DEFENCE INNOVATION ECOSYSTEMS AND RURAL ECONOMIC DEVELOPMENT: PATHWAYS TO SUSTAINABLE GROWTH AND MILITARY ADAPTATION

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Abstract
The full-scale war in Ukraine and the shifting geopolitical landscape have prompted European nations to reassess their defence strategies. Latvia has identified defence innovation as a strategic priority, with growing emphasis on integrating rural regions into its Defence Innovation Ecosystem (DIE). This study examines the structure, mechanisms, and development pathways of Latvia's DIE specifically focusing on the role of rural integration in regions such as Latgale. Through a systematic review of academic literature and national policy documents, the paper analyzes stakeholder roles, institutional coordination, and policy frameworks. It highlights concrete measures including the establishment of test and evaluation sites in Latgale, targeted Ministry of Defence grant programs for dual-use technologies, and national action plans aimed at decentralizing innovation. While public investment has increased, rural engagement remains constrained by infrastructural limitations, low SME participation, and funding disparities. The paper offers targeted policy recommendations to enhance rural innovation potential, align with NATO and EU frameworks, and support sustainable, innovation-led defence development in small states.
Keywords: defence innovation ecosystem, national security, rural development, public-private partnerships.

Introduction

In response to escalating geopolitical risks, particularly Russia's actions in Ukraine, European leaders have emphasized the urgent need to enhance defence readiness (Centrone & Fernandes, 2024). Innovation plays a critical role in strengthening national security, serving as a catalyst for advanced defence capabilities (Langham & Wrigley, 2020). Reflecting this global trend, the United States increased its research, development, test, and evaluation (RDT&E) spending by 9.4% in 2023, continuing a focus on advanced systems since 2014 (Tian et al., 2024). Sustained investment in research and development (R&D) remains essential for fostering defence innovation.

Innovation ecosystems dynamic networks of diverse stakeholders are key drivers of economic growth and competitiveness. Their resilience depends on consistent government support and legal frameworks (Abdi et al., 2024). As collaborative platforms, they enable technological advancement across sectors (Caliari et al., 2024; Thomas & Autio, 2019).

Rural regions are integral to national economies and are increasingly relevant to defence innovation efforts (Cabinet of Ministers of the Republic of Latvia, 2025). Regional development in the Baltic States is supported by international actors like the World Bank and European Commission, especially in vulnerable border areas. Digitalisation and community engagement are essential for rural resilience and autonomy (Nasution et al., 2025).

Defence Innovation Ecosystems (DIEs) vary significantly across countries based on strategic needs, policy frameworks, and geopolitical context (Budden & Murray, 2019). Studies from Ukraine, Armenia, Malaysia, and others illustrate different models shaped by national priorities (Hmyria et al., 2024; Harutyunyan, 2024; Balakrishnan & Johar, 2023). The DIE's form reflects assessments of threat levels, military readiness, and regional security dynamics (Kumar, 2017).

Latvia's DIE is rooted in its post-1990 independence trajectory and NATO/EU membership since 2004, relying on allied security guarantees (North Atlantic Treaty Organization, 1949). Its defence policy reflects geographic proximity to Russia, modest size, and strategic alliances. Though Latvia committed to a 2% GDP defence target by 2020, economic constraints delayed progress (Rublovskis, 2014). More recently, growing U.S. pressure to increase defence spending to 5% of GDP (Hendrix, 2025) has prompted Latvia to adopt a more proactive security strategy (Sprūds, 2025). While defence innovation spending is increasing, research on DIE mechanisms especially in rural integration remains limited. Understanding Latvia's DIE structure and its link to regional development is essential for informed policymaking. Most existing studies focus on broader defence policy, not ecosystem dynamics or rural contributions.

Research question: How does the DIE in Latvia function, and what are its implications for rural development and economic growth?

Aim: To analyze the structure, mechanisms, and policy frameworks of Latvia's DIE, with a focus on its impact on rural development.

Objectives: 1) Define key concepts and frameworks; 2) Identify primary stakeholders; 3) Propose policy recommendations to enhance innovation-driven military adaptation.

This paper concludes with strategic recommendations for aligning Latvia's DIE with NATO and EU priorities and identifies future research directions.

Limitations: Due to limited scholarly focus and the confidentiality of defence data, the study relies heavily on grey literature and policy analysis. Latvia's small research community and the scarcity of defence-specific academic publications further constrain comprehensive insights. Notably, no prior research has

addressed rural contributions to Latvia's DIE or benchmarked it internationally.

Materials and Methods

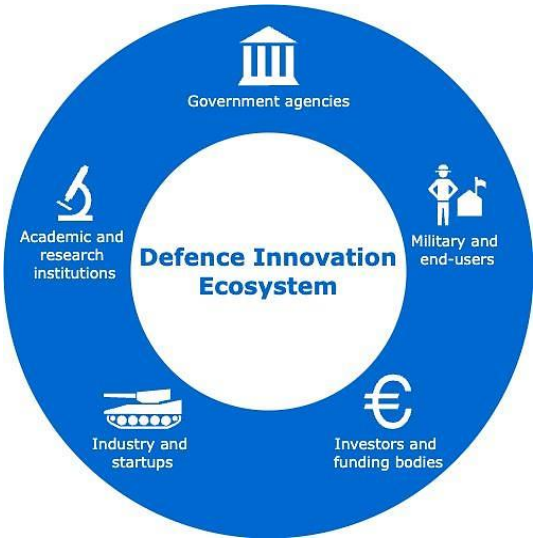
This scientific article adopts realism as its ontological stance and positivism as its epistemological foundation. The research object is the development and functioning of defence innovation ecosystems, with a particular focus on their impact on rural economic development within NATO and EU member states. This study is qualitative in nature and is based on a narrative literature review combined with grey literature analysis. These methods are particularly suited for exploring complex and evolving phenomena where primary data collection is not feasible. A narrative literature review is used to provide a broad, interpretive synthesis of existing scientific and policy knowledge, rather than to systematically analyze all available data. Relevant scientific studies and grey literature were identified through a systematic search in the Scopus academic database and via Google search, using keywords such as 'defence innovation ecosystem', 'rural development', 'rural economic development', 'defence expenditure', 'innovation ecosystem', 'defence industry', and 'national security and military capabilities'. The search focused on the subject areas of Social Sciences, Economics, Econometrics, and Finance, and was geographically limited to exclude Russia and Belarus. Only English-language publications from 2019 to 2025 were considered. While this approach provides a comprehensive overview of the topic using publicly available data, it has certain limitations. Chief among these is the lack of primary data, which constrains the ability to validate findings through empirical fieldwork or stakeholder interviews. Furthermore, the reliance on policy documents and secondary sources may introduce bias or restrict the depth of insight into real-world implementation dynamics.

