Anton Andriienko
State Scientific Research Institute for Informatization and Economic Modeling, Kyiv, Ukraine
E-mail: a.andriienko@gmail.com
ORCID: https://orcid.org/0000-0001-7780-0557
ResearcherID: https://www.researchid.co/rid130076

Methodological Approaches to Assessing Industrial Parks: R&D Potential and the Quadruple Helix Model in the Context of Strategic Resilience

Abstract

The subject of this research is the methodological framework for evaluating the multi-dimensional performance of industrial parks (IPs). The focus is on R&D potential and the Quadruple Helix (QH) governance model. The present study explores how such institutional structures in transitional economies can be optimised to foster strategic resilience and structural transformation during post-war recovery. *Methodology.* The study employs a hybrid Multi-Criteria Decision-Making (MCDM) approach grounded in the OPERRA framework (Operational Performance, Plug-and-Play Readiness, Economic Vibrancy, Risk and Security Management, Resource and Climate Resilience, and Social and ESG Adaptation). The assessment combines the Analytic Hierarchy Process (AHP) for rigorous criteria weighting and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) to benchmark industrial ecosystems against ideal operational profiles. The *purpose* of the research is to establish a comprehensive rating methodology that mitigates information asymmetry in the investment market. The study proposes a verified signalling mechanism as a means of distinguishing high-performing innovation hubs from non-functional "paper parks", with a view to optimising state support and attracting long-term foreign direct investment (FDI). The research *concludes* that the viability of industrial parks in transitional settings is contingent on their evolution from passive land plots into integrated innovation ecosystems. The QH model is a governance logic that is necessary to ensure societal alignment and knowledge co-creation. The operationalisation of strategic resilience is to be achieved through dual-use infrastructure and climate adaptation metrics. Furthermore, a robust rating system functions as a narrative device that facilitates a shift in investor perception from "war-related risk" to "institutional opportunity".

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Keywords

industrial parks, Quadruple Helix, R&D potential, strategic resilience, narrative economics, OPERRA framework

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1 Introduction

The contemporary global industrial landscape is navigating a period of unprecedented volatility, driven by geopolitical shifts, technological disruptions, and the mandate for a green transition. In the context of transitional economies, particularly those grappling with the aftermath of large-scale military conflict, the imperative of re-industrialisation is inextricably intertwined with the pursuit of technological sovereignty. The importance of industrial parks as pivotal instruments for spatial development and the attraction of foreign direct investment has long been recognised by governments (Andriienko, 2026). However, the quantitative expansion of such zones often masks a qualitative crisis characterised by the "Ghost Park" syndrome, where sites exist legally but fail to become functional economic engines (Andriienko, 2025b). The crux of this issue pertains to a market failure that has been termed the "market for lemons", wherein information asymmetries impede investors from discerning between viable, infrastructure-ready ecosystems and dormant entities (Akerlof, 1970).

In order to surmount this issue, it is necessary to adopt a robust methodological approach grounded in Signaling Theory. A credible signal must involve a significant, irreversible cost that only a high-quality entity can afford (Spence, 1973). In the industrial sector, this "signal" is the pre-delivery of high-standard "plug-and-play" infrastructure and the institutionalisation of R&D potential (Andriienko, 2025b). The scientific novelty of this study lies in the integration of the Quadruple Helix (QH) model as a governance logic. Whilst earlier models concentrated on the relationship between universities, industry and government, the QH framework introduces civil society as a structural actor (Carayannis & Campbell,

2010). This addition is critical for transitional economies where institutional trust is low and social anchoring of innovation is necessary for sustainability (Andriienko, 2025e). Moreover, the research addresses the "resilience gap" in conventional assessment tools by treating resilience as an internal capacity for operational continuity under stress (Andriienko, 2025b). In Ukraine, the adoption of the national standard DSTU 9328:2025 on eco-industrial parks, in conjunction with the implementation of the "Made in Ukraine" state policy, provides a unique laboratory for the testing of these methodological approaches (Andriienko, 2025c).

2 The Quadruple Helix Governance Logic and Educational R&D Integration

The evolution of industrial innovation theory has been characterised by a shift from linear, technocratic planning to collaborative, multi-actor governance. Conventionally, innovation has been conceptualised within the linear model, whereby progress is assumed to progress in a predictable manner from fundamental research to commercial application. The Triple Helix model posits that interactions between academia, industry, and the state represent the primary drivers of development (Etzkowitz & Leydesdorff, 2000). However, this model failed to take into account broader societal dynamics and normative values that shape technological transformation. The QH model addresses these limitations by explicitly incorporating civil society as the fourth helix, representing a shift towards knowledge democracy where knowledge is a co-created public value (Carayannis & Campbell, 2010). In the context of industrial parks, the degree of alignment with societal needs and regional priorities is a critical factor in determining success (Andriienko, 2025e).

