

РЕГІОНАЛЬНЕ УПРАВЛІННЯ ТА МІСЦЕВЕ САМОВРЯДУВАННЯ

DOI: <https://doi.org/10.26565/1684-8489-2025-1-07>

УДК 332.1:339.92

Kiryukhin Oleksiy Mykhailovych,

PhD, invited researcher,

*Interdisciplinary Center of Expertise "UniGR-Center for Border Studies", Porte des Sciences,
L-4366 Esch-sur-Alzette, Luxembourg*

e-mail: kiryukhin.research@gmail.com <https://orcid.org/0009-0006-8797-1417>

Wille Christian,

*PhD, Head of the Interdisciplinary Center of Expertise "UniGR-Center for Border Studies",
Porte des Sciences, L-4366 Esch-sur-Alzette, Luxembourg*

e-mail: christian.wille@uni.lu <https://orcid.org/0000-0002-5402-3860>

Yampolskyi Daniil,

*IT student, University of Luxembourg,
Porte des Sciences, L-4366 Esch-sur-Alzette, Luxembourg*

e-mail: daniil.yampolskyi@liser.lu <https://orcid.org/0009-0007-8480-3941>

ANALYSING TERRITORIAL IMPACT ASSESSMENT DYNAMIC IN CROSS-BORDER REGIONS: CHALLENGES AND FUTURE PERSPECTIVES

Abstract. This article presents a novel methodological approach to territorial impact assessment in border regions: Dynamical Territorial Impact Assessment (DyTIA). Grounded in dynamical systems theory, DyTIA offers a framework for modelling complex and interdependent relationships between economic, social, environmental, and institutional dimensions of territorial development. In contrast to conventional static methodologies, DyTIA focuses on identifying feedback loops, time lags, threshold effects, and network interactions, thereby enabling a more accurate representation of the dynamic and often non-linear nature of border regions. The methodology was tested using data from the European Court of Auditors covering 23 INTERREG V-A programmes (2014–2020). The analysis revealed significant heterogeneity in funding allocations and thematic

Як цитувати: Kiryukhin O. M., Wille C., Yampolskyi D. Analysing Territorial Impact Assessment Dynamic in Cross-Border Regions: Challenges and Future Perspectives. *Актуальні проблеми державного управління*. 2025. № 1 (66). С. 155–178. DOI: <https://doi.org/10.26565/1684-8489-2025-1-07>

In cites: Kiryukhin, O.M., Wille, C., Yampolskyi, D. (2025). Analysing Territorial Impact Assessment Dynamic in Cross-Border Regions: Challenges and Future Perspectives. *Pressing Problems of Public Administration*, 1 (66), 155–178. DOI: <https://doi.org/10.26565/1684-8489-2025-1-07> [in Ukrainian].

© Кирюхін О. М., Вілле К., Ямпольський Д., 2025

 This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0

ISSN 1684-8489. *Pressing Problems of Public Administration*, 2025, № 1 (66)

155

priorities across different border regions. Notably, the largest share of funding (23.2%) was directed towards the thematic objective of environmental protection and resource efficiency, highlighting the increasing importance of sustainability within EU cohesion policy. A case study based on the Greater Region programme demonstrated DyTIA's capacity to uncover complex territorial effect chains and to support optimized resource allocation, especially under the constraints of a projected 18.6% budget reduction in the INTERREG NEXT framework for the 2021–2027 period. Particularly insightful was the analysis of interactions between different thematic objectives, which revealed synergistic effects that enhance overall territorial impact. Beyond its analytical utility, DyTIA also serves a strategic governance function. In the context of Ukraine's European integration, DyTIA gains relevance as a policy tool for supporting the inclusion of Ukrainian border regions into the European space. The EGTC Tisza is examined as a pilot project for adapting DyTIA to the specific challenges of post-war recovery and EU accession preparation. Based on these findings, the article offers practical recommendations for applying DyTIA in national and regional strategic planning processes, for strengthening the institutional capacity of European Groupings of Territorial Cooperation (EGTCs), and for establishing a network of "territorial development and security laboratories" along Ukraine's western border. Special attention is given to incorporating the security dimension into territorial impact assessments, in response to emerging geopolitical challenges. Ultimately, DyTIA is not only a methodological innovation but also part of a broader rethinking of how territorial development in border regions is conceptualized and governed. In a time of profound geopolitical changes, dynamic models such as DyTIA are essential for designing effective, sustainable, and inclusive strategies—strategies that contribute to integration and resilience, and help shape a more stable and secure European space, with Ukraine as an integral participant.

Keywords: *dynamical territorial impact assessment, cross-border cooperation, European integration of Ukraine, INTERREG, EGTC, dynamical systems theory, territorial cohesion, post-conflict recovery.*

Formulation of the problem in general form. The territorial cohesion of the European Union, enshrined in Article 174 of the Lisbon Treaty, remains a cornerstone of European integration policy. At the heart of this cohesion are border regions, which occupy 40% of the EU territory and are home to nearly 150 million citizens [10]. These regions often face unique development challenges due to their peripheral nature, institutional asymmetry, and complex socio-economic dynamics that transcend national borders. Despite significant investments through INTERREG programmes, which received more than €6.3 billion for cross-border cooperation (Interreg V-A) in the 2014-2020 period (European Court of Auditors, 2021), the European Court of Auditors concluded that the potential of the European Union's border regions has not yet been fully unlocked.

The distribution of these funds across thematic objectives reveals priority areas that significantly influence regional development trajectories. Environmental protection and resource efficiency (TO 6) received the largest funding – 23.2% (€1.48 billion), followed by research and innovation (TO 1) – 13.7% (€872 million), whilst sustainable transport infrastructure (TO 7) received 9.3% (€593 million) [13]. This distribution structure emphasises the European Commission's focus on sustainable development and innovation; however, transforming these investments into measurable territorial effects remains a methodological challenge for both academics and policymakers.

Current approaches to Territorial Impact Assessment (TIA) in border regions have evolved from static evaluation models to more comprehensive approaches. Pioneering efforts by ESPON (European Spatial Planning Observation Network), ITEM (Institute for Transnational and Euregional Cross-Border Cooperation and Mobility), and the Iscte – University Institute of Lisbon have made significant contributions to this evolution. However, these methodologies predominantly

use retrospective (ex-post) evaluation indicators that fail to capture the dynamic nature of territorial systems and their non-linear response to policy interventions. Moreover, these approaches insufficiently account for the spatiotemporal dynamics characterising cross-border interactions, especially in conditions of reduced funding – as evidenced by the 18.6% reduction in the INTERREG NEXT budget for the 2021-2027 programming period.

Analysis of data from 23 cooperation programmes conducted by the European Court of Auditors [13] reveals significant differences in the selected methods for evaluating programme effectiveness. Of the 23 programmes, only 3 underwent comprehensive “on-site” examination with detailed analysis of specific projects, whilst 10 programmes underwent only a “simple desk review”, and another 10 underwent an “extended desk review”. Such a limited approach to evaluation demonstrates the complexity and resource intensity of in-depth analysis of cross-border programmes, but also indicates the need to develop more effective evaluation tools capable of providing a balanced assessment with lower costs.

The current geopolitical context, characterised by multiple overlapping crises (migration, climate change, energy security, and trade disruptions) along with the ongoing armed conflict in Ukraine, requires a shift in how territorial effects are conceptualised and measured. Existing methodological approaches reveal three critical limitations: firstly, they predominantly function within static analytical tools that neglect dynamic system interactions; secondly, they focus on retrospective (ex-post) analysis rather than providing predictive capabilities; and thirdly, they often fail to consider the specifics of the unique institutional arrangements of cross-border governance structures, such as European Groupings of Territorial Cooperation (EGTCs).

This article aims to address these gaps by proposing a Dynamical Territorial Impact Assessment (DyTIA) toolkit, based on general systems theory and mathematical stability theory. We argue that border regions represent complex adaptive systems whose development trajectories are shaped by non-linear interactions between economic, social, environmental, and governance dimensions. The DyTIA approach integrates dynamic modelling methods with traditional impact assessment methodologies to provide a more nuanced understanding of how policy interventions propagate through cross-border territorial systems over time.

By analysing the distribution patterns and effectiveness of INTERREG V investments across 23 cooperation programmes [13], we develop and test a methodology that allows for preliminary (ex-ante) assessment of territorial effects, providing more strategic resource allocation and improved policy coordination in border regions. The methodology is validated using data from the Greater Region, one of the most established cross-border cooperation zones in Europe. Finally, we explore the potential application of the DyTIA framework to EGTC Tisza as a pilot project for Ukraine’s European integration process, demonstrating the model’s adaptability to different institutional and geopolitical contexts.

