“THE ADAPTIVE HELIX MODEL: A PROPOSED FRAMEWORK FOR SUSTAINABLE INNOVATION VALUE”

Research Paper

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“Abstract”

Innovation zones and ecosystems (IZEs) are increasingly crucial for national development, economic support, and resource sustainability. However, many fail to meet expectations for reasons related to the structure and composition of the ecosystems model implemented or how these models are implemented. Existing helix models: Triple, Quadruple, Quintuple, and N-Tuple helix provide applicable conceptual models, but they are rigid and fragmented for dynamic and decentralized IZEs. This article presents the Adaptive Helix Model, a transformation-driven and holistic framework designed to ensure smooth and flexible implementation applicable to various types of IZEs. The model is structured around eight interconnected helices and components implemented by IZEs owners. This study demonstrates how the Adaptive Helix Model overcomes the gaps in existing helix models and the challenges facing IZEs. It also provides practical guidance for applying the model across diverse IZEs, aiming to enhance resilience and sustainable value creation.

Keywords: Innovation zones and ecosystems, Helix models, Transformation, Adaptive systems.

1 Introduction

Innovation zones and ecosystems (IZEs) have become increasingly vital tools for achieving economic resilience, technological leadership, and sustainable development in a rapidly changing global landscape. Countries have invested in these ecosystems to foster entrepreneurship, accelerate knowledge transfer, and address complex societal challenges. Over the past two decades, helix models have provided theoretical insights into driving, activating, and measuring innovations in IZEs, which have struggled in practice. However, the performance of many IZEs continues to decline due to numerous challenges facing IZEs, their operators, and even the selection of the appropriate model.

In successive sections, this article reviews the answers to these questions and proposes appropriate solutions to the various challenges. The literature review analyzes previous studies and articles on different spiral models and identifies the key gaps in each model. It also proposes an adaptive model, which builds on previous helix models by delving into the philosophy of transforming systems into adaptive systems. The proposed adaptive spiral model is a more flexible and viable alternative, enabling dynamic interactions between the various key components of IZEs. The article discusses how the adaptive spiral model can overcome some of the most significant global challenges facing IZEs, such as policy inconsistencies, governance, structural challenges, lack of funding, and marketing failures.

2 Literature Review

A system called the Helix Model of Innovation was created to promote economic and social development through the interaction of multiple parties to generate new knowledge and innovations and expand and support interaction between actors (Weingart, 1997; Godin, 1998).
Innovation ecosystems have evolved over time, with each model becoming more coherent. Model 2, or the **Double Helix**, began with collaboration between academia and industry to drive innovation and economic growth. Then, for the first time, Henry Etzkowitz and Loyt Leydesdorff developed the **Triple Helix** model, which highlighted interactions between universities and industry and introduced government as a legislative body and driver of economic growth. This was done in 1995 and 2000 (Etzkowitz and Leydesdorff, 2000; Leydesdorff, 2012; Carayannis and Campbell, 2021).

The triple helix model (university-industry-government) faces structural imbalances among its three main players. The most important of these is the mismatch between academia and industry, as universities focus on theoretical research, while industries demand practical, market-oriented solutions. Coordination problems also arise due to divergent goals, funding cycles, and timelines among universities, industries, and governments, leading to inefficiencies. Regulatory and political constraints have also emerged, as governments must balance promoting innovation with national security, intellectual property laws, and market regulations. Furthermore, resistance to change is high among academic institutions and traditional industries to the shift toward collaborative innovation due to bureaucratic rigidity (Shinn, 2002; Leydesdorff, 2012).

Researchers have recognized that innovation extends beyond academia and industry and may be driven by other non-governmental actors. Therefore, in 2009, Carayannis & Campbell proposed adding a fourth player to the helix: civil society and the media, proposing the **Quadruple Helix** Model (Leydesdorff, 2012).

The quadruple helix model also faces challenges in achieving public participation and aligning civil society interests with economic goals, such as difficulties in engaging the public (citizens and the media) in innovation processes within regulatory frameworks. The media can also accelerate and distort innovation, raising public skepticism about technological progress. Furthermore, the goals of civil society (such as ethical considerations) often conflict with the profit-driven motivations of industry. Another challenge is the lack of standardization, meaning there is no universally agreed-upon representation of how civil society interacts with universities, industry, and governments (Mineiro, Assis De Souza and Carvalho De Castro, 2021).