In view of these findings, the operationalisation of the QH model necessitates a sophisticated governance logic that emphasises institutional bridging and participatory legitimacy. Universities have been posited as "innovation brokers" that act as mediators between state objectives and grassroots innovation (Morawska-Jancelewicz, 2022). This role is of particular importance in peripheral regions where institutional voids may impede formal coordination (Andriienko, 2025e). Paradoxically, although the institutional framework indicates a shift towards inclusive co-creation, many transitional economies continue to grapple with civic capacity deficits. To mitigate this risk, successful European regions, such as the Helsinki-Uusimaa region in Finland, have integrated participatory foresight processes, such as the 'Wings and Roots' initiative, into their Smart Specialisation Strategies, ensuring that they reflect priorities defined by citizens (Albrecht & Huovila, 2022).

Within the QH model, the educational function has evolved into a driver of "socially relevant education", where curricula are co-designed by partners from different sectors to align with Industry 5.0 requirements (Horvat et al., 2024). In the Baltic context, the Latvian Science, Technology and Innovation Guidelines (2021–2027) prioritise acquiring high-level digital skills to foster an innovative environment (Ministry of Education and Science of the Republic of Latvia, 2021). This aligns with the "ICC4VET" project, which involves partners from Poland and the Baltic States and focuses on developing industry competence centres to reduce the shortage of qualified workers (Baltic Sea Academy, 2025). The R&D potential of an industrial park is further enhanced when shared infrastructure, such as Smart Factory Labs, provides SMEs with access to Industry 4.0 technologies, such as AI and robotics (Andriienko, 2025f). The 2025 EU Industrial R&D Investment Scoreboard reveals that regions leading the way in innovation achieve higher R&D growth by fostering cross-sectoral collaboration (Joint Research Centre, 2025). In Latvia, the Defence Industry and Innovation Strategy 2025–2036 aims to invest at least 1.5% of the defence budget in R&D, with the ultimate goal of reaching 3%. Universities will play a key role in adapting disruptive technologies for civilian dual use (Ministry of Economics of the Republic of Latvia, 2025).

3 Mathematical Foundations of the OPERRA Framework and Multi-Criteria Assessment

The persistence of "Ghost Parks" can be considered a significant misallocation of sovereign capital. In order to address this issue, a transition from declarative monitoring to a synthetic, multi-criteria assessment methodology is necessary. The proposed rating system (S_{total}) for industrial parks integrates quantitative economic indicators with strategic imperatives such as innovation, ecological compliance, and resilience (Andriienko, 2026). The total score is calculated as the weighted sum of four strategic blocks: Economic Performance (S_{Econ}), Innovation and Technology (S_{Inn}), Environmental Efficiency (S_{Eco}), and Social Integration & Resilience (S_{Soc}) (Andriienko, 2026). The formula is expressed as $S_{total} = S_{Econ} + S_{Inn} + S_{Eco} + S_{Soc}$. A pivotal feature of the economic block is the Wage Premium (WP), which measures the ratio of the park's average salary to the regional average: $WP = W_{IP} / W_{Reg}$. This indicator discourages low-wage models, positioning the park as a local development anchor (Andriienko, 2026).

The OPERRA framework employs a hybrid MCDM model that combines AHP and TOPSIS to provide the mathematical rigour for this assessment. In the AHP stage, pairwise comparisons are used to derive

the weights of the criteria, ensuring that divergent stakeholder preferences – such as experts' focus on feasibility and residents' focus on liveability – are balanced (Park et al., 2025). The Consistency Ratio (CR) is evaluated to ensure logical coherence; a CR of less than 0.1 is required for validity (Kumar, 2025). After weighting has been applied, the TOPSIS method is used to rank the alternatives based on their geometric distance from the Positive Ideal Solution (PIS) and the Negative Ideal Solution (NIS). The final performance is represented by the Closeness Coefficient (C_i^*), where $C_i^* = D_i^- / (D_i^- + D_i^+)$, with D_i^- and D_i^+ being the Euclidean distances from the NIS and PIS, respectively (Kumar, 2025).

A high C_i^* value indicates a fully operational, high-wage, and secure "National Champion", while a low value signals a "Ghost Park" profile (Andriienko, 2025b). This transition from measuring inputs (e.g., land designated) to quantifying realised outputs (e.g., actual occupancy rate and job density) is essential for evidence-based policymaking. In terms of economic viability, the "Plug-and-Play" (PnP) readiness score functions as a signalling device, verifying that a park offers genuinely investment-ready spaces with last-mile connectivity to utilities (Agarwal, 2024). The integration of Risk & Security Management into the resilience metrics is a key aspect of the framework, as it ensures that non-market risks associated with Fragility, Conflict, and Violence (FCV) are addressed. This, in turn, ensures that industrial ecosystems remain protected from external geopolitical shocks (Andriienko, 2025b).