Definition and conceptual framework

The author proposes the concept of a DIE to highlight the necessity of strengthening national security and military capabilities through technological advancements and cross-sector collaboration. As illustrated in Figure 1, an innovation ecosystem is a dynamic network of actors including government agencies, academic institutions, private industry, military and investors working together to drive technological breakthroughs and economic growth (Caliari et al., 2024). While the general principles of innovation ecosystems have been widely studied (Thomas & Autio, 2019; Granstrand & Holgersson, 2020; Alka et al., 2024; Sotirofski, 2024), DIEs exhibit distinct characteristics due to their reliance on national security policies, strategic alliances, and military needs. An innovation ecosystem consists of actors, artifacts, and activities interconnected through complementary and substitute relations. Additionally, institutions and the evolving nature of these ecosystems play a crucial role (Granstrand & Holgersson, 2020). The key definitions of the study's main concepts are outlined in Table 1. While the list could be expanded and refined, these represent the most essential concepts.

Figure 1

Key stakeholders in Defence Innovation Ecosystem



Conceptual framework of the defence innovation ecosystem

The DIE framework builds upon existing innovation ecosystem theories but integrates security-related constraints, regulatory mechanisms, and strategic imperatives. It is influenced by national policies, defence budgets, geopolitical pressures, and technological advancements.

Figure 2

Innovation mechanisms within Defence Innovation Ecosystem

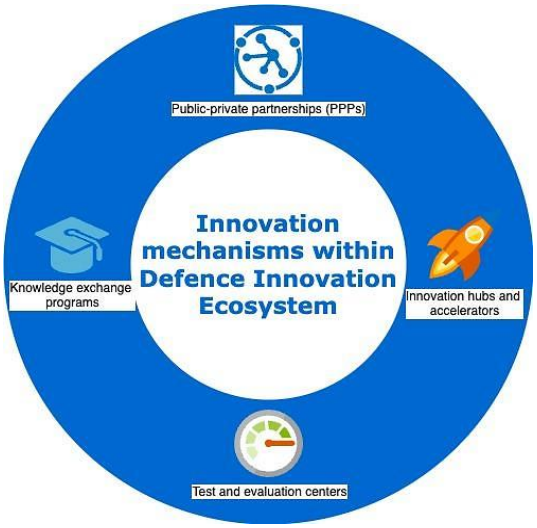


Table 1
Definition of key concepts

Concept	***Definition***	***Reference***
Defence Innovation Ecosystem	Network of stakeholders (gov., industry, academia, NGOs) collaborating on defence tech.	Authors definition
National Security and Military Capabilities	Ensures sovereignty and safety through policy and military strength.	Szpyra, 2014
Rural Economic Development	Enhancing rural economies via agriculture, infrastructure, and sustainability.	Wang, 2023
Innovation Ecosystem Resilience	Ecosystem's ability to adapt and recover from disruptions.	Abdi et al., 2024
Triple Helix Model	Collaboration between academia, industry, and government for innovation.	Cai & Amaral, 2021
Technology Transfer	Movement of tech/knowledge across entities to boost development.	Günsel, 2015
Dual-Use Technologies	Technologies with both civilian and military applications.	Vaynman & Volpe, 2023

Governance and policy frameworks
National and international regulations influence the structure of DIEs. For instance, in the European context, the European Defence Fund (EDF) plays a crucial role in funding defence R&D and fostering collaboration across member states (Lawrenson & Sabatino, 2024). Strategic initiatives such as NATO's Defence Innovation Accelerator for the North Atlantic (DIANA) encourage the development of cutting-edge military technologies by leveraging startups and small enterprises (NATO DIANA, 2024; Szkurłat, 2024). Beyond military applications, DIEs contribute to broader economic development, particularly in rural regions where defence industries can drive employment and infrastructure investments. A strong DIE fosters supply chain resilience, reducing dependency on foreign defence suppliers.

Results and Discussion
This research explored interconnected areas to better understand the DIE. To achieve this, it was essential to first comprehend what constitutes an innovation ecosystem, its components, various models, operational mechanisms, and resilience assessment. Rural development plays a crucial role in the DIE, as innovation can emerge in any region nationally, in capital cities, urban centers, or rural areas. R&D spending on defence is a key factor, encompassing both national and international support aimed at fostering defence innovation. Understanding the impact of innovation on national security and capabilities, as well as its economic influence particularly on rural development is vital. To achieve this, further in-depth and focused studies are needed, examining specific use cases across the innovation lifecycle, assessing their implications for security and economic growth.

Comparative concentration of defence innovation infrastructure: Urban vs. rural
Despite the Latvian government's efforts to promote regional development, defence innovation infrastructure remains largely concentrated in urban areas, particularly in and around Riga. Rural regions like Latgale, though emphasized in strategic documents, still face significant infrastructure and capacity gaps. While urban centres host the majority of defence companies, accelerators, and university-linked R&D hubs, rural regions have only recently begun to see the emergence of test sites or minor manufacturing capacity.