With the emergence of the United Nations Sustainable Development Goals in 2009 and their focus on the environment, the model was developed into The **Quintuple Helix**, adding a fifth perspective: the integration of natural environments into society, which emphasizes the necessary socio-ecological transformation of society and the economy (Carayannis, Barth and Campbell, 2012a, 2012b; Durán-Romero *et al.*, 2020; Kholiavko *et al.*, 2021; Zen and Shibakawa, 2022; Dewika *et al.*, 2024).

The quintuple helix model faces tensions between sustainability and economic growth, regulatory barriers, high adoption costs, and a weak prioritization of environmental versus economic outcomes. The discrepancy between sustainability goals and business profitability hinders the effectiveness of green innovation policies. Impact measurement is also complicated, as assessing the long-term effects of eco-innovation is difficult due to the interconnectedness of social and environmental factors (Zhou and Etzkowitz, 2021; Cai, 2022).

With the increase in subsystems and the development of many new innovation concepts such as global finance, cybersecurity, digital transformation, artificial intelligence, and others, Loet Leydesdorff introduced a tiered model in 2021 called The **N-Tuple Helix** (Carayannis and Campbell, 2010; Leydesdorff, 2012; Fitjar, Gjelsvik and Rodríguez-Pose, 2014; Villarreal and Calvo, 2015; Carayannis *et al.*, 2018; Roman *et al.*, 2020). This has faced significant challenges due to excessive complexity, unclear governance, as the roles and responsibilities of emerging stakeholders (such as AI governance

bodies and digital infrastructure providers) remain undefined, and coordination difficulties, as the addition of too many spiral models hinders the model's application in practical decision-making. Reconciling the interests of various stakeholders (such as AI ethics boards, international trade organizations, and local communities) is also a significant challenge. Furthermore, the inclusion of more actors in the spiral model makes it difficult to ensure long-term commitment and maintain innovation momentum (Donati, Stefani and Bellandi, 2023; Sloup, Riedl and Machoň, 2023; Haryadi, Sulistyadi and Asmoro, 2025).

All these challenges and others have led to the need to search for a model that offers the optimal solution. This leads to the need to develop an adaptive model that is more flexible, dynamic, and technically integrated, one that is compatible with economic, political, and societal issues, as well as emerging and constantly evolving technologies. Implementing entities should take what they need from this adaptive model to achieve the best results, efficient implementation, and effective IZEs.

3 Research Approach

The adaptive model design follows a three-stage approach: (1) A comparative analysis of existing helix frameworks (Triple Helix, Quadruple Helix, Quintuple Helix, and N-Tuple Helix) to select key parameters. (2) A thematic synthesis of current shortcomings observed in real regions. (3) The formulation of a new model that incorporates the main and sub-components of Innovation Zones and their goals. This article proposes an adaptive model that builds upon previous helix models, addresses their shortcomings, and provides solutions to Innovative Zones and Enterprises (IZEs) challenges to enhance their performance. **The Adaptive Helix Model** serves as a theoretical framework for this research based on a systematic review and synthesis of secondary sources. These sources include peer-reviewed academic literature, global theory indices, reputable reports from organizations such as the OECD and the United Nations, case studies on innovative regions, various models, and an examination of numerous books and theories related to transforming systems into adaptive systems.. (Cheung, 2002; Ioannou and Fidan, 2006; Miller and Page, 2007, 2007; Hovakimyan and Cao, 2010; Principe, Liu and Haykin, 2010, 2010; Viale and Pozzali, 2010; Gros, 2015; Stankovic, 2015; Ian, Yoshua and Aaron, 2016).

4 The Adaptive Helix Model

Rooted in the foundational logic of the Triple Helix model: universities, government, and industry (Figure 1). This article advances a more nuanced and adaptable framework: the adaptive helix model. In the triple helix configuration, the intersection of these three areas defines the core innovation workspace, shaped by the degree of synergy among its components. Each area encompasses a multitude of sub-components that collectively influence the structure and behavior of IZEs, and these components vary depending on the innovation domain and its contextual demands:

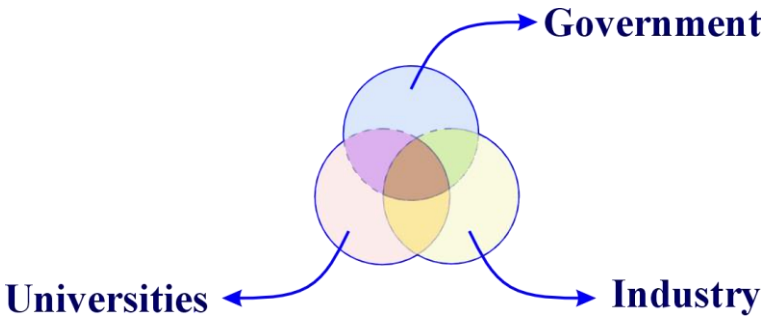

Figure 1. The Triple Helix Model

Recognizing the limitations of static models in dynamic environments, the Adaptive Helix Model builds upon this conceptual foundation by introducing eight helices, each representing a progressive stage in the design, formation, and evolution of an IZEs (Figure 2). These helices operate within a continuous application loop, organized into two interlinked phases: the Foundation and Expansion cycles. The implementation process commences with strategic alignment and advances sequentially through each helix respectively. The cycle is inherently repeatable, allowing for strategic recalibration and directional renewal as the IZE evolves.

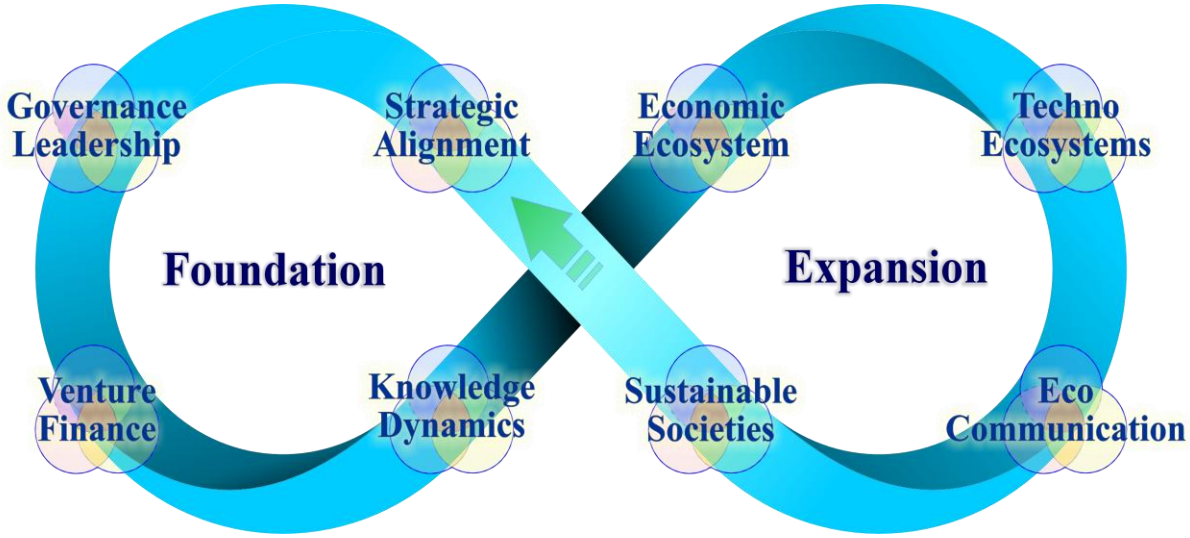

Figure 2. The Proposed Adaptive Helix Model

The Adaptive Helix Model has several key features that enhance its effectiveness. It includes all necessary components that enable a clear definition of complex problems while allowing for the dynamic refinement of goals. Additionally, it provides a structured yet flexible framework, overcoming the rigidity commonly found in earlier helix models; this flexibility allows the main or sub-components of the helix to be adjusted or removed based on the specific needs and requirements of the IZE, offering a sense of customization and uniqueness without neglecting any of the eight fundamental aspects. Furthermore, the model's clarity and directness make it easy to adopt across various institutional and geographic contexts, enabling its use as a diagnostic and assessment tool for existing IZE initiatives. Lastly, it acts as a compensative framework designed to address structural gaps, resolve inter-organizational misalignments, and promote realignment among stakeholders, strategies, and intended outcomes. These features position the Adaptive Helix Model as a comprehensive, scalable, and context-sensitive tool for facilitating transformation-driven innovation and delivering sustainable value across innovation ecosystems.

