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Trilateral Innovation Ecosystems In Industry 5.0: Startup Management, Collaborative Administration, And Resilient Governance

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Abstract

The transition to Industry 5.0 represents a fundamental shift from technology-centric automation to human-centric, sustainable, and resilient innovation systems. This paper introduces the concept of Trilateral Innovation Ecosystems (TIEs) as a strategic framework that integrates three interdependent components: Start-up Management, Collaborative Administration, and Resilient Governance. Drawing on theories of open innovation, networked governance, and triple helix collaboration, the study proposes a conceptual model (TIE-5.0) and a methodological framework (TIE-MODEL) to identify, assess, and enhance the performance of innovation ecosystems operating within Industry 5.0 environments. Through empirical references and case illustrations, the paper demonstrates how trilateral interaction supports innovation scalability, regulatory adaptability, and ecosystem resilience.

Keywords: *public–private partnership, ecosystemic governance, institutional resilience, collaborative public administration, socio-institutional ecosystem, trilateral partnerships, innovations, start-up management, Industry 5.0, digitalization*

INTRODUCTION

The emergence of Industry 5.0 marks a pivotal evolution in the trajectory of industrial and technological development. While Industry 4.0 introduced the digital integration of cyber-physical systems, the Internet of Things (IoT), and data-driven automation into manufacturing and services, it largely emphasized efficiency, scalability, and process optimization. However, the acceleration of global crises—including climate change, geopolitical instability, pandemics, and economic volatility—has revealed the limitations of purely techno-centric progress. Industry 5.0, as envisioned by the European Commission (2021), shifts the paradigm toward a more holistic model—one that places human needs, social equity, and environmental sustainability at the centre of industrial systems.

This reorientation calls for innovation ecosystems that are not only technologically advanced but also resilient, inclusive, and adaptive. The integration of ethical AI, circular economy principles, workforce empowerment, and crisis-responsive governance into innovation agendas is no longer optional but essential. Industry 5.0 thus reframes innovation as a societal function, requiring the coordinated action of diverse institutional actors beyond traditional market or academic boundaries.

Historically, innovation models have been built on bilateral configurations—such as public-private partnerships or university–industry collaborations. While these have generated considerable value, they often lack the systemic integration and institutional depth needed to respond to the dynamic complexity of modern socio-technical challenges. In this context, there is a growing consensus that effective

innovation systems must move beyond linear and siloed approaches toward multilateral, reflexive, and distributed architectures.

In response to this need, we propose the concept of Trilateral Innovation Ecosystems (TIEs)—an integrative model that foregrounds the interaction among three core actors:

- Startups, as agile agents of technological and business innovation;
- Collaborative administrative bodies, which facilitate infrastructure, policy experimentation, and ecosystem support;
- Resilient governance institutions, which enable long-term coordination, ethical regulation, and adaptive strategy under uncertainty.

The TIE model aligns with and expands upon existing frameworks such as the Triple Helix and open innovation ecosystems, but it also introduces a deliberate focus on governance resilience and the institutional co-evolution of entrepreneurial, administrative, and regulatory capacities. In particular, TIEs are conceptualized as dynamic networks where innovation is not merely generated but also supported, guided, and scaled through continuous trilateral interaction.

The central argument of this paper is that trilateral cooperation—when properly structured—can significantly enhance the capacity of innovation ecosystems to deliver not only technological outputs, but also social value, institutional trust, and systemic resilience. By developing and operationalizing the TIE-5.0 conceptual framework and the TIE-MODEL methodological approach, this study offers a new lens for understanding how startups, public administration, and governance bodies can co-create sustainable futures in the era of Industry 5.0.

1.1. Research Objective and Questions

Research Objective is to develop a conceptual and methodological framework for analyzing Trilateral Innovation Ecosystems (TIEs) within the context of Industry 5.0.

Research Questions are:

RQ1: What are the core components and functions of TIEs?

RQ2: How do start-ups, collaborative administration, and governance institutions interact within these ecosystems?