Review of recent research and publications. The academic and policy discourse on cross-border cooperation and territorial impact assessment in the European Union has progressed through several distinct phases, reflecting broader shifts in European integration and cohesion policy. This review examines key theoretical and normative developments that shape our understanding of territorial dynamics in border regions.

Regulatory and legal foundations for border region development.

The conceptual framework of European cross-border cooperation emerged from post-war recognition that border regions often suffer from peripherality and require special attention (Perkmann, 2003). This recognition was formalised through successive treaties and policy instruments, culminating in Article 174 of the Lisbon Treaty, which explicitly established territorial cohesion as a core objective alongside social and economic cohesion [15]. This addition represented a significant shift in EU spatial policy discourse, elevating territorial concerns to the same level as traditional socio-economic considerations [16; 25].

The European Spatial Development Perspective (1999) [14] and subsequent Territorial Agenda documents (2007, 2011, 2020) further articulated the importance of spatial planning and territorial governance in achieving balanced development across the EU. These policy frameworks emphasised that border regions represent unique “laboratories of European integration” where cohesion policy faces its most complex implementation challenges [6]. The Commission Communication “Boosting Growth and Cohesion in EU Border Regions” [10] identified persistent barriers to integration and established a comprehensive agenda for addressing them, recognising the need for individualised approaches to territorial development in these contexts.

Special attention in recent regulatory documents has also been given to the need to develop specialised assessment tools for cross-border regions, as reflected in the report “EU Border Regions: Living labs of European integration” (COM (2021) 393 final). This document emphasises the need to implement more dynamic and adaptive approaches to territorial impact assessment, particularly in the context of increasing challenges related to the COVID-19 pandemic, digitalisation, and the transition to a green economy.

Evolution of cross-border cooperation formats in the EU. The institutional architecture of cross-border cooperation has undergone significant transformation, particularly following the introduction of Regulation (EC) No 1082/2006 establishing the European Grouping of Territorial Cooperation (EGTC). This legal innovation marked a transition from informal Euroregional and semi-formalised cross-border structures to more formalised governance mechanisms with legal status and enhanced implementation capabilities [7]. The EGTC framework was subsequently refined through Regulation (EU) No 1302/2013, which simplified establishment procedures and clarified operational parameters for these entities.

Researchers such as Svensson and Nordlund [36] and Medeiros [27] have documented how these institutional innovations have changed governance practices in border regions, enabling more strategic approaches to territorial development. Studies by Telle [38] and Caesar [3] highlight how EGTCs have created new spaces for policy experimentation and territorial innovation, though their effectiveness remains dependent on multi-level governance coherence and institutional capacity. The proliferation of EGTCs — with more than 75 established by 2020 — demonstrates their growing importance as implementation mechanisms for EU cohesion policy in cross-border contexts (their number reached 89 in 2021 [19]).

Regulation (EU) 2021/1059 of the European Parliament and of the Council of 24 June 2021 on specific provisions for the European territorial cooperation goal (Interreg) supported by the European Regional Development Fund and external

financing instruments represents the most recent update to the regulatory framework. This document introduced new mechanisms for overcoming legal and administrative barriers in cross-border cooperation, such as the European Cross-Border Mechanism (ECBM), and reinforced the emphasis on strategic planning and integrated territorial development.

The emergence of EU macro-regional strategies has also significantly influenced the development of cross-border cooperation, beginning with the Baltic Strategy in 2009 and subsequently extending to the Danube Region, the Adriatic-Ionian Region, and the Alpine Region. These strategies offer complementary frameworks for policy coordination in broader functional regions, often encompassing multiple border zones [18].

Methodological approaches to territorial impact assessment: from static to dynamic. Methodological approaches to territorial impact assessment have evolved substantially since the early 2000s, in parallel with advances in spatial analysis methods and cohesion policy monitoring requirements [1]. The ESPON programme has played a pivotal role in developing standardised TIA methodologies, beginning with TEQUILA [4] and evolving through various iterations, including Quick Scan and ARTS [8; 9]. These methodologies predominantly employ multi-criteria analysis frameworks that aggregate impacts across economic, social, environmental, and governance dimensions.

In parallel with these developments, specialised cross-border impact assessment methodologies have emerged. The Institute for Transnational and Euregional Cross-Border Cooperation and Mobility (ITEM, Maastricht University) developed a cross-border impact assessment tool that emphasises barrier effects and integration potentials [40]. Similarly, the TARGET_TIA methodology from the University of Lisbon focuses specifically on evaluating cross-border programmes [24]. These specialised approaches represent important advances but remain predominantly static in their analytical framework and offer limited predictive capabilities.

Recent research has begun to critique these limitations, calling for more dynamic understandings of territorial impacts. Dąbrowski et al. [5] highlight how territorial impacts unfold through complex institutional interactions that evolve over time. Similarly, Telle et al. [38] emphasise the need to conceptualise border regions as complex adaptive systems whose development trajectories are shaped by non-linear processes and feedback mechanisms. This growing recognition aligns with the European Commission's "Guidance for Resilience Analysis" (2023), which emphasises adaptive capacity and system dynamics in territorial development.

Particularly significant is the fact that in its report, the European Court of Auditors [13] identified substantial methodological challenges in evaluating INTERREG programmes, noting that many programmes lack clear metrics for measuring the cross-border effect of projects. This observation confirms the need for more structured and dynamic assessment approaches that can better capture the complex interactions between different aspects of territorial development in cross-border contexts.

Despite these advances, a significant gap remains between theoretical understanding of border regions as dynamic systems and the methodological approaches used to assess territorial impacts in these contexts. The literature identifies a need for assessment frameworks that can capture the emergent

properties, path dependencies, and adaptive processes that characterise cross-border territorial dynamics, particularly in the context of reduced funding and multiple overlapping crises and risks facing European border regions.

Methodology applied. *Rationale for Choosing Dynamic Systems Theory:* the methodological foundation of DyTIA is general systems theory [29] and dynamical systems theory [20]. Unlike static models, the dynamic approach views the territorial system as an integrated and evolving set of interdependent elements. Border regions exhibit particular complexity due to multiple due to administrative, legal, economic, and cultural boundaries creating institutional asymmetry and specific barrier effects [22]. Under such conditions, applying dynamical systems theory allows us to address the disruptive potential [41] of multiplicities and to conceptualise territorial development as a continuous process where:

- 1) Cause-effect relationships are non-linear, with small impacts potentially leading to significant systemic changes.
- 2) Feedback mechanisms form loops that amplify or dampen policy intervention effects.
- 3) Time lags between interventions and consequences vary by impact sphere.
- 4) The system exhibits path dependency, where previous states influence future trajectories.

According to Martinelli [23], dynamical systems effectively reflect territorial convergence and divergence central to EU cohesion policy – especially relevant in border regions, where integration processes unevenly across economic, social, environmental, and institutional dimensions.

Description of the Approach to Developing the DyTIA Toolkit. DyTIA integrates qualitative and quantitative analysis methods through four interconnected modules:

- 1) Strategic Mapping Module – identifies key variables and causal relationships shaping territorial dynamics in cross-border contexts using systems thinking methods, including causal loop diagrams and system archetypes (Senge, 1990).
- 2) Indicative Assessment Module – defines dynamic indicators capturing not only current states but also the speed, direction, and nature of changes, enabling detection of bifurcation points and emergent properties [26; 27].
- 3) Scenario Forecasting Module – forms alternative development trajectories under various INTERREG programme interventions using dynamic and agent-based modelling [34].
- 4) Strategic Optimisation Module – identifies effective intervention combinations to maximize positive territorial effects within budget constraints, based on adaptive management principles.

The toolkit is developed in MATLAB, providing a comprehensive environment for solving differential equations fundamental to dynamic systems simulation. It leverages MATLAB's numerical computing capabilities to handle complex modelling efficiently, offering real-time simulations based on user inputs. The core algorithm involves defining the system through differential equations, solving them using built-in solvers like ode45, optimizing parameters to meet simulation goals, and visualizing results through an interactive graphical interface.