4.1 Strategic alignment helix

The Strategic Alignment Helix (Figure 3) forms the foundational pillar of the Adaptive Helix Model. It enables innovation ecosystems to operate with clarity of purpose, strategic coherence, and future resilience. By integrating vision-setting, adaptive planning, and performance evaluation, this helix ensures that innovation activities are aligned with national priorities and capable of responding to dynamic environments. (Chesbrough, 2003; Hall, Lotti and Mairesse, 2009; Christensen, Horn and Staker, 2013; Ranga *et al.*, 2013; Pisano, 2015; Gault, 2018)

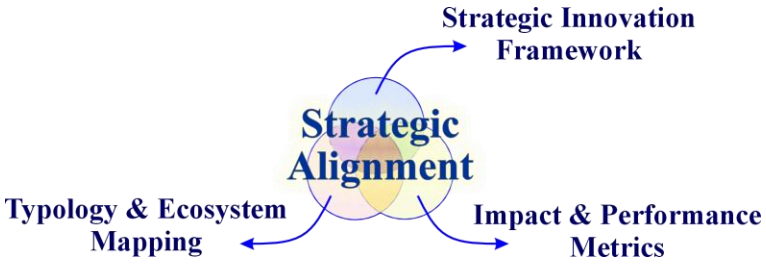

Figure 3. Strategic Alignment Helix.

4.1.1 Strategic innovation framework

The strategic innovation framework establishes the overarching strategic direction by aligning long-term vision with adaptive planning and scenario foresight. It integrates three subcomponents: vision and strategic alignment, adaptive planning and execution models, and scenario foresight with risk intelligence.

4.1.2 Impact & performance metrics

The impact and performance metrics component ensures accountability and effectiveness by linking innovation outcomes to development goals and global standards. Its subcomponents include KPIs, national performance metrics, economic and sectoral impact indicators, and global competitiveness and policy alignment.

4.1.3 Typology & ecosystem mapping

The typology and ecosystem mapping component provides a structural overview of innovation activity within the ecosystem. It includes classifying innovation types, mapping ecosystem interactions, and tracing value chains and commercialization pathways.

4.2 Governance leadership helix

The governance leadership helix (Figure 4) focuses on the institutional structures, regulatory frameworks, and geopolitical dynamics that shape and guide innovation ecosystems. It is critical to ensure that innovative governance remains transparent, accountable, and responsive, anchored in national priorities and aligned with international standards. This helix enables ethical experimentation, stakeholder inclusion, and regulatory agility by bridging domestic leadership with global cooperation. (Sassanelli and Terzi, 2022; Takala and Tukiainen, 2023; Agenda, 2024)

Figure 4. Governance Leadership Helix.

4.2.1 Committees and matter experts

The committees and matter expert's components engage expert advisory bodies and cross-sectoral committees to develop inclusive governance mechanisms. It emphasizes regulatory frameworks and

policies, stakeholder coordination and power balancing, and mechanisms that ensure transparency and accountability.

4.2.2 Geopolitical & international organizations

The geopolitical and international organizations component strengthens the alignment of innovation ecosystems with global norms through diplomacy, multilateral R&D collaboration, and strategic alliances. Its focus includes global policy harmonization, international research cooperation, and geopolitical competitiveness.

4.2.3 Regulatory agility & policy experimentation

The regulatory agility and policy experimentation component introduces flexible regulatory tools such as sandboxes and dynamic frameworks to support real-time governance and innovation testing. It addresses experimental regulation, adaptive policymaking, and integrating ethics and public trust into governance design.

4.3 Venture finance helix

The venture finance helix (Figure 5) focuses on the financial infrastructure and capital flows necessary to support innovation across its lifecycle. It encompasses traditional and emerging funding mechanisms, institutional investment pathways, and supportive ecosystems such as incubators and accelerators. This helix is vital in de-risking entrepreneurship, promoting sustainable growth, and aligning financial strategies with long-term economic and environmental goals. (Arzeni, Cusmano and Robano, 2015; de la Rosa *et al.*, 2024; Park, 2024; Alka, Sreenivasan and Suresh, 2025; Baby, 2025; Fan *et al.*, 2025; Mittal, 2025; Muddasir and Llorens, 2025; NAGESH and Murugan, 2025; Ogundu, 2025; Wood *et al.*, 2025; Borgaard and Einfeldt, no date)

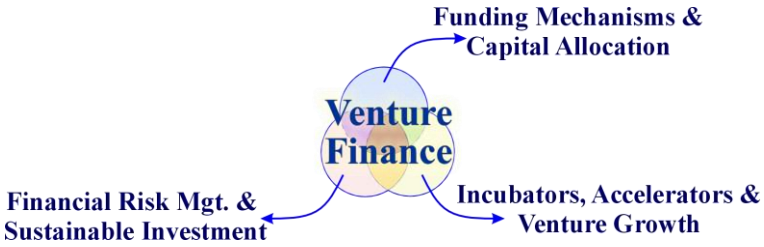

Figure 5. Venture Finance Helix.