Table 2
Approximate distribution of defence innovation infrastructure in Latvia

Type of Infrastructure	***Urban (e.g., Riga, Jelgava)***	***Rural (e.g., Latgale)***
R&D centres	80%	20%
Dual-use industrial capacity	70%	30%
Startups engaged in DIE	85%	15%
Test sites and proving grounds	40%	60%
Public-private innovation initiatives	90%	10%

These are estimated figures outlined in Table 2 based on policy document content, hackathon locations, and known investments from Ministry of Defence (e.g., Rezekne Hackathon 2025). They illustrate a stark imbalance in innovation density and accessibility.

Regional disparities in defence grant funding

Grant funding provided by the Ministry of Defence between 2020–2024 has been predominantly awarded to organizations located in or near urban areas. Precise geospatial data is not publicly available; however, anecdotal evidence from news releases and project announcements suggests that rural applicants are significantly underrepresented among successful recipients. Key observations: 1) In 2024, out of 5 grant beneficiaries, only 1 was from a rural region (Rezekne); 2) In previous years (2020–2022), no rural-based projects were highlighted in MOD publications; 3) There is no dedicated rural stream or priority indicator in existing grant calls.

Policy gap analysis: Rural barriers and enablers in defence innovation (SWOT)

In the absence of fully disaggregated data, the following SWOT analysis (Table 3) outlines systemic issues and opportunities affecting rural engagement in the defence innovation ecosystem.

Table 3

SWOT analysis: Rural participation in Latvia's DIE

Strengths	**Weaknesses**
Strategic assets (test sites, low-cost land)	Limited access to R&D funding
Community interest and motivation	Talent drain to urban areas
Emerging infrastructure in Latgale	Low awareness of MOD programs
Government policy support (Action Plan 2025–2027)	Few linkages with industry leaders
Opportunities	**Threats**
EU and NATO funding for rural tech	Continued concentration of innovation in Riga
Dual-use tech deployment for civilian use	Infrastructure decay without investment
International collaborations (e.g., NATO DIANA)	Bureaucratic barriers for SMEs in periphery

Policy gap analysis reveals that despite strategic potential and emerging initiatives in rural regions, systemic barriers such as limited funding access, low institutional connectivity, and talent outmigration continue to hinder their full integration into Latvia's Defence Innovation Ecosystem.

Key mechanisms of defence innovation ecosystem

The evolving technological landscape and shifting geopolitical dynamics influence the long-term relevance and applicability of defence innovation (Girardi, 2024). As noted by the Massachusetts Institute of Technology (MIT) report (Budden & Murray, 2019), there is no universal approach to defence innovation. Countries are adapting established practices, and the Defence Innovation Ecosystem (DIE) described by MIT includes entrepreneurs, government agencies, universities, corporations, and risk capital providers. In Malaysia, key R&D stakeholders include the government, end-users, industry, and academia, who collaborate to advance technology through policy, research, development, and funding (Balakrishnan & Johar, 2023). The traditional Triple Helix model falls short in defence, as globalization necessitates international collaboration, especially in Europe (Cai & Amaral, 2021). The Quintuple Helix model better reflects modern needs by integrating environmental and technological factors, while emphasizing R&D investment and cooperation among defence firms, academia, and military centers (Reis et al., 2022). In the Dutch defence sector, spin-ins from civilian R&D dominate, with SMEs playing a leading role. Civilian-developed IT, supported by the Triple Helix framework, sustains both defence innovation and the national economy (Sezal & Giumelli, 2022). To overcome current gaps, deeper civilian-military integration and international cooperation are essential. The Russo-Ukrainian war has spurred innovation, enabling SMEs to enter the defence sector, though funding remains a hurdle (Mészáros, 2024). Partnerships are critical for implementing external innovations (Langham & Wrigley, 2020). The Estonian anti-armor mine case supports the value of a national innovation system and multi-stakeholder approach in procurement success (Ploom et al., 2024). Warfare continues to drive innovation by challenging developers to support armed forces. Studying DIE culture is vital. Bloomberg emphasized flexibility and risk-taking in U.S. DOD technology adoption, advocating for 'failing fast' to improve battlefield performance. Both he and General Milley linked innovation to military superiority (Dew & Lewis, 2024). While large defence contractors dominate integration and production, smaller firms focus on innovation. Many DOD-funded projects fail to transition to production due to limited fielding budgets creating the so-called 'valley of death' (Dew & Lewis, 2024). This study thus examines DIEs in the context of leading military powers.

Ukraine's DIE relies on government, defence enterprises, research institutions, and startups, supported by procurement policies, PPPs, and international cooperation (Hmyria et al., 2024). Innovation is costly but critical for battlefield advantage. Armenia's DIE includes state and private actors in R&D and weapons production, geared toward security and economic growth (Harutyunyan, 2024). With growing global uncertainty, Europe must invest

in defence innovation to ensure technological leadership and reduce reliance on U.S. support (Bērziņš, 2024). Figure 2 highlights core innovation mechanisms in DIEs: PPPs, knowledge exchange, innovation hubs, and testing centers.

Rural development integration

The successful integration of newcomers into rural Latvia enhances local communities by leveraging their vision, knowledge, and skills, fostering remote work, driving new economic practices, and revitalizing remote and depopulated areas as valuable human resources (Kruzmetra & Bite, 2023). Financial capital within a network influences the ties actors form, with less prosperous communities creating more bridging ties to secure funding (Rahe et al., 2025).

Recent studies from Ukraine underscore the strategic relevance of agricultural and rural land for dual-use defence infrastructure. Tonkha et al. (2021) emphasize the importance of geospatial assessments in optimizing land use for both agricultural productivity and defence infrastructure planning. Their methodology, which integrates satellite imagery and GIS analysis, highlights how terrain suitability can be leveraged to identify optimal locations for test ranges, logistics hubs, or surveillance installations. Similarly, Tykhenko et al. (2024) explore how soil quality and land valuation can inform national strategies for preserving high-value farmland while enabling military use on marginal or underutilized land. Applying these insights to Latvia, particularly in sparsely populated areas like Latgale, suggests the potential for coexistence between traditional land use and strategically planned defence innovation zones.