4 Institutional Convergence and Srategic Resilience in Post-War Recovery

In the modern industrial context, strategic resilience is defined by the "green and digital" dual transition. In Ukraine, structural deformations exacerbated by conflict have reduced the manufacturing share of GDP to 8.41% in 2024 (Andriienko, 2025c). Eco-industrial parks (EIPs) are emerging as the primary institutional mechanism to address this issue, combining re-industrialisation with environmental modernisation. Ukraine's adoption of the national standard DSTU 9328:2025 establishes a formalised system for assessing sustainability, guaranteeing adherence to the EU Green Deal and the Carbon Border Adjustment Mechanism (CBAM) (Andriienko, 2025c).

These perspectives are synthesised in the Latvian National Industrial Policy Guidelines (2021–2027) and the Science, Technology and Innovation Guidelines (2021–2027), which provide a relevant regional benchmark. The focus of these guidelines is on strengthening human capital, building a competitive workforce through STEM education and increasing innovation capacity, with the aim of achieving export targets of 27 billion EUR by 2027 (Ministry of Economics of the Republic of Latvia, 2021). Latvia's strategy explicitly promotes industrial clusters to support the full innovation cycle of firms in Smart Specialisation (RIS3) areas, integrating all Triple Helix representatives (Ministry of Education and Science of the Republic of Latvia, 2021). In light of these findings, Ukrainian industrial parks should also operate as "transit platforms" for industrial convergence, enabling manufacturers to implement EU regulatory requirements within localised clusters (Andriienko, 2025d).

Strategic resilience also necessitates a 'whole-of-society' approach to infrastructure development, whereby dual-use infrastructure, such as civil defence shelters, is incorporated into the design of industrial zones (Andriienko, 2026). This spatial resilience ensures operational continuity in times of stress by drawing on models such as Israeli industrial zones, which provide stable environments for high-tech production despite regional conflict. The "Made in Ukraine" state policy strengthens these platforms by offering production incentives and localisation in public procurement, thereby creating a positive image for manufacturers (Andriienko, 2025c). Ultimately, the effectiveness of industrial parks as drivers of strategic resilience hinges on their capacity to generate a fresh economic narrative. By converting complex data into straightforward signals, such as an "A+" rating, the state enables investors to make informed decisions and encourages local authorities to strive to improve management quality (Andriienko, 2026).

5 Conclusions

Developing methodological approaches to assessing industrial parks is essential for successfully transforming transitional and post-war economies. In synthesis, the implementation of an integral scoring system (S_{total}) serves as a robust mechanism to mitigate systemic information asymmetry, effectively overcoming the "market for lemons" scenario by creating a transparent, signal-based hierarchy of quality. This methodological shift enables functional industrial hubs to differentiate themselves from inactive "paper parks", thereby reducing the search and due diligence costs for global investors and restoring efficiency to the industrial land market. Furthermore, integrating the Quadruple Helix model positions civil society as an equal stakeholder in the innovation ecosystem, ensuring the social anchoring and legitimacy of industrial policy. Within this framework, universities emerge as "innovation brokers" that play a key role in aligning R&D activities with regional needs and equipping individuals with the forward-looking skills required for the Industry 5.0 paradigm.

In light of these findings, the OPERRA framework reinforces mathematical rigour by utilising hybrid AHP-TOPSIS models to transform subjective stakeholder preferences into objective ratio scales. Prioritising verifiable outputs such as job density and plug-and-play readiness over planned inputs provides a reliable benchmark for identifying viable industrial ecosystems and prevents sovereign capital from being misallocated towards speculative real estate projects. Paradoxically, resilience, which was traditionally considered an external safety feature, is now recognised as an integral part of the design of industrial infrastructure. This includes the integration of dual-use shelters (DBN V.2.2-5:2023), energy autonomy and climate adaptation measures. These features signal a park's institutional preparedness to maintain operational continuity in the event of geopolitical stress.

The role of industrial parks as transit platforms for convergence with the European Union's industrial architecture is equally significant. Adopting the eco-industrial park model, as defined by standards such as DSTU 9328:2025 and the "Made in Ukraine" initiative, enables manufacturers to fulfil the rigorous demands of the EU Green Deal and CBAM, thereby strengthening their position in global supply chains. Similar to the Latvian National Industrial Policy 2021-2027, the Ukrainian support platform serves as a strategic narrative tool, uniting society around the concept of recovery through high-value production. Ultimately, publicly accessible ratings create a "tournament effect" that incentivises regional authorities to upgrade their infrastructure. This shifts the dominant national narrative from "war-related risk" to "institutional opportunity", catalysing a virtuous cycle of sustainable economic growth. Future research should prioritise automating these rating systems using blockchain technology to ensure real-time verification and eliminate manual reporting bias.

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