4.3.1 Funding mechanisms & capital allocation

The funding mechanisms and capital allocation component include various financing options, from government grants and venture capital to crowdfunding and decentralized finance, ensuring a diverse and accessible capital base for innovation.

4.3.2 Incubators, accelerators & venture growth

The incubators, accelerators, and venture growth component support early-stage ventures through structured programs that offer mentorship, investment readiness, and scale-up pathways, bridging the gap between ideation and commercialization.

4.3.3 Financial risk management & sustainable investment

The financial risk management and sustainable investment component focuses on mitigating financial risks and promoting impact-driven investment by integrating ESG principles, regulatory compliance, and responsible financial governance.

4.4 Knowledge dynamics helix

The knowledge dynamics helix (Figure 6) focuses on creating, circulating, and applying knowledge as a central driver of innovation performance and sustainability. It integrates research infrastructure, open innovation practices, educational systems, and human capital development into a cohesive knowledge environment. This helix strengthens the intellectual foundations of innovation ecosystems by fostering continuous learning, cross-sector collaboration, and knowledge commercialization. (Howells and Roberts, 2000; Gassmann and Enkel, 2004; Jackson, 2010; Bagheri and Pihie, 2011; J. Jackson, 2011; Madden *et al.*, 2013; Maruska and Perry, 2013; Stracke, 2013; Dobrenkov *et al.*, 2017; Karpov, 2017; Ustundag, Cevikcan and Karacay, 2018; Moueddene *et al.*, 2019; Gao *et al.*, 2020; Gu *et al.*, 2021; Pauceanu *et al.*, 2021; Pradhan and Saxena, 2023; Ashal and Morshed, 2024; Das, Mahabub and Hossain, 2024; Li, 2024; Zupok and Dyrka, 2024; Bhatti, Saxena and Singh, 2025; Dieguez, 2025; Long *et al.*, 2025)

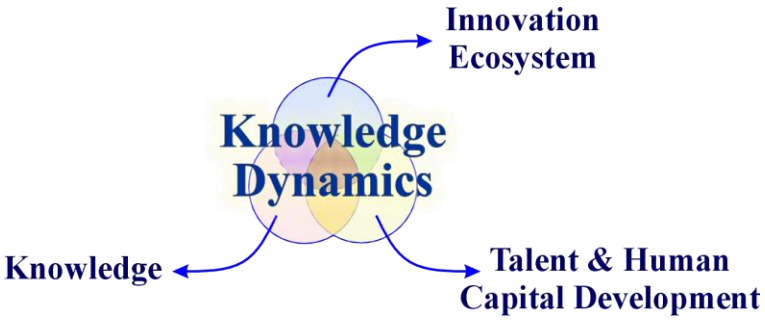

Figure 6. Knowledge Dynamics Helix.

4.4.1 Innovation ecosystem

The innovation ecosystem component represents the interconnected environment that enables innovation through collaboration among institutions, supported by R&D infrastructure, open innovation networks, and regulatory frameworks.

4.4.2 Knowledge

The knowledge component encompasses the systems and tools that convert information into actionable insight and innovation, including education, research institutions, data analytics, and intellectual property and knowledge transfer mechanisms.

4.4.3 Talent & human capital development

The talent and human capital development component ensures a future-ready workforce by investing in science, technology, engineering, and mathematics (STEM) education, workforce reskilling, and programs that promote leadership, entrepreneurship, and interdisciplinary competencies.