The Ukrainian Agricultural War Damages, Losses, and Needs Review (Kyiv School of Economics, 2023) further illustrates the vulnerability and importance of rural land during conflict, detailing extensive damage to arable land, infrastructure, and ecosystems due to military operations. While Latvia is not currently experiencing armed conflict, these findings serve as a warning and a planning opportunity. By proactively integrating rural land into the defence innovation ecosystem—through resilient infrastructure, redundant supply chains, and dual-use installations Latvia can enhance both national security and rural economic resilience. Strategic land use planning, informed by environmental and economic data, will be crucial in safeguarding Latvia's food security, rural livelihoods, and territorial integrity under future threat scenarios.

The U.S. Department of Defense and major prime defence contractors are actively seeking deeper collaboration with allied and partner nations, recognizing that integrating international industrial capabilities is essential for maintaining technological superiority, strengthening global security networks, and ensuring a resilient defence supply chain (Defense Innovation Board, 2024). Integrating rural regions into the DIE requires close collaboration between the Ministry of Defence, industry associations, and regional planning authorities (Langham & Wrigley, 2020). The first step is to identify regional industrial capabilities, compile them into a centralized database, and inform the Ministry of Defence. Military production in rural areas is viable when there is a clear long-term demand (Garin & Rothbaum, 2025). Based on the Cabinet of Ministers 2025 Action Plan, the Latvian government emphasizes the development of strategic infrastructure in regions like Latgale including industrial parks, transport and dual-use facilities to attract investment, support emerging rural startups, and create conditions for job creation, talent retention, and potential test and evaluation capabilities aligned with national security objectives (Cabinet of Ministers of the Republic of Latvia, 2025). Defence innovation initiatives are being actively promoted in rural regions of Latvia, exemplified by the EUDIS Defence Hackathon 2025 held at Riga Technical University's Rezekne Academy, which brought together innovators to develop rapid defence solutions tailored to Ukraine's operational needs (Latvia's Official Legal Information Portal, 2025a). Ministry of Defence engages with NATO defence attachés to present the Defence Industry and Innovation Support Strategy 2025–2036, which aims to enhance local industrial capacities and foster innovation beyond urban centres (Latvia's Official Legal Information Portal, 2025b). The Plan for the Development of a Cohesive and Civically Active Society 2024–2027 includes measures that indirectly support innovation in rural regions by strengthening civil society, enhancing the capacity of regional NGOs, promoting volunteerism and local solidarity, and fostering civic engagement through forums and think tanks, thereby creating a supportive environment for grassroots innovation (Cabinet of Ministers of the Republic of Latvia, 2024).

Defence innovation ecosystem in Latvia

Latvia's national defence budget for 2025 is 3.45% of GDP, making it the largest defence budget in the country's history and the 4th highest defence expenditure as a share of GDP among NATO member states (NATO, 2024b). The defence budget is allocated not only to the development of military capabilities, personnel and maintenance costs, and military infrastructure but also to fostering the DIE. Latvia plans to increase funding for defence research, technology development, and innovation to 1.5% of the defence budget by 2028 (Ministry of Defence of the Republic of Latvia, 2024). However, publicly available and consolidated data on defence spending for R&D is lacking.

The Ministry of Defence's Industry and Services Policy, as defined in national strategic documents, stresses the urgent need to strengthen Latvia's defence industry in response to rising geopolitical threats. The ability of the industry to scale production rapidly is essential for the National Armed Forces (NAF) to fulfil

their roles during peace, crises, and war, while also contributing to EU and NATO capabilities. Enhancing industrial capacity ensures both operational sustainability and innovation, even in conflict situations (Ministry of Defence of the Republic of Latvia, 2024).

The Defence Industry Law (Parliament of the Republic of Latvia, 2024), adopted in 2024, creates a legal framework for fostering innovation and cooperation among government, industry, and research institutions. It promotes defence R&D, supports public-private partnerships, and facilitates the integration of emerging technologies into military use. The law also encourages local production, strengthens resilience, improves funding access, and simplifies procurement to support a robust and competitive defence ecosystem.

Table 4
Latvian defence budget

Year	*% from GDP*	*Million EUR*
2020	2.20%	700
2021	2.20%	758
2022	2.20%	800
2023	2.25%	987
2024	3.20%	1 367
2025	3.45%	1 559

Table 4 presents Latvia's defence budget as a percentage of GDP and in million EUR. However, information on defence R&D expenditures is not publicly available. To obtain this data, expert interviews with the Ministry of Defence would be required. The Central Statistical Bureau of Latvia does not have data on the use of the Ministry of Defence budget, including specifically for research.

Table 5 presents the funding amounts allocated in the **Ministry of Defence grant program** for the development of military or dual-use products, along with the number of applications submitted and the number of recipients.

The grant competition serves as the primary national support mechanism within Latvia's DIE. The Ministry of Defence grant program has provided financial support to a total of 25 beneficiaries between 2020 and 2024.

The total available funding over these years amounts to 2.15 million EUR, with annual grants ranging from 450,000 EUR to 600,000 EUR. The number of applicants has varied each year, with the highest recorded in 2024 (37 applicants), while data for 2023 is unavailable.

Table 5
Ministry of defence grant program in numbers

Year	*Available funding in thousands EUR*	*Number of applicants*	*Number of beneficiaries*
2020	500	31	9
2021	450	Unknown	7
2022	600	33	4
2023	-	-	-
2024	600	37	5

This program plays a crucial role in fostering defence-related innovation and strengthening national security through targeted financial support (Ministry of Defence of the Republic of Latvia, 2025a).

The Defence Innovation Research Program is a key government initiative that supports technological advancements and strengthens national security. With a budget of 1.5 million EUR, it funds research institutions and businesses developing cutting-edge defence solutions. In 2021, three projects were approved in areas such as cybersecurity, unmanned systems, and advanced soldier equipment. These include innovations like electromagnetic shielding, hybrid composites for drone protection, and smart ballistic vests, reinforcing Latvia's Defence Innovation Ecosystem (Ministry of Defence of the Republic of Latvia, 2021).