RQ3: How can the effectiveness of TIEs be measured and enhanced?

LITERATURE REVIEW

The development of the Trilateral Innovation Ecosystem (TIE-5.0) is grounded in a synthesis of four foundational theoretical paradigms: Industry 5.0 vision, the Triple Helix model, the Open Innovation Ecosystem approach, and the emerging framework of Resilient Governance. These schools of thought converge in recognizing that innovation, to be sustainable and inclusive, must be shaped by multidimensional interactions—technological, institutional, and societal.

2.1. Industry 5.0 Vision

The concept of Industry 5.0, as outlined by the European Commission (2021), emphasizes a departure from the techno-centrism of Industry 4.0. Rather than optimizing only productivity and automation, Industry 5.0 underscores human-centricity, sustainability, and resilience as core objectives of future industrial systems.

“Industry should not only be efficient and productive, but should also become a resilient provider of prosperity, by making production more sustainable and placing the well-being of the worker at the centre of the production process” (EC, 2021).

This vision serves as a normative backdrop for the TIE-5.0 model, which assumes that technological innovation must co-evolve with institutional adaptability and societal benefit. It positions the start-up not merely as a productivity driver but as an agent of socially responsive innovation embedded in collaborative ecosystems.

The digital transformation of national economies is highly uneven across sectors, particularly in emerging markets. As Myahkykh, Kokhno, and Sopin (2025) show in a composite analysis of Ukrainian industries, substantial disparities exist in digital maturity and readiness. ICT and financial sectors demonstrate high integration of digital tools and innovation capacity, while sectors such as agriculture and construction lag

considerably. These findings suggest that ecosystem design must be sector-sensitive, with trilateral collaboration tailored to the digital realities and constraints of each domain.

2.2. Triple Helix Model of Innovation

The Triple Helix model (Etzkowitz & Leydesdorff, 2000) postulates that innovation emerges at the intersection of three institutional spheres: university (knowledge production), industry (commercialization and application), and government (regulation and facilitation). In contrast to linear innovation models, the Triple Helix emphasizes interactive and recursive feedback mechanisms that stimulate emergent knowledge and innovation. In the context of TIE-5.0, the model is extended beyond its traditional academic framing to account for the entrepreneurial dynamics of start-ups and the coordinating role of administrative actors. This results in a more fluid configuration of roles, where knowledge actors may also be entrepreneurial, and government actors may co-develop or co-own innovation platforms.

2.3. Open Innovation Ecosystems

The theory of Open Innovation (Chesbrough, 2003) asserts that firms can and should leverage external and internal ideas, technologies, and networks to advance their innovation strategies. Open Innovation Ecosystems, as articulated by Adner (2017), expand this idea into a networked structure in which value creation and value capture are distributed across organizational boundaries.

This logic is directly relevant to the startup-driven core of the TIE-5.0 model. Startups in such ecosystems are both contributors and beneficiaries of a shared innovation infrastructure, including public–private platforms, accelerators, digital sandboxes, and cross-sector partnerships. Administrative actors serve not only as regulators but also as enablers of openness, while governance frameworks must evolve to support trust, reciprocity, and data-sharing norms.

In the Ukrainian post-war context, Zolkover et al. (2025) propose a phased roadmap that integrates digital innovation, regional clustering, and adaptive finance into recovery strategy. Their findings emphasize the necessity of sector-specific innovation policies, backed by data from a longitudinal survey of 120 firms across Ukraine. Notably, they advocate for a combination of resilience scoring and EU-compatible mechanisms to direct capital toward IT, agro-tech, and green energy — sectors that closely align with our TIE-5.0 framework's emphasis on trilateral innovation coordination.

2.4. Resilient Governance

Governance under conditions of rapid change and systemic uncertainty requires a shift from static rule enforcement to dynamic, adaptive, and anticipatory modes. The concept of Resilient Governance, elaborated by Ansell and Gash (2007) and later expanded by Duit (2016), emphasizes collaborative problem-solving, institutional learning, and the capacity to respond to crises without system breakdown.