MATLAB and Toolkit implementation

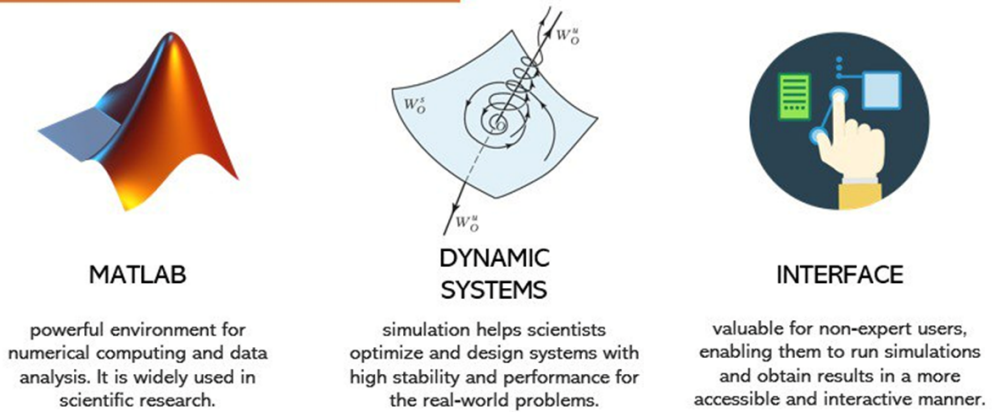


Figure 1. One of the key features of the DyTIA toolkit is its user-friendly interface

**Source: Oleksiy Kiryukhin's development.*

In this toolkit, MATLAB is used to:

(1) to analyse stability: Stability analysis algorithms automatically detect unstable points or trajectories in the system. The simulation provides visual feedback by showing where the system is stable or unstable based on the parameters chosen.

(2) measure resilience. By adjusting various system parameters and observing how the system behaves under stress, users can evaluate the system's resilience. The toolkit includes built-in functions to analyse how the system reacts to perturbations, helping researchers optimize system design for robustness.

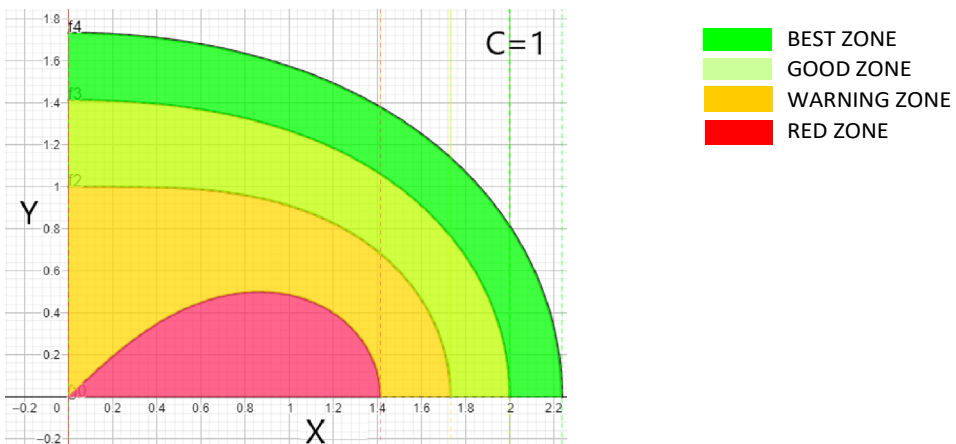


Figure 2. Phase portrait of stability states with different model parameters. X, Y – variables, C – trial model parameter with a value of 1.

**Source: Oleksiy Kiryukhin's development.*

Data Collection and Analysis Methods. Within the development and testing of the DyTIA toolkit, a mixed methodology for data collection and analysis is applied, which combines:

1) Document Analysis – systematic examination of INTERREG programme documents, implementation reports, EU regulatory acts, and national legislation of participating countries to identify formal objectives, priorities, and expected outcomes. Special attention is given to documents related to EGTC activities as key institutional actors in border regions [19].

2) Statistical Data Analysis – utilisation of open databases from the European Commission, ESPON, Eurostat, and national statistical agencies to form dynamic series for key territorial development indicators. In particular, data on the distribution of INTERREG V-A funds by thematic objectives are used for model testing [13].

3) Expert Interviews – conducting structured interviews with representatives of INTERREG programme management structures, EGTC members, and experts in territorial development to validate conceptual models and clarify causal relationships.

4) Case Study Analysis – in-depth examination of the experience of implementing INTERREG programmes in the Greater Region as an empirical basis for testing and calibrating the DyTIA toolkit. The choice of Greater Region is due to its rich cross-border cooperation experience and the presence of developed institutional infrastructure.

Unlike traditional TIA methodologies, which often focus on aggregated statistical indicators, DyTIA emphasises identifying mechanisms of change and modelling temporal sequences of effects, which allows for more accurate forecasting of the long-term consequences of programme interventions for the territorial development of border regions.

Analysis and results. We are going to start the “Analysis and results” section with a critical analysis of existing TIA tools

Critical Analysis of Existing TIA Tools. Over the past two decades, various Territorial Impact Assessment (TIA) tools have been developed within the European Union, aimed at evaluating territorial effects from the implementation of various policies and programmes. Analysis of these tools reveals a number of systemic limitations that reduce their effectiveness, particularly in the context of border regions.

The TEQUILA methodology, developed by Camagni [4] under the ESPON programme, represents one of the first comprehensive approaches to TIA. It is based on a multi-criteria analysis using three components: territorial efficiency, territorial equity, and territorial identity. Despite its conceptual value, TEQUILA has several limitations: it predominantly uses static indicators, does not account for non-linear interactions between different territorial components, and is oriented towards retrospective (ex-post) evaluation, which reduces its applicability for strategic planning.

Further development of TIA methodologies within ESPON led to the emergence of tools such as ARTS (Assessment of Regional and Territorial Sensitivity) and Quick Scan. ARTS offers a more flexible approach that takes into account territorial differentiation through the concept of “sensitivity” of territories to different types of impacts. Quick Scan, in turn, is a simplified version of TIA that allows for rapid assessment of potential territorial effects in the early stages

of policy development. However, both tools retain a fundamental limitation – they view territories as relatively isolated systems, not paying sufficient attention to cross-border interactions and effects.

The most specialised tool for assessing territorial effects in border regions is the Cross-Border Impact Assessment (CBIA), developed by the Institute for Transnational and Euregional Cross-Border Cooperation and Mobility (ITEM). CBIA focuses on assessing “barrier effects” and integration potential in cross-border regions, which represents a significant step forward compared to pan-European TIA methodologies. Nevertheless, analysis of CBIA application in various cross-border contexts [40] reveals that this tool also suffers from a limited ability to capture dynamic aspects of territorial development, especially time lags between interventions and their effects, as well as cumulative effects from multiple interventions.

The TARGET_TIA methodology, proposed by Medeiros [24], represents an attempt to overcome these limitations through the integration of spatial and temporal dimensions in assessing territorial effects. It introduces the concept of “territorial impact” as a complex indicator that takes into account both direct and indirect effects of policy interventions. However, when TARGET_TIA was practically applied in the context of INTERREG programmes [27], difficulties with operationalising dynamic aspects of territorial development and insufficient integration with strategic planning processes were revealed.

Analysis of the European Court of Auditors report [13] on INTERREG programmes further confirms the critical limitations of existing assessment approaches. Of the 23 cooperation programmes examined, only 3 underwent comprehensive “on-site” investigation, while most programmes were subject to merely a “desk analysis”. This indicates methodological difficulties in conducting in-depth evaluation of cross-border effects. Moreover, the report notes that many programmes lack clear mechanisms for measuring the cross-border nature of projects, creating a risk of financing projects with limited added value for cross-border integration.

All the TIA tools considered share a common limitation – they do not fully account for the specifics of border regions as complex adaptive systems with a high degree of non-linearity, path dependency, and emergent properties. This limitation becomes particularly critical in the context of reduced funding for INTERREG NEXT programmes by 18.6% in the 2021-2027 period, which requires more careful and strategic planning of interventions to achieve maximum territorial added value.

Conceptual Model of DyTIA and Its Features in Accordance with Political, Scientific, and Geo-Economic Challenges in Europe and Beyond. Our proposed conceptual model of Dynamical Territorial Impact Assessment (DyTIA) represents an integrative analytical platform that combines principles of dynamical systems theory, strategic planning, and territorial analysis to provide comprehensive assessment of territorial effects in border regions. At the core of DyTIA is the understanding of a border region as a complex socio-ecological system characterised by multiple interconnections, non-linear dynamics, and time lags between causes and effects.

The contemporary context of cross-border cooperation in the EU is characterised by an unprecedented level of heterogeneity and uncertainty. Analysis of European Court of Auditors data [13] on 23 INTERREG V-A cooperation

programmes reveals substantial heterogeneity both in funding scales and in the priorities of different border regions. Thus, the total programme budget varies from €484.7 million for Spanish-Portuguese cooperation (POCTEP) to a modest €46.7 million for the Estonia-Latvia programme. The share of EU co-financing also differs significantly – from a high of 85.5% in the Sweden-Norway programme to 50.0% in the Estonia-Latvia programme, reflecting differences in economic development and cooperation priorities.