Descriptive Statistics was used to summarize key characteristics of the dataset, as presented in Table 6, providing insights into trends in defence budget allocation, grant funding, and industry participation over time. This method allowed for the identification of central tendencies, variability, and missing data points, highlighting fluctuations in defence spending and grant distribution while offering a quantitative foundation for further analysis.

The Latvian Ministry of Defence allocated €5.5 million for R&D in 2024 and €6.8 million for 2025, supporting innovation initiatives including drone grants, defence research, NATO contributions, and European Defence Fund co-financing. Priority areas include autonomous systems, AI, and quantum technologies (Ministry of Defence, 2024). NATO countries allocate a large share of defence budgets to R&D; the 2024 NATO defence budget is estimated at $1.18 trillion, with Europe and Canada contributing about $430 billion (NATO, 2024b).

The literature identifies three knowledge gaps. First, more research is needed on evolving defence culture to better integrate SMEs, start-ups, and disruptive innovation (Mészáros, 2024).

Second, the lack of public data on failed projects limits learning opportunities; analyzing such cases could help identify promising ideas sooner (Langham & Wrigley, 2020). Third, there's no robust model for measuring innovation ecosystem resilience using System Dynamics or Agent-Based Modeling (Abdi et al., 2024). Each country's Defence Innovation Ecosystem (DIE) reflects its strategic priorities, shaped by national defence policy.

Table 6
Descriptive statistics summary of defence innovation ecosystem data

	Year	***Defence Budget (% GDP)***	***Defence Budget (Million EUR)***	***Available Grant Funding (Thousand EUR)***	***Number of Applicants***	***Number of Beneficiaries***
count	6	6	6	4	3	4
mean	2022	2.58	1028.5	537.5	33.67	6.25
std	1.87	0.58	355.25	75	3.06	2.22
min	2020	2.2	700	450	31	4
25%	2021	2.2	768.5	487.5	32	4.75
50%	2022	2.23	893.5	550	33	6
75%	2023	2.96	1272	600	35	7.5
max	2025	3.45	1559	600	37	9

In Latvia, key DIE stakeholders are listed in the National Defence Policy report and shown in Figure 3. Latvia's DIE includes government, military, academia, industry, and associations. The Ministry of Defence leads policy and funding; the Ministry of Economics promotes industrial growth. The Investment and Development Agency supports businesses, and the Defence Logistics and Procurement Center manages procurement. The National Armed Forces are key end-users, shaping capability development. The Latvian Science Council (LZP) fosters research in defence technologies alongside universities and institutes specializing in cybersecurity, materials science, and advanced tech. Industry, including start-ups, drives dual-use and military tech development.

The State Defence Corporation was established to build national industrial capacity (Ministry of Defence, 2025b).

Industry associations and competence centres promote collaboration and public-private partnerships. Internationally, Latvia engages through platforms like NATO DIANA, supporting defence start-ups (NATO, 2024a). These actors form a dynamic ecosystem that drives innovation and strengthens national and allied security.

Comparative Perspective: Latvia and Ukraine's Defence Innovation Ecosystems

To contextualize Latvia's DIE trajectory, a brief comparative perspective with Ukraine's wartime innovation ecosystem reveals instructive parallels and divergences. Table 7 summarizes selected features of both systems:

Table 7
Comparative Overview of Latvia's and Ukraine's Defence Innovation Ecosystems

Feature	***Latvia DIE (2020–2025)***	***Ukraine DIE (2022–2024)***
Strategic driver	NATO/EU integration, deterrence policy	Full-scale invasion and urgent battlefield needs
Key rural integration approach	Regional test sites (e.g., Latgale), MOD hackathons	Rural-based production hubs, field R&D in frontline
Governance model	Policy-driven, grant-based	State-led procurement, wartime executive authority
Innovation mechanisms	Grants, public-private initiatives, EU co-funding	Dual-use innovation under conflict, startup-military partnerships
Speed of transformation	Gradual	Rapid and responsive (Hmyria et al., 2024)
International collaboration	NATO DIANA, EDF projects	Bilateral support, Lend-Lease, multilateral R&D

Ukraine's defence innovation ecosystem, transformed by existential urgency, illustrates how war catalyzes system-wide shifts in innovation management, stakeholder roles, and rural integration. Rural areas in Ukraine, particularly underutilized farmland and remote zones, became strategic assets for both conventional logistics and experimental technology deployments (Hmyria et al., 2024; Tykhenko et al., 2024). Latvia's rural innovation push particularly in regions like Latgale can draw valuable insights from Ukraine's rapid establishment of local innovation hubs. These included makeshift fabrication labs, drone-testing ranges, and logistics nodes situated in rural settings far from

urban frontlines. While Latvia operates under peacetime constraints, the Ukrainian case emphasizes the importance of agility, decentralized innovation, and the dual civil-defence use of rural territories (Harutyunyan, 2024).

Figure 3
Defence innovation ecosystem stakeholders in Latvia

The defence sector is inherently confidential for justified reasons, as it involves not only commercial secrecy but also national security concerns. Disclosing information about vulnerabilities and weaknesses in defence systems can pose significant risks to national security (Cardona, 2018). The analysis of the defence innovation ecosystem was based on scientific literature, policy documents, and reliable industry research. However, given the time required for the publication of scientific articles, the information available in academic journals may not always reflect the most current developments. This is particularly relevant in the context of shifting global dynamics, where geopolitical changes influence the evolving needs of the innovation ecosystem (Cochrane & Zaidan, 2024).

Future Research Directions

To build upon these findings, future DIE research should employ alternative methodologies, including expert interviews, observations, surveys, and case studies, to capture a more nuanced understanding of ecosystem dynamics. A comparative analysis of DIE frameworks across different nations is necessary to establish best practices and explore the feasibility of an international alliance-scale DIE framework at the NATO and EU levels. Further studies should focus on the collaboration mechanisms among DIE stakeholders, using the innovation lifecycle as a foundation to assess efficiency, adaptability, and long-term sustainability. Additionally, research should determine whether any critical stakeholders are absent in Latvia's DIE, drawing lessons from other innovation ecosystems to enhance governance and operational effectiveness.

