative indicators. Beyond increasing investment in RDI or improving the management of royalties, what is ultimately at stake is the possibility of constructing a robust and sustainable innovation ecosystem in which knowledge becomes a genuine driver of social and economic transformation [3]. This approach acknowledges that the competitiveness of Amazonas will not rely solely on exploiting its comparative advantages but rather on its ability to transform them into sustainable competitive advantages through science, technology, and innovation.

The success of this initiative will be determined by key factors such as the political will of local and national governments, the timely allocation of resources, and, above all, the active participation of quadruple-helix actors. Government, academy, the business sector, and civil society must assume a shared commitment to building consensus and co-creating solutions that respond to the specificities and opportunities of the territory.

In sum, Amazonas faces the possibility of becoming a benchmark for how a peripheral territory—historically marginalized from major research centers—can transform its weaknesses into strengths through innovation, collaboration, and the strategic use of knowledge. This study aspires, in that sense, to serve as a valuable input for guiding policies and actions aimed at constructing a more equitable, sustainable, and knowledge-based development model.

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