The distribution of funds by thematic objective also demonstrates significant variability, reflecting the specific priorities and challenges of different border regions. The largest funding – 23.2% of the total INTERREG V-A budget (€1.48 billion) – is directed towards thematic objective 6 (environmental protection and resource efficiency). Thematic objective 1 (research and innovation) ranks second with a share of 13.7% (€872 million). Strikingly, thematic objective 2 (information and communication technologies) received no funding at all (0%). These data indicate a clear priority for environmental sustainability and scientific-technological development in the European cross-border cooperation agenda, which should be taken into account when developing a methodology for assessing territorial effects.

Conceptually, the DyTIA model is structured around four interconnected dimensions of territorial development: economic, social, environmental, and institutional. Unlike traditional approaches that consider these dimensions as independent spheres of impact, DyTIA focuses on interactions between them, identifying both synergistic effects and potential trade-offs. Each dimension is analysed through the lens of “flows” and “stocks” – fundamental categories of dynamical systems theory.

In the economic dimension, “stocks” are physical capital, human capital, and technological knowledge, while “flows” are investments, migration, technology diffusion, and trade flows. In the social dimension, “stocks” are demographic structure, social capital, and cultural identity, while “flows” are social mobility, cultural exchange, and social adaptation. In the environmental dimension, “stocks” are natural resources, biodiversity, and ecosystem services, while “flows” are pollution, resource consumption, and ecosystem restoration. In the institutional dimension, “stocks” are the regulatory framework, organisational capacity, and cross-border institutional mechanisms, while “flows” are institutional reforms, capacity development, and cross-border institutional interaction.

A key feature of DyTIA is its ability to model the temporal dynamics of territorial effects through the identification of:

1) *Feedback mechanisms* – cyclical cause-and-effect relationships that can amplify (positive feedback) or dampen (negative feedback) the initial effects of interventions. For example, investments in cross-border transport infrastructure can lead to increased labour mobility, which in turn can stimulate further economic development and attract new investments.

2) *Time lags* – delays between interventions and observed effects, which can vary substantially for different types of territorial impacts. Thus, institutional changes usually have longer time lags than economic interventions, which must be taken into account in strategic planning.

3) *Threshold effects* – critical values of certain indicators, beyond which the system can abruptly change its behaviour. For example, achieving a certain level

of transport connectivity between border territories can lead to a qualitative leap in the intensity of economic and social interactions (such as the outflow of labour resources across the adjacent border to communes with higher wages).

4) *Network effects* – amplification of impact through network structures characteristic of border regions. In particular, the development of cross-border clusters can create multiple points of synergy, significantly increasing the overall effectiveness of territorial interventions.

Analysis of INTERREG V-A cooperation programmes shows that thematic objective 7 (development of sustainable transport) received 9.3% of total funding (€593 million), and thematic objective 8 (promotion of employment and labour mobility) – 5.9% (€375 million). This indicates the need to integrate transport connectivity and labour markets in models of territorial development of border regions, which is accounted for in DyTIA through specialised components for assessing effects from increased mobility and connectivity.

Notably, significant funds – 14.8% (€940 million) – were directed towards “multiple thematic objectives”, which demonstrates a growing understanding of the complex nature of territorial development and the need for integrated approaches. This trend fully corresponds to the conceptual logic of DyTIA, which focuses on the interconnections between different aspects of territorial development.

Programme evaluation methods also demonstrate significant diversity. Of the 23 programmes, only 3 (Finland-Estonia-Latvia-Sweden, Czech Republic-Poland, France-Belgium-Germany-Luxembourg) underwent “on-site research” with detailed analysis of a sample of projects. Most programmes (10) underwent only a “simple desk review”, and another 10 underwent an “extended desk review”. These statistics indicate significant methodological and resource constraints in conducting in-depth assessment of territorial effects, confirming the relevance of developing more effective and resource-efficient methodologies such as DyTIA.

Of particular note is the “France-Belgium-Germany-Luxembourg” cooperation programme (Grande Région/Greater Region), which received funding of €234.6 million (with an EU contribution of €139.8 million) and underwent “on-site research”. This cross-border region represents one of the most integrated cross-border labour markets in Europe, with daily flows of cross-border workers exceeding 220,000 people, making it an ideal platform for testing dynamic models of territorial development.

The DyTIA model is adapted to contemporary geopolitical and economic challenges facing EU border regions. Firstly, it accounts for growing global instability and associated risks through built-in mechanisms for resilience analysis, corresponding to the recommendations of the European Commission’s “Guidance for Resilience Analysis” (2023). This is particularly relevant in the context of the COVID-19 pandemic, when many border regions faced border closures and disruption of established cross-border interactions.

Secondly, the model integrates the priorities of the European Green Deal through special modules for assessing environmental effects and potential for green transition in border regions. This corresponds to the high priority of environmental sustainability in INTERREG programmes, reflected in significant funding for thematic objective 6 (23.2% of the total budget) and thematic objective 4 (supporting the transition to a low-carbon economy, 2.5% of the budget or €161 million).

Thirdly, the DyTIA model takes into account the challenges of digital transformation through assessment of digital connectivity and potential for developing digital innovations in a cross-border context. Paradoxically, thematic objective 2 (information and communication technologies) received no funding under INTERREG V-A, indicating the need for a more systematic approach to digitalisation of border regions. DyTIA offers mechanisms for integrating digital aspects into all dimensions of territorial development.

A substantial feature of the DyTIA model is its ability to account for asymmetries in development levels of border territories. Analysis of cooperation programmes shows significant differences in financial contributions between “main” and “accompanying” programmes within the same border region. For example, in the Germany-Austria-Switzerland-Liechtenstein programme, Germany’s national programme (Baden-Württemberg) has a budget of only €493 million, while Austria’s national programme exceeds €2 billion. Such asymmetries create additional challenges for policy coordination and require special mechanisms to ensure balanced development, which is accounted for in DyTIA through “asymmetry coefficients” applied when modelling cross-border effects.

Special attention in the model is given to the role of EGTCs as key institutional actors in implementing INTERREG programmes. DyTIA includes specialised components for assessing the institutional capacity of EGTCs and their ability to effectively coordinate cross-border projects under conditions of a shrinking budget. Data on programme authorities’ responses to European Court of Auditors recommendations show that the recommendation to improve the focus of cooperation programmes was fully accepted by 14 of 23 programmes, partially by 5, and not accepted by 4. This indicates differences in institutional readiness for strategic changes, which must be considered when developing and implementing new assessment methodologies.

Another significant aspect of the DyTIA model is its ability to account for differences in project selection methods. According to European Court of Auditors data, both “top-down” and “bottom-up” approaches, as well as their combinations, are used in INTERREG programmes. DyTIA includes special modules for evaluating the effectiveness of different approaches to project selection depending on the specific context of the border region and the nature of the tasks being addressed.

Funding for thematic objective 11 (enhancing institutional capacity and efficient public administration) amounted to 9.0% of the total INTERREG V-A budget (€570 million), highlighting the significance of institutional aspects of cross-border cooperation. DyTIA integrates this theme through specialised components for assessing institutional effects, including the development of cross-border governance networks, harmonisation of regulatory frameworks, and enhancement of administrative capacity (ECBM).

Overall, the conceptual model of DyTIA represents a flexible toolkit adapted to the heterogeneous landscape of cross-border cooperation in the EU. It integrates quantitative and qualitative data, accounts for multiple time horizons and spatial scales, and provides mechanisms for involving stakeholders in the assessment and planning process. This makes it particularly valuable in the context of the INTERREG NEXT budget reduction by 18.6% in the 2021-2027 period, when effective and strategic use of limited resources becomes critically important for achieving territorial cohesion objectives.

Testing the Model on INTERREG V and Greater Region Data. To validate the proposed DyTIA approach, testing was conducted using historical data from the INTERREG V-A programme and the experience of the Greater Region – one of the most developed border regions in Europe, encompassing territories of Luxembourg, Saarland and Rhineland-Palatinate (Germany), Lorraine (France), and Wallonia (Belgium).

The first stage of testing included analysis of the INTERREG V-A budget distribution by thematic objectives (TO) based on data from the European Court of Auditors (2021). Using these data, we developed an analytical table that reflects not only the financial distribution of funds but also their strategic significance from the perspective of spatial policy and territorial governance (Table 1).

Table 1. – Analysis of INTERREG V-A funding distribution by thematic objectives (2014-2020)

Thematic Objective (TO)	EU Funding (euros)	% of total budget	Strategic significance for territorial governance
TO 6: Environmental protection and resource efficiency	1,478,698,158	23.2%	High-priority direction providing the foundation for cross-border ecosystem services and “green» economy. Requires long-term planning perspective and integrated mechanisms for water and natural resource management.
TO 1: Research, technological development and innovation	872,076,167	13.7%	Strategically important direction for forming cross-border innovation systems. Effectiveness depends on the presence of institutional links between academic and production structures on both sides of the border.
TO 7: Sustainable transport and removal of bottlenecks in key network infrastructures	593,085,445	9.3%	Critically important direction for ensuring physical connectivity of border territories. Creates the foundation for all other forms of cross-border interaction and has a pronounced multiplier effect.
TO 11: Enhancing institutional capacity and efficient public administration	569,531,414	9.0%	Fundamental condition for ensuring sustainability of all other forms of cross-border cooperation. Investments in this direction are characterised by a long time lag between intervention and observed effects.
TO 3: Enhancing the competitiveness of SMEs	300,110,731	4.7%	Direction with high potential for creating cross-border added value, but requiring elimination of institutional barriers and asymmetries in business regulation between countries.