From a policy perspective, Latvia can strengthen its DIE by:

- Incentivizing private-sector R&D investment;
- Enhancing SME participation in defence procurement;
- Strengthening international partnerships through NATO and the EU.

By addressing these challenges and leveraging international best practices, Latvia can build a more resilient and effective DIE that supports both national security and economic growth.

Conclusions

1. Latvia's Defence Innovation Ecosystem (DIE) operates within a small, strategically positioned economy where national security imperatives and innovation goals are increasingly interlinked. Despite the establishment of supportive frameworks such as the Defence Industry Law and national funding mechanisms, systemic gaps remain particularly in rural participation, inter-institutional coordination, and ecosystem transparency (Ministry of Defence of the Republic of Latvia, 2024). Rural regions, especially Latgale, present untapped innovation potential yet remain underrepresented in funding allocations and stakeholder networks (Tables 2 and 3).
2. Rural areas such as Latgale possess key strategic enablers including available land, emerging infrastructure, and growing community engagement that could support decentralization of defence R&D and production. These areas are well-positioned for establishing dual-use industrial zones, test and evaluation sites, and localized innovation hubs (Tykhenko et al., 2024; Garin & Rothbaum, 2025). Government initiatives like the Action Plan for the Eastern Border Region and the EUDIS Defence Hackathon 2025 in Rezekne represent promising steps toward harnessing rural innovation capacity (Cabinet of Ministers of the Republic of Latvia, 2025; Latvia's Official Legal Information Portal, 2025a).
3. Targeted investment and cross-sector collaboration are essential to close existing urban–rural innovation gaps. Enhanced data collection, grant streamlining, and the inclusion of rural-specific priorities in MOD programming would create incentives for SME participation and build local capacity. Lessons from Ukraine demonstrate the strategic value of rural regions for logistical, production, and rapid prototyping functions under stress conditions insights Latvia can proactively apply in peacetime (Hmyria et al., 2024; Tonkha et al., 2021).
4. Latvia's DIE lacks transparency on innovation failures and resilience metrics. The absence of systematic evaluation tools limits the ability to learn from past initiatives or forecast future adaptability. Integrating underutilized modeling techniques and rural innovation indicators would enhance ecosystem governance. Future research should prioritize the development of rural innovation readiness frameworks, informed by community-driven, data-rich approaches (Abdi et al., 2024; Rahe et al., 2025).

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References

Abdi, S., Yazdani, M., & Najafi, E. (2024). Evaluating innovation ecosystem resiliency using agent-based modeling and systems dynamics. *Journal of Safety Science and Resilience*, 5, 204–221. https://doi.org/10.1016/j.jnlssr.2024.03.004

Achmadi, B. & Sutawidjaya, A. H. (2024). The role and dynamics of actor relations in implementing defense industry-based policies: A comparative study of Indonesia and Brazil. *Journal of Ecohumanism, 4*(1), 1–11. https://doi.org/10.62754/joe.v4i1.4216

Alka, T. A., Raman, R., & Suresh, M. (2024). Research trends in innovation ecosystem and circular economy. *Discover Sustainability*, 5, 323. https://doi.org/10.1007/s43621-024-00535-5

Andžāns, M. (2021). Latvia's defence: still gradually advancing. In book: *Latvian Foreign and Security Policy Yearbook 2021*. Latvian Institute of International Affairs. https://www.researchgate.net/publication/348751875

Balakrishnan, K. & Johar, T. N. (2023). The role of stakeholders in managing government research and development funding for defence industrial innovation: The case of Malaysia. *Defence and Peace Economics, 34*(8), 1110–1129. https://doi.org/10.1080/10242694.2022.2100588

Baltics Catching-up Regions Initiative (CuRI). (2024). *Draft Scoping Report for Stakeholder Review* (27 Sep 2024). World Bank.

Bērziņš, J., Bērziņa, I., & Rostoks, T. (2024). *Contemporary challenges to European security: Neoliberalism, democratic backsliding, and alliance cohesion*. Centre for Security and Strategic Research, National Defence Academy of Latvia. https://www.naa.mil.lv/sites/naa/files/document/Contemporary_Challenges_to_European_Security.pdf

Budden, P. & Murray, F. (2019). *Defense Innovation Report: Applying MIT's Innovation Ecosystem & Stakeholder Approach to Innovation in Defense on a Country-by-Country Basis.* MIT Sloan School of Management, MIT Innovation Initiative. https://innovation.mit.edu/assets/Defense-Innovation-Report.pdf

Cabinet of Ministers of the Republic of Latvia. (2024). *Plan for the Development of a Cohesive and Civically Active Society 2024–2027* (Cabinet Order No. 1195, December 17, 2024). Retrieved from https://likumi.lv/ta/id/357419

Cabinet of Ministers of the Republic of Latvia. (2025). *Action Plan for Economic Growth and Security Enhancement in the Eastern Border Region of Latvia 2025–2027* (Cabinet Order No. 32, January 20, 2025). Retrieved from https://likumi.lv/ta/id/358105

Cai, Y. & Amaral, M. (2021). The Triple Helix Model and the Future of Innovation: A Reflection on the Triple Helix Research Agenda. *Triple Helix Journal, 8*(1), 217–229. https://doi.org/10.1163/21971927-12340004

Caliari, L., Coletto, C., Donato, R. S., Reichert, F. M., & Menezes, D. C. (2024). Regional innovation ecosystem as a facilitator of digital transformation: Evidence from Pacto Alegre (Brazil). *International Journal of Innovation - IJI, São Paulo, 12(*4), Article e25143. https://doi.org/10.5585/2024.25143

Cardona, F. (2018). *Balancing openness and confidentiality in the defence sector: Lessons from international good practice.* Centre for Integrity in the Defence Sector (CIDS). Norwegian Ministry of Defence. https://www.nato.int/nato_static_fl2014/assets/pdf/2020/7/pdf/200724-BI-GGG6-en.pdf