4.5 Economic ecosystem helix

The economic ecosystem helix (Figure 7) explores the intersection of innovation and market dynamics, focusing on how technological advancement, entrepreneurship, and globalization drive

economic transformation. It supports industrial competitiveness, the diffusion of circular business models, and the strengthening supply chain resilience. This helix ensures that innovation contributes directly to measurable economic growth, sustainable development, and long-term sectoral leadership. (Babcock, 1970; Pack, 1993; Kama, 2001; Jackson, 2009; Pukthuanthong and Roll, 2009; Louw, van Der Krabben and Van Amsterdam, 2012; Auerswald and Dani, 2018; Teece, 2018; Agustian *et al.*, 2023; Asimiyu, 2024; Han *et al.*, 2024; Rosário, Lopes and Rosário, 2024; Judijanto *et al.*, 2025; Kannan and Gambetta, 2025)

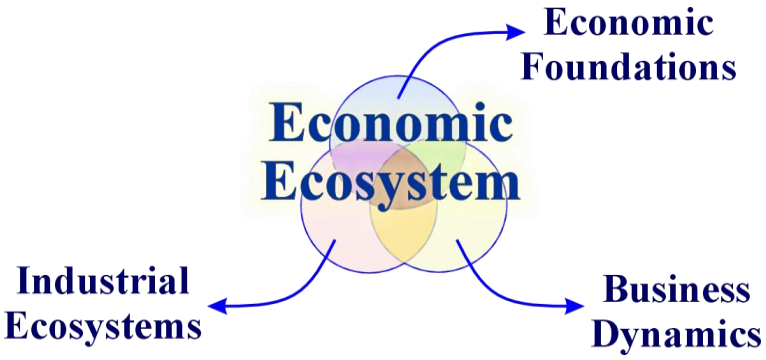

Figure 7. Economic Ecosystem Helix.

4.5.1 Economic foundations

The economic foundations component focuses on productivity growth, global trade integration, and the transition toward sustainable economic models, such as the circular economy, serving as the base for long-term value creation.

4.5.2 Business dynamics

The business dynamics component emphasizes adaptive business models, entrepreneurship, and SME development, enabling firms to remain competitive and responsive to evolving market conditions.

4.5.3 Industrial ecosystems

The industrial ecosystems component addresses sectoral transformation through digitalization, improved competitiveness, and robust supply chains, positioning the industry as a key enabler of scalable innovation and national economic strength.

4.6 Techno-ecosystems helix

The techno-ecosystems helix (Figure 8) focuses on the digital and physical infrastructure that powers intelligent, connected, and adaptive innovation environments. It integrates advanced technologies with smart infrastructure to enable real-time operations, predictive intelligence, and secure digital ecosystems. This helix is central in shaping technology-integrated Innovation Zones and Ecosystems (IZEs), ensuring they are data-driven, resilient, and future-ready. (J. Jackson, 2011; Shrestha, Ben-Menahem and von Krogh, 2019; Rodrigue, 2020; European Union Agency for Cybersecurity., 2021; Füller *et al.*, 2022; Biswas and Wang, 2023; Li and Chen, 2024; Nguyen, Nguyen and Nguyen Gia, 2024; Secundo *et al.*, 2024).

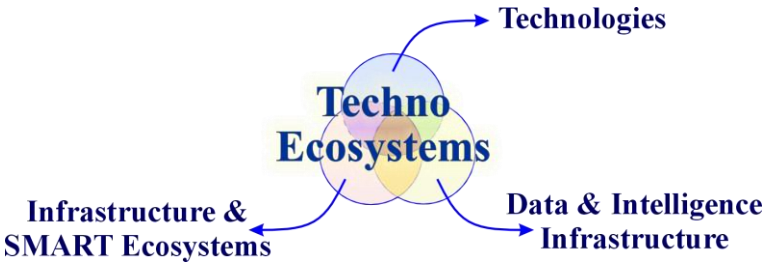

Figure 8. Techno-Ecosystems Helix.

4.6.1 Technology

The Technology component encompasses foundational and emerging technologies, including artificial intelligence, blockchain, and cybersecurity, supporting SMART automation and secure digital ecosystems.

4.6.2 Data & intelligence infrastructure

The data and intelligence infrastructure component includes the systems that convert data into predictive insights through big data analytics, decentralized data governance, and AI-augmented decision-making.

4.6.3 Infrastructure & smart ecosystems

The infrastructure and smart ecosystems component encompasses the physical and digital systems, including 5G networks, IoT connectivity, and sustainable urban design, facilitating real-time data flows and coordinating intelligent urban and industrial systems.

4.7 Eco-communication helix

The eco-communication helix (Figure 9) facilitates the flow of knowledge, perception, and environmental awareness across innovation ecosystems through media, digital networks, and science communication. It plays a vital role in influencing public discourse, guiding policy directions, and reinforcing sustainability narratives. This helix also advances environmental protection and supports integration with global sustainable development agendas through transparent communication, multilateral collaboration, and inclusive knowledge exchange. (Featherstone and Lash, 1999; Rook, 2013; Biermann, Kanie and Kim, 2017; Schroeder, 2018; Chen, Viardot and Brem, 2019; Taddicken and Krämer, 2021; Conzen and Larkham, 2022; Anshari et al., 2025; Avdeenko and Frölich, 2025; Khoiri et al., 2025).