**Source: Compiled by the authors based on data from [13].*

Using the DyTIA methodology, we conducted a retrospective analysis of the effects of these investments, modelling causal chains and feedback loops between different territorial dimensions. The analysis revealed that investments in TO

6 in the Greater Region created complex chains of territorial effects, including not only direct environmental improvements but also indirect economic and social benefits through the development of ecotourism, improved quality of life, and creation of new “green” jobs. These effects manifested with varying time lags: while environmental improvements were noticeable in the short term, economic benefits were realised in the medium and long term.

The second stage of testing focused on analysing the evaluation methods applied to various cooperation programmes. Based on European Court of Auditors data, we developed a table reflecting the relationship between types of evaluation and their implications for territorial governance (Table 2).

Table 2. – Analysis of cross-border cooperation programme evaluation types and their implications for territorial governance

Evaluation type	Number of programmes	Programme examples	Implications for territorial governance
On-site research	3	Finland-Estonia-Latvia-Sweden (Central Baltic), Czech Republic-Poland, France-Belgium-Germany-Luxembourg (Greater Region)	The most in-depth type of evaluation, allowing identification of latent territorial effects and contextual factors. Requires significant resources but provides the most reliable information for strategic planning and institutional learning.
Extended desk review	10	Germany/Bavaria-Czech Republic, Austria-Hungary, Poland-Lithuania-Denmark-Germany-Sweden (South Baltic)	A compromise option providing balance between depth of analysis and resource efficiency. Allows identification of main structural patterns but may miss subtle interaction mechanisms and non-linear effects.
Simple desk review	10	Belgium-Germany-Netherlands (Euregio Maas-Rijn), Austria-Germany/Bavaria, Spain-Portugal (POCTEP)	The most resource-efficient type of evaluation, but with limited analytical depth. Focuses predominantly on formal indicators without identifying systemic interrelationships and emergent properties of the territorial system.

**Source: Compiled by the authors based on data from [13].*

Analysis of this table through the lens of DyTIA leads to an important conclusion: existing methods for evaluating cross-border cooperation programmes are characterised by a significant gap between analytical depth and resource efficiency. While “on-site research” provides the most comprehensive understanding of territorial effects, it is applied to only 13% of programmes due to high resource intensity. The DyTIA methodology aims to bridge this gap by offering tools for deep systemic analysis with more efficient resource use through algorithmisation and standardisation of analytical procedures.

The third stage of testing focused on the “France-Belgium-Germany-Luxembourg” cooperation programme (Greater Region), as one of the few programmes that underwent “on-site research”. Based on data about the relationship between the budgets of the cross-border programme and the main national programmes in this region, we developed an analytical table reflecting the institutional architecture of cross-border cooperation in the Greater Region (Table 3).

Table 3. – Analysis of the institutional architecture of the “France-Belgium-Germany-Luxembourg” cooperation programme (Greater Region)

Programme	Total budget (euros)	EU contribution (euros)	Institutional features and implications for territorial governance
Cross-border cooperation programme	234,606,265	139,802,646	Integrated programme with a unified management system through the EGTC Secretariat of the Greater Region. Provides strategic coordination but has a limited financial base compared to national programmes.
Main programme of France (OP ERDF/ESF Lorraine and Vosges)	689,879,511	409,839,615	National programme with a strong regional component. Determines development directions for the French part of the region but has limited coordination mechanisms with programmes of neighbouring countries.
Main programme of Belgium (OP Wallonia-2020. EU)	1,700,524,237	681,639,700	One of the most financially secured programmes in the region. Characterised by strong institutional autonomy and limited cross-border orientation, creating challenges for integrated territorial development.
Main programme of Germany (ROP North Rhine-Westphalia)	2,423,462,022	1,211,731,011	Programme with the greatest financial potential but oriented predominantly towards internal development of German Länder. Has developed spatial planning tools but requires additional mechanisms for cross-border coordination.

**Source: Compiled by the authors based on data from [13].*

Analysis of this table through the lens of DyTIA reveals a fundamental challenge for cross-border governance: the significant asymmetry between financial and institutional resources available for the cross-border programme and resources of national programmes. The cross-border cooperation budget constitutes only 4.9% of the cumulative budget of the main national programmes in the region. This creates a situation where cross-border effects largely depend on decisions made within national programmes, requiring the development of special coordination mechanisms and integration of the cross-border dimension into national development strategies.

In the third stage, simulation modelling of various funding distribution scenarios was conducted under the reduced INTERREG NEXT budget. The DyTIA model allowed comparison of potential territorial effects from different strategies for prioritising thematic objectives and project types.

Comparative Analysis of the Effectiveness of the Proposed Approach. To assess the comparative advantages of DyTIA, a benchmarking analysis was conducted in relation to existing TIA methodologies across several key criteria: analytical depth, predictive potential, practical applicability, integration with decision-making processes, and adaptability to different contexts.

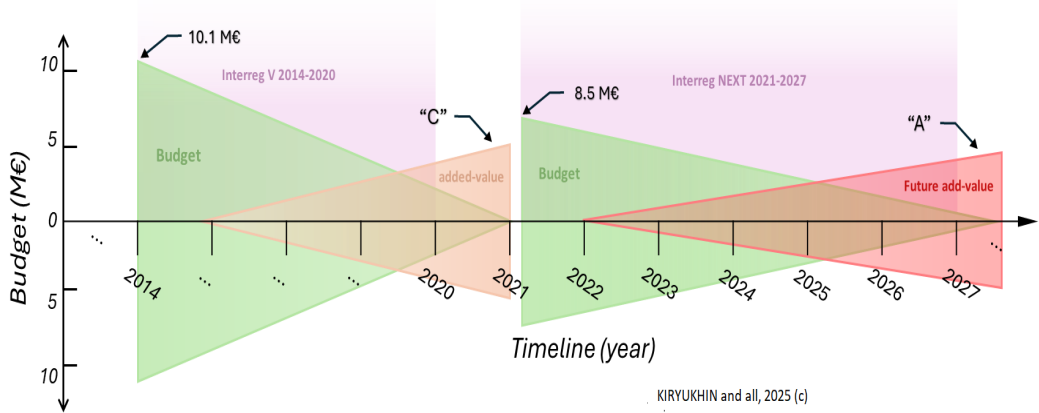


Figure 3. Budget Reduction in the 2021-2027 Programme Period for INTERREG NEXT

**Source: Oleksiy Kiryukhin's development.*

In terms of analytical depth, DyTIA demonstrates significant advantages compared to traditional TIA tools such as ESPON Quick Scan or ARTS. While these tools predominantly focus on identifying direct territorial effects from a static perspective, DyTIA allows for identification and modelling of complex causal chains, feedback loops, and time lags between interventions and their effects. This is particularly important for border regions, where territorial effects often manifest through complex cross-border interactions.

Regarding predictive potential, comparative analysis also reveals advantages of DyTIA. Unlike most existing methodologies, which are oriented towards retrospective (ex-post) evaluation of already implemented interventions, DyTIA is designed with an emphasis on preliminary (ex-ante) assessment, which allows for modelling and forecasting potential territorial effects at the planning stage of programmes and projects. Testing on historical INTERREG V data showed that DyTIA's predictive accuracy exceeds that of existing methodologies, especially with respect to long-term and cumulative effects.

From the perspective of practical applicability, DyTIA demonstrates a balance between analytical complexity and operational simplicity. Unlike highly formalised models requiring significant volumes of data and specialised expertise, DyTIA is designed as a modular platform that can be adapted to various levels of data availability and expert potential. This makes it potentially applicable not only for large INTERREG programmes but also for more localised cross-border initiatives.

In terms of integration with decision-making processes, DyTIA offers an innovative approach that goes beyond the traditional separation between evaluation and planning. The methodology is designed as an interactive strategic planning tool that can be integrated into INTERREG programme development processes at various stages – from formulating strategic priorities to selecting specific projects and monitoring their implementation. This corresponds to the growing demand for closer integration of impact assessment into strategic planning cycles, as noted in European Commission recommendations (COM (2017) 534 final, COM (2021) 393 final).