Centrone, M. & Fernandes, M. (2024). *Improving the quality of European defence spending. European Parliamentary Research Servic*e. Cost of non-Europe report, PE 762.855. https://doi.org/10.2861/2105737

Cochrane, L. & Zaidan, E. (2024). Shifting global dynamics: An empirical analysis of BRICS+ expansion and its economic, trade, and military implications in the context of the G7. *Cogent Social Sciences, 10*(1), Article 2333422. https://doi.org/10.1080/23311886.2024.2333422

Defense Innovation Board. (2024). *Optimizing Innovation Cooperation with Allies and Partners*. U.S. Department of Defense. https://innovation.defense.gov.lv

Dew, N. & Lewis, I. (2024). *U.S. defense innovation and industrial policy: An assessment of where things currently stand*. Expeditions with MCUP. https://doi.org/10.36304/ExpwMCUP.2024.05

Garin, A. & Rothbaum, J. (2025). The long-run impacts of public industrial investment on local development and economic mobility: Evidence from World War II. *The Quarterly Journal of Economics, 140*(1), 459–520. https://doi.org/10.1093/qje/qjae031.

Girardi, R. (2024). Innovation management in the defense sector: A systematic literature review focusing on developing countries. Journal of Infrastructure. *Policy and Development, 8*(11), Article 6065. https://doi.org/10.24294/jipd.v8i11.6065

Granstrand, O. & Holgersson, M. (2020). Innovation ecosystems: A conceptual review and a new definition. *Technovation*, Article 102098, 90-91. https://doi.org/10.1016/j.technovation.2019.102098

Green, B. N., Johnson, C. D., & Adams, A. (2006). Writing narrative literature reviews for peer-reviewed journals: Secrets of the trade. *Journal of Chiropractic Medicine, 5*(3), 101-117. https://doi.org/10.1016/S0899-3467(07)60142-6

Günsel, A. (2015). Research on effectiveness of technology transfer from a knowledge-based perspective. *Procedia - Social and Behavioral Sciences*, 207, 777–785. https://doi.org/10.1016/j.sbspro.2015.10.165

Harutyunyan, G. E. (2024). Defense expenditures within the framework of positive external effects from the production of high-tech weapons (The case of Armenia). *Public Administration Issues*, 5, 25–37. https://doi.org/10.17323/1999-5431-2024-0-5-25-37

Hendrix, C. S. (2025, February 28). *Trump's five percent doctrine and NATO defense spending*. RealTime Economics. https://www.piie.com/blogs/realtime-economics/2025/trumps-five-percent-doctrine-and-nato-defense-spending

Hmyria, V., Nikitchenko, V., Shynkarenko, O., Aleskerova, Y., & Kostyuk, O. (2024). Development of the defence industry of Ukraine to ensure national security. *Financial and Credit Activity: Problems of Theory and Practice*, *3*(56), 321–333. https://doi.org/10.55643/fcaptp.3.56.2024.4366

Kruzmetra, Z. & Bite, D. (2023). *Newcomers in Latvian countryside: Economic and social potential. New Challenges in Economic and Business Development – 2023: Recovery and Resilience*. Latvia University of Life Sciences and Technologies. https://dspace.rsu.lv/jspui/bitstream/123456789/15131/1/Newcomers_in_Latvian_countryside.pdf

Kumar, G. (2017). Countries' military expenditures: Definitions and determinants. *Economic Affairs*, *62*(4), 647–654. https://doi.org/10.5958/0976-4666.2017.00078.X

Kyiv School of Economics. (2023). *Agricultural war damages, losses, and needs review* (Issue 3, April 2023). https://kse.ua/wp-content/uploads/2023/05/RDNA2.pdf

Langham, J. & Wrigley, C. (2020). Defence innovation: The role of design-led innovation in disrupting the conservative paradigm. *Academy of Management Proceedings, 2020*(1), Article 21494. https://doi.org/10.5465/AMBPP.2020.21494abstract

Latvia's Official Legal Information Portal. (2025a). *Ministry of Defence invites applications for participation in the Defence Industry Hackathon 2025*. Retrieved from https://lvportals.lv/dienaskartiba/375804-aizsardzibas-ministrija-aicina-pieteikties-dalibai-aizsardzibas-industrijas-hakatona-2025

Latvia's Official Legal Information Portal. (2025b). *NATO defence attachés familiarize themselves with the Defence Industry and Innovation Support Strategy 2025–2036.* Retrieved from https://lvportals.lv/dienaskartiba/374105-nato-aizsardzibas-ataseji-iepazistas-ar-aizsardzibas-industrijas-un-inovaciju-atbalsta-strategiju-2025

Lawrenson, T. & Sabatino, E. (2024). *The impact of the European Defence Fund on cooperation with third-country entities*. International Institute for Strategic Studies. https://www.iiss.org/research-paper/2024/10/the-impact-of-the-european-defence-fund-on-cooperation-with-third-country-entities/

Mészáros, A. Á. (2024). Innovation in the defence industry from the end of the Cold War to the war in Ukraine. *Journal of Regional Security*, *19*(1), 97–118. https://doi.org/10.5937/jrs19-42865

Ministry of Defence of the Republic of Latvia. (2021). *Defense Innovation Research Program.* https://www.mod.gov.lv/lv/nozares-politika/zinatniski-petnieciska-darbiba/aizsardzibas-inovaciju-petijumu-programma

Ministry of Defence of the Republic of Latvia. (2024). *Guidelines for the involvement of the defence and security industry in strengthening defence capabilities.* https://www.mod.gov.lv/sites/mod/files/document/Vadl%C4%ABnijas%20aizsardz%C4%ABbas%20un%20dro%C5%A1%C4%ABbas%20industrijas%20iesaistei%20aizsardz%C4%ABbas%20sp%C4%93ju%20stiprin%C4%81%C5%A1an%C4%81.pdf