This is especially salient in the face of 21st-century grand challenges—ranging from climate risk to geopolitical instability. In TIE-5.0, resilient governance is not merely reactive but proactively co-created with start-ups and administrative institutions. It entails creating regulatory sandboxes, ethical AI standards, and real-time feedback loops between citizens, innovators, and policymakers.

The interplay between innovation, governance, and recovery has gained significant attention in contexts of crisis and post-crisis resilience building. Research shows that sustainable innovation ecosystems must be designed not only for growth but also for shock absorption, rapid adaptation, and long-term recovery (Duit, 2016; Ansell & Gash, 2007). This is especially relevant in light of global disruptions such as pandemics, economic instability, and armed conflict.

In this regard, the work of Gorokhova et al. (2024) provides a contextually grounded analysis of Ukraine's post-war economic recovery strategies, emphasizing alignment with the UN Sustainable Development Goals (SDGs). Their study identifies multi-level coordination, digital transformation, and entrepreneurial innovation as key levers in rebuilding national economic capacity. Crucially, it highlights the role of adaptive governance and start-up-driven initiatives in fostering inclusive and resilient recovery pathways.

Recent work on consumer resilience during wartime (Kostynets & Kostynets, 2023) highlights how demand for non-essential services like tourism can persist, even under severe institutional stress. While not focused on startups or formal governance, such findings reinforce the broader premise that innovation ecosystems must include mechanisms to anticipate, monitor, and respond to behavioural patterns across multiple levels of interaction—including the end user.

This contribution reinforces the premise of the TIE-5.0 framework—that innovation ecosystems must integrate bottom-up entrepreneurship, collaborative administrative mechanisms, and strategic governance interventions to navigate complex post-crisis transitions. The alignment with SDG-oriented governance also supports the notion that resilience must be institutionalized not just as a reaction to crises, but as a permanent feature of innovation strategy.
Each of these theoretical perspectives contributes a distinct dimension to the TIE-5.0 framework:

Table 1 The Theoretical background to the TIE-5.0 framework

Theory	Contribution to TIE-5.0
Industry 5.0 Vision	Establishes the normative goals: sustainability, human-centricity, resilience
Triple Helix	Provides a structural model of trilateral interaction across institutional spheres
Open Innovation Ecosystems	Defines the logic of distributed collaboration, value co-creation, and networked innovation
Resilient Governance	Embeds adaptive and anticipatory capacity into the system's institutional backbone

Together, these paradigms provide the theoretical scaffolding for a systemic, dynamic, and inclusive model of innovation tailored for the complexities and demands of Industry 5.0.
Despite robust scholarship on open innovation, triple helix synergy, and governance resilience, there is still no unified model that explicitly integrates:

- Start-up-centric innovation management
- Collaborative administrative coordination
- Adaptive, resilience-driven institutional governance into a coherent framework tailored for Industry 5.0 transformations.

This gap justifies the proposed Trilateral Innovation Ecosystem (TIE-5.0) model and its methodological operationalization (TIE-MODEL), as these frameworks offer an integrative lens to study how start-ups, public administration, and governance institutions co-evolve to produce resilient, human-centric, sustainable innovation outputs.

METHODOLOGY

The TIE-5.0 model conceptualizes trilateral innovation ecosystems as an integrated interaction of three domains (table 2).

Table 2 Conceptual Model: TIE-5.0

Component	**Primary Functions**	**Outputs**
Startup Management	Innovation generation, product development, agile experimentation	New technologies, business models, digital solutions
Collaborative Administration	Facilitation, coordination, public-private partnership development	Shared infrastructure, innovation platforms
Resilient Governance	Policy adaptation, regulation, ethical standards enforcement	Regulatory flexibility, institutional trust, societal value

This model emphasizes co-evolution and alignment among these actors to achieve ecosystem-level innovation and sustainability.

3.1 Methodological Framework: TIE-MODEL

To operationalize the TIE-5.0 concept, we propose a three-stage methodology (TIE-MODEL) for the identification, evaluation, and strategic development of trilateral innovation ecosystems.