Figure 9. Eco-Communication Helix.

4.7.1 Media & digital networks

The media and digital networks component examines how science communication, digital platforms, and public media influence environmental awareness, shape public opinion and promote policies aligned with sustainability goals.

4.7.2 Natural environment

The natural environment component focuses on ecological preservation and resilience through climate adaptation strategies, sustainable resource management, and biodiversity protection within innovation frameworks.

4.7.3 UN sustainable development goals & global impact

The UN sustainable development goals (SDGs) and global Impact component highlight how innovation ecosystems contribute to achieving the SDGs through technology-enabled solutions, cross-sector partnerships, and sustainable financing mechanisms.

4.8 Society & sustainability helix

The society & sustainability helix (Figure 10) represents human, cultural, and ethical dimensions of innovation. It emphasizes inclusivity, social responsibility, and behavioral readiness in adopting emerging technologies. Rooted in the principles of Society 5.0 is a concept that envisions a future where advanced technologies, such as AI, IoT, and robotics, address societal challenges while promoting human well-being and inclusive growth. It expands Industry 4.0 into a people-centered framework that ensures societal benefits and technological advancements. This concept has recently evolved, and some scholars have discussed Society 6.0; therefore, it has been reformulated as Society x.0 to ensure that innovation ecosystems are technologically advanced, socially resilient, and ethically grounded. (Ang and Van Dyne, 2008; Stilgoe, Owen and Macnaghten, 2013; Taebi et al., 2014, 2014; Haque, 2015; H-UTokyo Lab, 2020; Pfeiffer et al., 2020; Alkhalifa, 2021; Viola and Laidler, 2021; Huang et al., 2022; Samarawickrama, 2022; James, 2023; Yaqot et al., 2024)

Figure 10. Society & Sustainability Helix.

4.8.1 Society x.0

The Society x.0 component envisions a future where technologies such as AI and IoT are deployed to solve societal challenges through inclusive, human-centric innovation models. It encompasses SMART and sustainable living, digital citizenship, and technological equity.

4.8.2 Ethical & responsible innovation

The ethical and responsible innovation component focuses on embedding ethical standards and sustainability principles into the innovation lifecycle, addressing risks, aligning AI with public values, and ensuring transparent governance.

4.8.3 Cultural & behavioral adoption

The cultural and behavioral adoption component examines how cultural context, public trust, and psychological readiness influence the successful integration of innovation, promoting meaningful adoption across diverse communities.

5 Discussions

5.1 The adaptive helix model implementation

The implementation of the adaptive helix model begins with the structured activation of its eight interdependent helices, forming a continuous system that supports innovation ecosystem design and transformation. This implementation follows a sequential path, beginning with a foundational strategy and expanding through governance, economy, technology, and society. Unlike rigid models, the adaptive helix ensures that each helix builds on the previous, maintaining alignment between vision, structure, policy, and performance. The phased approach also allows for recalibration and customization based on each innovation zonse's readiness and needs.

The Adaptive Helix Model directly responds to persistent barriers in innovation zones, such as strategic fragmentation, institutional rigidity, disconnected funding pipelines, and underdeveloped entrepreneurial ecosystems. Its eight helices structure responds directly to these issues. Strategic alignment improves focus and performance metrics; governance leadership enables regulatory agility; venture finance supports tailored funding; and knowledge dynamics strengthen talent, innovation, and culture. Together, these components promote flexibility, coordination, and long-term sustainability.

5.2 Addressing existing challenges

IZEs encounter several challenges when implementing multi-helix systems. These challenges include strategic misalignment, rigid governance, fragmented funding systems, and a weak entrepreneurial culture. This discussion will examine these challenges in detail and illustrate how the Adaptive Helix model effectively addresses them. It will present a structured and sequential framework, highlighting key case studies to demonstrate its application.

Strategic misalignment between vision and performance goals leads to inefficiency. Over 30% of executives cite unclear innovation objectives as a primary barrier (Daniel *et al.*, 2023). The Adaptive Helix responds by initiating implementation with Strategic Alignment, ensuring innovation activities are grounded in coherent vision, metrics, and typology from the outset.