Ministry of Defence of the Republic of Latvia. (2024). *Informative Report 'Defence Industry and Innovation Support Strategy 2025–2036'.* https://tapportals.mk.gov.lv/legal_acts/711db14a-fb9a-4625-a06d-f956824b7478

Ministry of Defence of the Republic of Latvia. (2025a). *Grant program for entrepreneurs*. https://www.mod.gov.lv/lv/uznemejiem/atbalsts-uznemejiem/grantu-programma

Ministry of Defence of the Republic of Latvia. (2025b). *State Defence Corporation*. https://www.mod.gov.lv/en/uznemejiem/state-defence-corporation

Ministry of Foreign Affairs of the Republic of Latvia. (2023). *Latvia in NATO: 19 years*. Ministry of Foreign Affairs of the Republic of Latvia. https://www.mfa.gov.lv/en/article/latvia-nato-19-years

Nasution, M. S., Rusli, Z., Heriyanto, M., Syahza, A., Zulkarnaini, M., Mayarni, D., …, & Ikhsan, M. (2025). Bibliometric analysis of rural economic development: Convergence between sustainable agriculture, digital technology, and community engagement for village self-reliance. *International Journal of Sustainable Development and Planning*, *20*(1), 245-262. https://doi.org/10.18280/ijsdp.200123

North Atlantic Treaty Organization (NATO). (1949). *The North Atlantic Treaty.* NATO. https://www.nato.int/cps/en/natolive/official_texts_17120.htm

North Atlantic Treaty Organization (NATO). (2024a). *Snapshots of Cohort 1, NATO DIANA* (April 2024), Defence Innovation Accelerator for the North Atlantic. https://www.diana.nato.int/about-diana.html

North Atlantic Treaty Organization (NATO). (2024b). *Defence expenditure of NATO countries (2014-2024)*. https://www.nato.int/nato_static_fl2014/assets/pdf/2024/6/pdf/240617-def-exp-2024-en.pdf

Parliament of the Republic of Latvia. (2024). *Defense Industry Law*. Legislation of the Republic of Latvia. https://likumi.lv/ta/id/351123-aizsardzibas-industrijas-likums

Ploom, I., Kalvet, T., Kütt, R., Veinla, M., & Tiits, M. (2024). Managing risks in public procurement of defense innovation: Lessons from the development of an anti-armor mine in Estonia. *Journal of Baltic Studies*, 1-25 https://doi.org/10.1080/01629778.2024.2375594

Rahe, M. L., Van Leuven, A. J., & Malone, T. (2025). Leveraging social ties to financial gains: Exploring the impact of social capital in rural development. *Journal of Rural Studies*, 114, Article 103539. https://doi.org/10.1016/j.jrurstud.2024.103539

Reis, J., Rosado, D. P., Ribeiro, D. F., & Melão, N. (2022). Quintuple Helix Innovation Model for the European Union Defense Industry - An Empirical Research. *Sustainability*, *14*(16499), 1-17. https://doi.org/10.3390/su142416499

Rublovskis, R. (2014). Latvian security and defense policy within the twenty-first century security environment. *Lithuanian Annual Strategic Review*, 12, 173–188. https://doi.org/10.2478/lasr-2014-0008

Sezal, M. A. & Giumelli, F. (2022). Technology transfer and defence sector dynamics: The case of the Netherlands. *European Security*, *31*(4), 558–575. https://doi.org/10.1080/09662839.2022.2028277

Sotirofski, I. (2024). Understanding Innovation Ecosystems. *Interdisciplinary Journal of Research and Development*, *11*(1), 1-15. https://doi.org/10.56345/ijrdv11n101

Sprūds, A. (2025). *Next year's defence funding must be increased to 4% of GDP*. Ministry of Defence of the Republic of Latvia. https://www.mod.gov.lv/en/news/spruds-next-years-defence-funding-must-be-increased-4-gdp

Supreme Court of the Republic of Latvia. (2025, February 28). *Restoration of independence. Senate Supreme Court of the Republic of Latvia.* https://www.at.gov.lv/en/par-augstako-tiesu/vesture/latvijas-republikas-augstaka-tiesa/neatkaribas-atjaunosana

Szkurłat, I. (2024). Selected NATO actions in the third decade of the 21st century. *Defence Science Review*, 20, 1-30. https://doi.org/10.37055/pno/202035.

Szpyra, R. (2014). Military security within the framework of security studies: Research results. *Connections: The Quarterly Journal*, *13*(3), 59-82. https://doi.org/10.11610/Connections.13.3.04

Thomas, L. D. W. & Autio, E. (2019). *Innovation ecosystems. Oxford Research Encyclopaedia of Business and Management*. Oxford University Press. https://doi.org/10.2139/ssrn.3476925

Tian, N., Lopes da Silva, D., Liang, X., & Scarazzato, L. (2024). *Trends in world military expenditure*, 2023. SIPRI Fact Sheet, Stockholm International Peace Research Institute (SIPRI). https://doi.org/10.55163/CQGC9685

Tonkha, O., Menshov, O., Sychevskyy, S., Pikovska, O., & Balaev, A. (2021). Geospatial and magnetic assessment of soil and relief of the farming lands at the Forest-Steppe zone of Ukraine. *Geoinformatics*, May 2021, 1–6. https://doi.org/10.3997/2214-4609.20215521108

Tykhenko, O., Martyn, A., Tykhenko, R., Openko, I., Shevchenko, O., Tsvyakch, O., …, & Volk, P. (2024). Impact of comparative assessment of soil quality on determining the value of agricultural land (Ukraine). *Ecological Engineering & Environmental Technology*, *25*(4), 252–261. https://doi.org/10.12912/27197050/183900

Vaynman, J. & Volpe, T. A. (2023). Dual use deception: How technology shapes cooperation in international relations. *International Organization*, *77*(3), 599–632. https://doi.org/10.1017/S0020818323000140

Wang, J. (2023). Research on the theoretical basis of rural economy based on the background of rural revitalization. *Proceedings of ICFIED 2023*, AEBMR 237, 615–619. https://doi.org/10.2991/978-94-6463-142-5_67.