3.1.1. Stages of the TIE-MODEL

1. Actor Identification
   - Mapping ecosystem participants using network analysis, platform registries, and open databases.
2. Interaction Assessment
   - Evaluating communication density, formal agreements, joint initiatives, and cross-sector platforms.
3. Performance Evaluation

Table 3 Using a trilateral set of indicators

Dimension	Indicators	Data Sources
Innovative Performance	Number of start-ups, patents, scaling success, innovation diffusion	Start-up databases, GII
Administrative Adaptability	Responsiveness time, service integration, digital maturity	e-Government benchmarks
Governance Resilience	Crisis mitigation capability, regulatory sandbox usage, trust indices	Governance indices, legal frameworks

3.2. Methods and Tools

- Qualitative interviews with founders, policymakers, and public administrators
- Policy and document analysis
- Social Network Analysis (SNA)
- Benchmarking (e.g., DESI, OECD Digital Government Index)

3.3. Case Illustrations

The applicability of the TIE-5.0 framework is illustrated using three emblematic cases:

- **Estonia**: e-Residency and its start-up-friendly digital governance structure.
- **Horizon Europe Projects**: Multi-actor research consortia fostering co-creation and resilience.
- **Ukraine's Diia.City**: A response to wartime disruption through digital public infrastructure and legal support for start-ups.

These cases reveal that trilateral collaboration enables ecosystems to adapt to volatility, while reinforcing systemic innovation and institutional trust.

RESULTS AND DISCUSSION

The findings of this study underscore the critical role of trilateral coordination in fostering resilient and high-performing innovation ecosystems within the Industry 5.0 paradigm. The presence of a collaborative administrative layer—functioning as an intermediary between start-ups and governance institutions—emerges as a key enabling factor. It acts not only as a policy facilitator but also as a platform orchestrator, ensuring that infrastructure, data governance, and regulatory mechanisms are appropriately aligned to support agile innovation. Our analysis suggests that the trilateral structure of the TIE-5.0 model offers systemic advantages over traditional bilateral models. The incorporation of startups, known for their experimentation and risk tolerance, introduces dynamism and responsiveness. In parallel, collaborative administration ensures structural stability, knowledge diffusion, and resource orchestration. Finally, resilient governance institutions contribute strategic foresight, ethical oversight, and long-term alignment with societal goals such as sustainability and equity. Sectoral asymmetries imply that trilateral models like TIE-5.0 must be adaptively deployed, aligning startup incentives, administrative capabilities, and governance mechanisms with sector-specific innovation maturity. Without such targeting, as observed by Myahkykh et al. (2025), even robust ecosystem policies risk reinforcing digital divides.

Crucially, trilateral alignment promotes ecosystem coherence, transforming isolated innovation experiments into scalable and institutionalized systems. This is particularly important in contexts marked by uncertainty, including post-crisis recovery (as illustrated by Ukraine's digital strategy and SDG-oriented development) or climate-driven transitions. The co-creation of value, facilitated through policy feedback loops and iterative engagement between actors, enables mutual learning and policy agility—two hallmarks of sustainable innovation systems.

To demonstrate the real-world applicability of the TIE-5.0 framework, three contrasting yet complementary case studies are presented. Each represents a distinct configuration of trilateral cooperation within a digitalized and evolving innovation ecosystem.

Table 4 TIE-5.0 Case Comparison Table

Case	Start-up Role	Administrative Coordination	Governance Resilience	Key Outcome

Estonia: e-Residency	International digital entrepreneurship; e-business registration	State-as-a-platform; digital registries and services	Secure, interoperable legal framework; digital identity law	Scalable, borderless start-up ecosystem
Horizon Europe Projects	SME-driven innovation in AI, energy, health	Project coordination by national bodies and universities	EU-level mission-oriented programs and funding governance	Formalized co-creation with institutional alignment
Ukraine: Diia.City	War-resilient IT firms; legal protection and benefits	Ministry of Digital Transformation managing Diia ecosystem	Adaptive legislation; sandboxing under wartime conditions	Crisis-adaptive innovation ecosystem with legal innovation