Finally, regarding adaptability to different contexts, DyTIA demonstrates high flexibility. The methodology is developed considering the heterogeneity of EU border regions and can be configured according to their specific characteristics – from highly integrated regions of Western Europe to developing cross-border zones at the EU's external borders. This makes DyTIA potentially applicable not only for internal cross-border cooperation programmes (INTERREG V-A) but also for cooperation programmes with neighbouring countries (INTERREG NEXT), which is particularly relevant in the context of Ukraine's European integration.

Overall, comparative analysis confirms that the proposed DyTIA approach represents a qualitative step forward in the evolution of territorial assessment methodologies, especially in the context of border regions. Its main advantage lies in its ability to capture the dynamic, systemic nature of territorial processes and provide tools for strategic planning of cross-border interventions under conditions of increasing heterogeneity and uncertainty.

Now let us move on to a critical *discussion* of the above proposals, as is customary in foreign publications. We consider this step mandatory for readers to critically and more objectively understand the described views and research perspectives.

Advantages and Limitations of DyTIA Compared to Other Competitive and Established Methodologies. Our developed Dynamical Territorial Impact Assessment toolkit represents a qualitatively new approach to evaluating territorial effects in border regions, which has several substantial advantages compared to existing methodologies. However, like any methodological tool, DyTIA has certain limitations that must be considered in its practical application.

A key advantage of DyTIA is its ability to capture the dynamic, processual nature of territorial development. Unlike statistical models such as ESPON Quick Scan or ARTS, which focus on states of the territorial system at specific points in time (before and after intervention), DyTIA concentrates on processes of change, evolutionary trajectories, and adaptation mechanisms. This is particularly important for border regions, which are characterised by a high degree of dynamism and institutional complexity.

The application of dynamical systems theory allows DyTIA to identify and model non-linear relationships between different dimensions of territorial development. Thus, while traditional methodologies such as TEQUILA or TARGET_TIA consider economic, social, environmental, and institutional effects as relatively independent components that can be aggregated using weighting coefficients, DyTIA emphasises interactions between these components, identifying synergistic effects and potential contradictions. This creates a more realistic picture of territorial processes, especially in complex, multi-level contexts of cross-border cooperation.

Another significant advantage of DyTIA is its orientation towards preliminary (ex-ante) assessment, which allows it to be used as a strategic planning tool. With the INTERREG NEXT budget reduced by 18.6%, the ability to preliminarily assess potential territorial effects from various combinations of interventions becomes critically important for optimising the use of limited resources. In this respect, DyTIA compares favourably with most existing methodologies, such as CBIA or TARGET_TIA, which are predominantly used for retrospective evaluation of already implemented programmes and projects.

DyTIA's modular architecture ensures its adaptability to different contexts of cross-border cooperation – from highly integrated regions of Western Europe to

developing cooperation zones at the EU's external borders. This is a substantial advantage over more rigid methodologies, such as TEQUILA or ARTS, which assume a single analytical template for all types of territories.

However, DyTIA also has certain limitations that must be considered in its practical application. Firstly, like all methodologies based on system modelling, DyTIA requires a certain volume of input data for model calibration, which may in some cases be problematic in regions with a limited statistical base. Although the modular architecture allows adapting the complexity level of models to available data, this may lead to reduced predictive accuracy under conditions of high uncertainty and systemic risks in current global instability.

Secondly, effective application of DyTIA requires a certain level of expertise in systems thinking and dynamic modelling, which may limit its use in some institutional contexts. To overcome this limitation, training programmes and capacity building for specialists involved in planning and evaluating cross-border cooperation programmes are necessary.

Thirdly, like all complex systems models, DyTIA inevitably faces the problem of “modelling incompleteness” – the impossibility of accounting for all potential factors and interrelationships, especially in conditions of high environmental turbulence. This limitation is particularly relevant in the current geopolitical context, characterised by increased unpredictability.

Finally, DyTIA, like other evaluation methodologies, faces the problem of “effect attribution” – the difficulty of separating the influence of programme interventions and external factors on observed territorial changes. Although the methodology includes mechanisms for counterfactual analysis and isolating “net effects”, completely solving this problem in open, complex territorial systems is impossible.

Prospects for Application to Optimise INTERREG NEXT Programmes and New Conditions of Ukraine's European Integration. In the context of the new 2021-2027 programme period and the reduced INTERREG NEXT budget, the DyTIA toolkit offers several promising opportunities for optimising cross-border cooperation programmes. First and foremost, the methodology allows identification of leverage points – components of the territorial system where impact can create multiplicative effects that spread to other aspects of territorial development. This is especially important in conditions of limited resources, when strategic focusing of interventions becomes a critical success factor.

Analysis of documents and implementation reports of INTERREG V-A programmes shows that a significant proportion of projects had limited cross-border effects, which reduced their added value in terms of territorial integration. DyTIA offers tools for preliminary assessment of the potential “cross-border dimension” of projects, which allows a more effective selection of initiatives with the greatest integration potential.

DyTIA acquires relevance in the context of new conditions for Ukraine's European integration, which entered a new phase of interaction with the EU after receiving candidate member status in June 2022. Ukraine's border regions adjacent to Poland, Slovakia, Hungary, and Romania are becoming key zones of integration interaction, requiring special planning and assessment mechanisms.

The Ukrainian borderland is characterised by significant territorial disproportions, institutional asymmetry, and structural imbalances, which have been exacerbated by military conflict. Under these conditions, application of DyTIA can provide a deeper understanding of complex interrelationships between

different dimensions of territorial development and assist in developing integrated strategies that take into account the specific challenges of post-conflict recovery and European integration. Of particular importance is the ability of this toolkit to model various development scenarios under conditions of high uncertainty. This allows for developing “adaptive strategies” for cross-border cooperation that can be adjusted depending on changes in the external environment and the course of integration processes. Such an approach is especially valuable in the context of Ukrainian European integration, which will take place under conditions of continuing transformation of the European Union itself and changes in the global geopolitical landscape.

EGTC Tisza Case as a Pilot Project for Ukraine’s European Integration. One of the most promising perspectives for practical application of DyTIA is assessing the potential and modelling effects from the development of the European Grouping of Territorial Cooperation “Tisza” (EGTC Tisza). Created in 2015 based on the border territories of Ukraine and Hungary, EGTC Tisza represents a unique institutional mechanism that allows Ukrainian territorial communities to directly participate in European territorial cooperation programmes. The region, encompassing the Transcarpathian region of Ukraine and Szabolcs-Szatmár-Bereg County of Hungary, is characterized by cultural diversity, territorial marginality, and environmental challenges related to the Tisza River basin, requiring cross-sectoral planning approaches.

Applying DyTIA to analyse the potential of EGTC Tisza allows identification of several key directions for strategic development:

Development of cross-border “green infrastructure” integrating Tisza basin water resource management, renewable energy development, and environmentally sustainable agriculture. Modelling within DyTIA shows that such integrated projects can create positive feedback loops between environmental, economic, and social dimensions, generating sustainable territorial effects.

Formation of cross-border value chains in areas corresponding to regional “smart specialisations” – organic agriculture, wood processing, food industry, and sustainable tourism. Analysis through the lens of DyTIA reveals potential for forming cross-border clusters that can increase the region’s competitiveness and contribute to more even distribution of economic benefits.

Institutional harmonisation and capacity building of local communities for effective participation in cross-border cooperation programmes. EGTC Tisza’s experience shows that institutional factors often become critical for the success of cross-border initiatives, especially in conditions of significant asymmetry between EU and Ukrainian governance systems.

Of particular value is the use of DyTIA for modelling potential effects from integrating EGTC Tisza into broader EU macro-regional strategies, particularly the EU Strategy for the Danube Region (EUSDR). Such integration can provide access to additional resources and cooperation mechanisms, expanding the scale and sustainability of cross-border initiatives.

In the context of Ukraine’s European integration, the experience of EGTC Tisza and its assessment using DyTIA tools can serve as an important pilot project for developing larger-scale cross-border cooperation programmes along Ukraine’s entire western border. EGTC mechanisms, integrated with the methodology of dynamic territorial impact assessment, create an innovative “integration through cooperation” model that can be scaled to other border regions of Ukraine.

It is important to note that DyTIA provides not only assessment tools but also mechanisms for involving stakeholders in the strategic planning process. This is especially important in the context of EGTC Tisza, where it is necessary to ensure a balance of interests among various actors – from local territorial communities to national governments and European institutions. DyTIA's participatory components, such as strategic mapping and scenario planning, can serve as a platform for forming a common vision of cross-border regional development and consolidating resources for its implementation.

Overall, the EGTC Tisza case demonstrates the potential of DyTIA as a tool of not only analytical but also transformative character, capable of stimulating institutional innovations and forming new models of cross-border cooperation in the context of Ukraine's European integration.