Rigid governance remains a core bottleneck, with over 50% of ecosystem failures linked to institutional rigidity and fragmentation (Daniel *et al.*, 2023). The governance leadership helix restructures oversight through stakeholder balancing, agile regulation, and global policy integration. The Stakeholder Coordination & Power Balancing component ensures clear roles and authority distribution, while Regulatory Agility & Policy Experimentation introduces flexible tools such as sandboxes and iterative policy design. Geopolitical & International Alignment expands this governance capability by positioning zones within broader global innovation frameworks. This helix restructures governance around adaptability and embeds learning systems that evolve with the ecosystem’s needs.

Funding gaps and inadequate support systems hinder equitable innovation development across global ecosystems. For example, global venture capital has dramatically declined, dropping by 67% in Latin America and over 38% in North America, Europe, and Asia-Pacific. Venture capital (VC) investments peaked in 2021 but fell by 60% by the second quarter of 2023, returning to levels seen in 2020. A slight recovery was noted in the second quarter of 2024, with VC values increasing by 50% in North America, 12% in Latin America, and 6% in Europe. However, investments in Asia-Pacific and Africa continued to decline, with 19% and 80% decreases, respectively.(Schwab and Zahidi, 2020; Gisbert

and Behrens, 2024). The Venture Finance helix addresses this through adaptive capital models, including startup incubation, growth acceleration, and impact-aligned investment channels. These sub-components collectively re-architect the funding landscape to ensure that capital flows exist and are equitably accessible, context-sensitive, and aligned with innovation maturity.

A weak entrepreneurial culture and lack of capacity-building restrict innovation potential in many zones. Without a robust entrepreneurial culture, the innovation potential is greatly diminished. Many studies have identified cultural factors such as risk aversion, poor institutional coordination, and resistance to change as ongoing barriers to innovation (Daniel *et al.*, 2023). The knowledge dynamics helix tackles this by embedding entrepreneurship through education, cultural activation, and networked learning ecosystems. It expands culture-building through Innovation culture development, promoting creativity, risk tolerance, and purpose-driven collaboration. Finally, Collaborative Knowledge Networks sustain these shifts by linking institutions, entrepreneurs, and communities in continuous exchange. The model trains talent and reshapes mindsets, embedding entrepreneurship as a societal norm rather than a niche exception.

5.3 Future insights

The Adaptive Helix Model is positioned as a forward-looking framework designed to accommodate the increasing complexity of innovation ecosystems. The model provides a flexible, group-based structure that enables real-time adaptation as these systems evolve in response to rapid technological change, environmental pressures, and shifting governance paradigms. It ensures that innovation zones can recalibrate their strategic focus, funding logic, and stakeholder roles to remain relevant and resilient. Researchers can utilize this model to categorize innovation strategies in alignment with ecosystem maturity and societal impact. They may also use it to develop adaptive governance frameworks and participatory mechanisms that address local needs and global priorities.

Furthermore, the model encourages the development of feedback systems to monitor innovation readiness and resilience. The Adaptive Helix provides entrepreneurs with a more straightforward pathway to scale innovations, access capital, and build meaningful partnerships. Structuring the ecosystem around transparency, agility, and modular implementation empowers innovation leaders to grow within zones and shape their evolution.

6 Conclusion

The Adaptive Helix Model presents a modular, phased framework for designing and managing innovation ecosystems. It moves beyond the limitations of traditional helix models by introducing a dynamic, group-based structure that addresses strategy, governance, finance, knowledge, economy, technology, communication, and social integration. This architecture enables innovation zones to evolve systematically, adapting to both local contexts and global changes. Unlike static frameworks, the model supports real-time stakeholder interaction, policy agility, and tailored innovation strategies. It facilitates strategic alignment, responsive governance, inclusive funding, and entrepreneurial capacity development. These features collectively contribute to system adaptability and long-term sustainability. Moreover, the model serves as a diagnostic and implementation tool, enabling ecosystem leaders to identify structural gaps, prioritize actions, and sequence development activities with clarity. The Adaptive Helix Model offers innovation zones a comprehensive pathway to resilience, scalability, and impact by bridging conceptual design with practical application. It positions them to navigate complexity and lead innovation transformation in an increasingly uncertain global landscape.

7 Conflict of Interest Statement

The author, Saleh Alnouman, confidently affirms that no conflicts of interest are associated with this article's research, authorship, and publication.

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