Estonia's case illustrates how collaborative administration can scale start-up ecosystems internationally while maintaining governance integrity. Horizon Europe promotes innovation through multi-actor consortia, where start-ups, public authorities, research institutions, and civil society co-develop technological and policy solutions. This illustrates institutionalized trilateral innovation with high formalization, built-in accountability mechanisms, and measurable impact across policy domains. Ukraine's case shows how innovation ecosystems can operate under extreme stress, with consumer demand, startup adaptation, and public infrastructure co-evolving to maintain continuity.

Despite contextual differences—post-industrial Estonia, structured EU consortia, and crisis-driven Ukraine—all cases demonstrate that trilateral alignment fosters not only innovation but also systemic trust, sustainability, and long-term transformation.

The TIE-5.0 framework finds resonance in the strategic recommendations by Zolkover, Iatsentiuk, and Aiyedogbon (2025), who advocate for adaptive policy instruments, innovation-finance coupling, and cross-sectoral alignment in post-war Ukraine. Their prioritization model — which incorporates sectoral resilience, digital maturity, and regional clustering potential — reinforces the need for trilateral governance architectures that can scale with both technological and institutional complexity.

Nonetheless, the implementation of trilateral models is not without challenges. The study identifies several structural and operational risks, including:

- Administrative overload caused by fragmented responsibilities or excessive regulatory requirements;
- Priority misalignment between entrepreneurial goals and public sector mandates;
- Regulatory inertia, which can hinder the adoption of novel governance instruments (e.g., sandboxes, testbeds, open data infrastructure).

Addressing these risks requires a careful balance between flexibility and structure, as well as institutional capacities for coordination, adaptation, and trust-building. The development of shared digital platforms, participatory foresight mechanisms, and inter-organizational learning frameworks are among the strategies that can mitigate these challenges and support trilateral synergy.

Overall, this discussion highlights that trilateral innovation ecosystems are not static arrangements but evolving, reflexive systems, shaped by ongoing negotiation, shared accountability, and strategic co-alignment among diverse actors.

CONCLUSION

This study advances the theoretical and practical understanding of innovation ecosystems by introducing the TIE-5.0 (Trilateral Innovation Ecosystem) model. Grounded in the principles of Industry 5.0, the model conceptualizes innovation as a co-evolutionary process involving entrepreneurial experimentation, administrative coordination, and resilient governance.

By embedding the logic of trilateral interaction into ecosystem design, the TIE-5.0 framework transcends the limitations of linear or bilateral innovation models. It offers a systemic, human-centered, and adaptive approach that is better suited to address the intertwined challenges of the digital transition, sustainability, and institutional complexity.

The TIE-MODEL methodological framework further provides a robust approach for identifying, assessing, and enhancing ecosystem performance through the analysis of innovation dynamics, administrative adaptability, and governance resilience.

Key contributions of this research include:

- A new conceptual model that aligns with the multidimensional demands of Industry 5.0;
- A methodological framework suitable for cross-sectoral and multilevel analysis of innovation ecosystems;
- Empirical illustrations demonstrating the operational relevance of trilateral ecosystems in diverse geopolitical contexts.

Future research directions may include:

- Quantitative validation of the TIE-5.0 model across national and regional innovation ecosystems using performance indicators and network metrics;
- Integration of AI-based tools for real-time monitoring, simulation, and scenario analysis within trilateral ecosystems;
- Comparative case studies exploring the effectiveness of trilateral innovation models in centralized versus decentralized governance settings;
- Policy-oriented studies on regulatory sandboxes, digital twins in governance, and ecosystem-based foresight in the public sector.

In conclusion, the TIE-5.0 framework lays the groundwork for a new generation of innovation ecosystem design—one that is attuned not only to the speed of technological change, but also to the ethical, institutional, and environmental imperatives of the 21st century.

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