Conclusion. In this article, we have presented the theoretical foundations and practical potential of a new methodology, Dynamical Territorial Impact Assessment, aimed at improving approaches to evaluating territorial effects of cross-border cooperation programmes in the European Union's border regions. The conducted research allows us to formulate a number of important conclusions and practical recommendations, as well as identify promising directions for further research.

Critical analysis of existing Territorial Impact Assessment (TIA) tools revealed their fundamental limitations related to the predominantly static nature of assessment, orientation towards retrospective analysis, and insufficient consideration of complex systemic interactions in border regions. These limitations become particularly problematic in the context of the INTERREG NEXT budget reduction by 18.6% in the 2021-2027 period, which requires more strategic and efficient use of limited resources.

Our developed conceptual model of DyTIA offers a qualitatively new approach based on dynamical systems theory and integrating economic, social, environmental, and institutional dimensions of territorial development. Key features of this model are its focus on identifying feedback mechanisms, time lags, threshold effects, and network interactions, which allows for more adequately reflecting the complex dynamics of border regions.

Testing DyTIA on INTERREG V-A programme data and the Greater Region experience demonstrated the potential of this methodology for identifying complex chains of territorial effects, revealing "leverage points", and optimising resource allocation under budget constraints. Particularly valuable was the analysis of interaction between different thematic objectives, such as the mutually reinforcing effects between investments in environmental protection (TO 6) and sustainable economic development.

In the context of Ukraine's European integration and the formation of a new European security architecture, DyTIA acquires strategic significance as a public governance tool facilitating effective integration of Ukrainian border regions into the European space. It is fundamentally important to emphasise that in the post-conflict period, Ukraine's border regions will perform not only the traditional function of "contact zones" for economic and socio-cultural interaction but also a critically important role in forming a new security architecture on the EU's eastern borders. DyTIA provides tools for modelling complex interrelationships between socio-economic development, institutional integration, and security, which is especially valuable in conditions of hybrid threats and new challenges to territorial integrity.

For practical implementation of DyTIA in planning and evaluation processes of cross-border cooperation programmes and strengthening public governance effects, we recommend:

1) Integrating DyTIA components into strategic planning processes at national and regional levels in Ukraine, ensuring coherence between the Ukraine-EU Association Agreement, sectoral reforms within European integration, and territorial development of border regions. This will create an integrated vertical governance of European integration processes from the national to local level.

2) Developing the institutional capacity of EGTCs through specialised training programmes in systems thinking and dynamic modelling, which will enable these structures to more effectively use DyTIA for strategic planning and evaluation of cross-border projects. Special emphasis should be placed on training Ukrainian specialists in cross-border cooperation, thereby creating a personnel reserve for Ukraine's future integration into EU structures (following the model of the Border Studies master's programme created at the UniGR-Center for Border Studies).

3) Creating a network of "territorial development and security laboratories" along Ukraine's entire western border, integrated with similar structures in neighbouring EU member states. These laboratories should become not only centres for monitoring and analysing territorial processes but also platforms for developing innovative approaches to integrating development strategies and ensuring security in border regions.

4) Developing a specialised DyTIA module for modelling post-conflict recovery and reconstruction processes in Ukraine's eastern regions with the prospect of their subsequent integration into the European space. This module should take into account specific challenges related to demilitarisation, demining, restoration of destroyed infrastructure, and social reintegration.

5) Initiating the creation of a multilateral platform "Cross-border Cooperation for Security and Development" involving Ukraine, neighbouring EU member states, and European institutions under the aegis of the European Committee of the Regions. This platform should ensure coordination of recovery, development, and security programmes, using the DyTIA methodology as a common analytical tool for aligning priorities and assessing integrated effects.

In the context of Ukraine's European integration, the EGTC Tisza case acquires special significance as a pilot project for testing and adapting DyTIA to the specific conditions of post-conflict recovery and preparation for EU membership. The experience of this grouping can serve as a model for developing other EGTCs along Ukraine's western border, forming a "belt of European integration and security" with intensive cross-border cooperation.

Promising directions for further research include:

1) Developing specialised DyTIA modules for integrated assessment of security and development in Ukraine's border regions, with a special focus on the interconnections between economic reconstruction, social stability, and ensuring physical security of population and infrastructure.

2) Investigating the potential for integrating DyTIA with early warning and crisis response tools, which will increase the adaptability of territorial systems to external shocks and hybrid threats, especially in conditions of the ongoing transformation of European security architecture.

3) Studying the possibilities of applying DyTIA for modelling cross-border effects from implementing large-scale infrastructure projects within the "Ukraine Recovery" initiative (Ukraine Recovery Conference), with emphasis on their

contribution to forming new transport, energy, and digital corridors integrating Ukraine into the single European market.

4) Analysing the potential of DyTIA as a “preventive diplomacy” tool in border regions, contributing to identifying potential conflicts of interest at early stages and developing mechanisms for their prevention through strengthening cross-border ties and creating interdependencies.

5) Investigating the role of DyTIA in the context of “integration through integrators” – a strategy involving active engagement of Ukrainian territorial communities in cross-border coalitions with partners from EU member states to accelerate the transfer of European governance practices and institutional norms.

In conclusion, it should be noted that DyTIA represents not merely a new methodological tool but an element of a broader shift in approaches to territorial development of border regions and ensuring European security. In an era of systemic geopolitical changes, a dynamic understanding of territorial processes becomes a necessary condition for developing effective, sustainable, and inclusive strategies that contribute not only to economic and social integration but also to forming a new architecture of stability and security in Europe with Ukraine’s active participation.

REFERENCES

1. Böhme, K., & Lürer, C. (2016). Assessing territorial impacts of future EU policies. *Terra Spectra: Central European Journal of Spatial and Landscape Planning*, 8(1), 22–27.
2. Building More Resilient Cross-border Regions. (2024). Considerations in governance and partnerships. OECD Multi-level Governance Studies. OECD Publishing. Paris. DOI: <https://doi.org/10.1787/d5fd3e59-en>
3. Caesar, B. (2017). European Groupings of Territorial Cooperation: A means to harden spatially dispersed cooperation? *Regional Studies, Regional Science*, 4(1), 247–254.
4. Camagni, R. (2009). Territorial Impact Assessment for European regions: A methodological proposal and an application to EU transport policy. *Evaluation and Program Planning*, 32(4), 342–350.
5. Dąbrowski, M., Musiałkowska, I., & Polverari, L. (2018). EU-China and EU–Brazil policy transfer in regional policy. *Regional Studies*, 52(9), 1169–1180.
6. Dühr, S., Colomb, C., & Nadin, V. (2010). *European Spatial Planning and Territorial Cooperation*. London: Routledge.
7. Engl, A. (2016). Bridging borders through institution-building: The EGTC as a facilitator of institutional integration in cross-border regions. *Regional & Federal Studies*, 26(2), 143–169.
8. ESPON (2012). ARTS – Assessment of Regional and Territorial Sensitivity. Luxembourg: ESPON.
9. ESPON (2013). EATIA – ESPON and Territorial Impact Assessment. Luxembourg: ESPON.
10. European Commission (2017). Boosting Growth and Cohesion in EU Border Regions (COM (2017) 534 final). Brussels: European Commission.
11. European Commission (2021). EU Border Regions: Living labs of European integration (COM (2021) 393 final). Brussels: European Commission.
12. European Commission (2023). Guidance for resilience analysis. Brussels: European Commission.
13. European Court of Auditors (2021). Interreg cooperation: The potential of the European Union's cross-border regions has not yet been fully unlocked. Special report 14/2021. Luxembourg: European Court of Auditors.
14. European Spatial Development Perspective: Towards balanced and sustainable development of the territory of the European Union (1999). URL: <https://op.europa.eu/en/publication-detail/-/publication/a8abd557-e346-4531-a6ef-e81d3d95027f/language-en>
15. European Union (2007). Treaty of Lisbon amending the Treaty on European Union and the Treaty establishing the European Community. *Official Journal of the European Union*, C 306, 17.12.2007.
16. Faludi, A. (2010). Cohesion, Coherence, Cooperation: European Spatial Planning Coming of Age? London: Routledge.

17. Folke, C., Hahn, T., Olsson, P., & Norberg, J. (2005). Adaptive governance of social-ecological systems. *Annual Review of Environment and Resources*, 30, 441–473.
18. Gänzle, S., & Kern, K. (2016). A 'Macro-regional' Europe in the Making: Theoretical Approaches and Empirical Evidence. Basingstoke: Palgrave Macmillan.
19. Guidebook on registering EGTCs (2021). Report of the European Committee of the Regions.
20. Katok, A., Hasselblatt, B. (1999). Introduction to the Modern Theory of Dynamical Systems: Cambridge University Press.
21. Kiryukhin A. (2016). Stability of cross-border functional region in the context of counter integrations. Part I. Theoretical and historical aspects. *Regional Innovations*, no. 4, 51–62. URL: http://irn.center/2016_4_regional-innovations-journal-special-issue-has-been-issued/
22. Kolosov, V. et Scott, J. (2013). Selected conceptual issues in border studies. *Belgeo* N1 Modelling and benchmarking of borders. URL: <http://belgeo.revues.org/10532>
23. Martinelli, F. (2019). A Dynamic Theory of Regional Inequalities: Production, Capital Mobility and Trade. *Regional Studies*, 53(7), 977–990.
24. Medeiros, E. (2015). Territorial Impact Assessment and Cross-Border Cooperation. *Regional Studies, Regional Science*, 2(1), 97–115.
25. Medeiros, E. (2016). Territorial Cohesion: An EU concept. *European Journal of Spatial Development*, 60, 1–30.
26. Medeiros, E. (2017). From smart growth to European spatial planning: a new paradigm for EU cohesion policy post-2020. *European Planning Studies*, 25(10), 1856–1875.
27. Medeiros, E. (2018). The Role of European Territorial Cooperation (ETC) in EU Cohesion Policy. In E. Medeiros (Ed.), *European Territorial Cooperation* (pp. 69-93). Cham: Springer.
28. Medeiros E. (Ed.) (2020) *Territorial Impact Assessment*. DOI: <https://doi.org/10.1007/978-3-030-54502-4>
29. Mesarovic, M.D., Takahara Y. (1975). General Systems Theory: Mathematical Foundations. *Mathematic in science and engineering*. Vol. 113.
30. Perkmann, M. (2003). Cross-border regions in Europe: Significance and drivers of regional cross-border co-operation. *European Urban and Regional Studies*, 10(2), 153–171.
31. Regulation (EC) No 1082/2006 of the European Parliament and of the Council of 5 July 2006 on a European grouping of territorial cooperation (EGTC).
32. Regulation (EU) No 1302/2013 of the European Parliament and of the Council of 17 December 2013 amending Regulation (EC) No 1082/2006 on a European grouping of territorial cooperation (EGTC).
33. Senge, P. M. (1990). The fifth discipline: The art and practice of the learning organization. New York: Doubleday.
34. Sterman, J. D. (2000). Business dynamics: Systems thinking and modeling for a complex world. Boston: Irwin/McGraw-Hill.
35. Strengthening the Resilience of EU Border Regions. Mapping Risks & Crisis Management Tools and Identifying Gaps (2024). URL: <https://nordregio.org/research/strengthening-the-resilience-of-eu-border-regions-mapping-risks-crisis/>
36. Svensson, S., & Nordlund, C. (2015). The building blocks of a Euroregion: Novel metrics to measure cross-border integration. *Journal of European Integration*, 37(3), 371–389.
37. Telle, S. (2017). Euroregions as soft spaces: Between consolidation and transformation. *European Spatial Research and Policy*, 24(2), 93–110.
38. Telle, S., Špaček, M., & Crăciun, D. (2020). Divergent paths to cohesion: The (unintended) consequences of a place-based Cohesion Policy. In I. Musiałkowska, P. Idczak & O. Potluka (Eds.), *Successes & Failures in EU Cohesion Policy: An Introduction to EU cohesion policy in Eastern, Central, and Southern Europe*. 7–28. Warsaw/Berlin: De Gruyter Open.
39. Territorial Cohesion – The Story (2023). URL: <https://territorialagenda.eu/wp-content/uploads/Territorial-Cohesion-The-Story-draft-30-June-2023.pdf>
40. Unfried, M., Kersken, K., & Espeter, M. (2016). "Cross-border impact assessment" als Beispiel für grenzüberschreitende Zusammenarbeit im öffentlichen Sektor: Entstehung, Relevanz und Grenzen. *Der moderne Staat*, 9(1), 187–210.
41. Wille Ch. (2024). Border Complexities. Outlines and Perspectives of a Complexity Shift in Border Studies. In Christian Wille, Carolin Leutloff-Grandits, Falk Bretschneider, Syvie Grimm-Hamen, Hedwig Wagner (Eds.). *Border Complexities and Logics of Dis/Order. Nomos*. 31–55). DOI: <https://doi.org/10.5771/9783748922292>

The article was received by the editors 15.01.2025.

The article is recommended for printing 29.02.2025.

Кирюхін Олексій Михайлович,
к.г.н., запрошений дослідник,
Міждисциплінарний центр експертизи «UniGR-Центр прикордонних досліджень»,
Порт де Сьянс, L-4366 Еш-сюр-Альзетт, Люксембург
e-mail: kiryukhin.research@gmail.com <https://orcid.org/0009-0006-8797-1417>

Вілліє Крістіан,
керівник
Міждисциплінарного центру експертизи «UniGR-Центр прикордонних досліджень»,
Порт де Сьянс, L-4366 Еш-сюр-Альзетт, Люксембург
e-mail: christian.wille@uni.lu <https://orcid.org/0000-0002-5402-3860>

Ямпольський Данііл,
студент IT-спеціальності, Університет Люксембургу,
Порт де Сьянс, L-4366 Еш-сюр-Альзетт, Люксембург
e-mail: daniil.yampolskyi@liser.lu <https://orcid.org/0009-0007-8480-3941>

АНАЛІЗ ДИНАМІКИ ОЦІНКИ ТЕРИТОРІАЛЬНОГО ВПЛИВУ В ТРАНСКОРДОННИХ РЕГІОНАХ: ВИКЛИКИ ТА ПЕРСПЕКТИВИ НА МАЙБУТНЄ

Анотація. У статті представлено новий методологічний підхід до оцінки територіального впливу в прикордонних регіонах: Динамічна оцінка територіального впливу (DuTIA). Заснована на теорії динамічних систем, DuTIA пропонує основу для моделювання складних і взаємозалежних взаємозв'язків між економічними, соціальними, екологічними та інституційними аспектами територіального розвитку. На відміну від традиційних статичних методологій, DuTIA зосереджується на виявленні зворотних зв'язків, часових лагів, порогових ефектів та мережевих взаємодій, що дозволяє більш точно відобразити динамічну і часто нелінійну природу прикордонних регіонів. Методологія була протестована з використанням даних Європейської рахункової палати, що охоплюють 23 програми INTERREG V-A (2014-2020). Аналіз виявив значну неоднорідність у розподілі фінансування та тематичних пріоритетах у різних прикордонних регіонах. Зокрема, найбільша частка фінансування (23,2%) була спрямована на тематичну мету захисту навколишнього середовища та ресурсоефективності, що підкреслює зростаючу важливість сталого розвитку в рамках політики згуртування ЄС. Тематичне дослідження на основі програми «Великий регіон» продемонструвало здатність DuTIA виявляти складні територіальні ланцюжки впливу та підтримувати оптимізований розподіл ресурсів, особливо в умовах прогнозованого скорочення бюджету програми INTERREG NEXT на 18,6% на період 2021-2027 років. Особливо глибоким був аналіз взаємодій між різними тематичними цілями, який виявив синергетичні ефекти, що посилюють загальний територіальний вплив. Окрім своєї аналітичної корисності, DuTIA також виконує функцію стратегічного управління. У контексті європейської інтеграції України DuTIA набуває актуальності як політичний інструмент для підтримки включення українських прикордонних регіонів до європейського простору. ЄУТС «Тиса» розглядається як пілотний проект з адаптації DuTIA до специфічних викликів післявоєнного відновлення та підготовки до вступу в ЄС. На основі цих висновків у статті пропонуються практичні рекомендації щодо застосування DuTIA у процесах національного та регіонального стратегічного планування, зміцнення інституційної спроможності європейських об'єднань територіального співробітництва (ЄОТС) та створення мережі «лабораторій територіального розвитку та безпеки» вздовж західного кордону України. Особлива увага приділяється включенню безпекового виміру в оцінку територіального впливу у відповідь на нові геополітичні виклики. Зрештою, DuTIA є не лише методологічною інновацією, але й частиною ширшого переосмислення того, як концептуалізується і управляється територіальний розвиток у прикордонних регіонах. У час глибоких геополітичних змін динамічні моделі, такі як DuTIA, мають важливе значення для розробки ефективних, сталих та інклюзивних стратегій - стратегій, які сприяють інтеграції та стійкості, а також допомагають формувати більш стабільний та безпечний європейський простір, невід'ємним учасником якого є Україна.

Ключові слова: динамічна оцінка територіального впливу, транскордонне співробітництво, європейська інтеграція України, INTERREG, EGTC, теорія динамічних систем, територіальна згуртованість, постконфліктне відновлення.

Стаття надійшла до редакції 15.01.2025 р.

Стаття рекомендована до друку 29.02.2025 р.