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Research paper

IMPLEMENTATION PATHWAYS OF NATURE-BASED SOLUTIONS IN THE URBAN REGENERATION OF MULTIFAMILY HOUSING: A COMPARATIVE STUDY OF TURIN AND ZAGREB

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Abstract

This paper explores the application of Nature-based Solutions (NbS) in the urban regeneration of multifamily housing areas dating from the second half of the 20th century, shifting the focus from traditional energy-efficiency frameworks to holistic eco-social performance. While previous studies often focus on spatial scales of NbS, this research provides an original scientific contribution by evaluating and comparing the institutional, managerial, and socio-economic implementation pathways in Western European and post-socialist transition contexts. Using a qualitative comparative analysis of two contemporary case studies funded under EU Horizon frameworks – as exemplars of Mirafiori Sud (Turin, Italy) and Sesvete (Zagreb, Croatia), the paper examines how varying urban planning paradigms affect the deployment of blue-green infrastructure within urban regeneration of housing areas. Findings indicate that while Western European contexts benefit from stable public funding and institutionalized co-design processes that mitigate risks like green gentrification, post-socialist environments rely heavily on bottom-up community initiatives that face structural, legislative, and property-ownership constraints. The paper concludes with actionable recommendations for integrating NbS into the urban planning practice of Serbia, demonstrating that cross-border model adaptation is essential for building climate-resilient cities.

Key words: *urban regeneration, multifamily housing areas, nature-based solutions, Western European pathways, post-socialist pathways*

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1. INTRODUCTION

In the contemporary era of intense climate change and rapid urbanization, the regeneration of multifamily housing areas built during the post-WWII period has emerged as a critical priority for European urban policies [1, 2, 3]. In South-Eastern Europe, and specifically in Serbia, these inherited estates comprise nearly 80% of the total multifamily housing stock, currently facing severe physical degradation, uncontrolled densification, loss of public space identity, and compromised ecological comfort [4, 5].

Traditional regeneration schemes have historically focused on narrow technical solutions, such as structural retrofitting and thermal insulation of building facades. While these measures reduce energy consumption, they fail to address broader ecosystem-level challenges like the urban heat island effect, localized pluvial flooding, and social isolation. In this context, Nature-based Solutions (NbS) serve as an integrative umbrella concept that harmonizes ecological performance with community resilience [6, 7, 8, 9, 10, 11].

This paper advances the current discourse by comparing two distinct European implementation pathways of NbS within inherited multifamily housing areas: the Western European welfare-driven model (Mirafiori Sud, Turin, Italy) and the post-socialist transitional model (Sesvete, Zagreb, Croatia). By identifying the structural barriers and success factors of these pathways, the study delivers practical insights for local planning frameworks in transition economies.

2. METHODOLOGY AND THEORETICAL FRAMEWORK

This study employs a qualitative comparative case-study methodology, evaluating empirical data from the EU-funded *proGIreg* (Productive Green Infrastructure for Post-industrial Urban Regeneration) project [12]. The selection of the specific case studies, Mirafiori Sud in Turin and Sesvete in Zagreb, is scientifically justified by two main criteria: 1) their shared programmatic foundation within the same European framework, and 2) their contrasting planning cultures which represent distinct European socio-political paradigms. Structurally, both areas function as large-scale residential and post-industrial zones that exhibit morphological similarities to Serbian modernist multifamily housing estates, such as generous open public spaces that currently suffer from ecological underperformance and climate vulnerability.

However, a critical contextual distinction must be highlighted: while Mirafiori Sud reflects a planned expansion of industrial worker housing, the spatial configuration of Sesvete represents a post-socialist transitional phenomenon where market-driven densification brought the multifamily housing fabric into direct contact with degraded brownfields. Despite these divergent spatial geneses, both areas function as critical testing grounds for NbS. While Turin and Zagreb cannot capture the entire complexity of their respective macro-regions, they serve as illustrative examples of contrasting Western European and post-socialist planning contexts. Their selection reflects the intention to compare two case studies developed within the same EU-funded

framework and addressing similar urban regeneration challenges, while differing primarily in their institutional and planning contexts, thereby enabling a meaningful comparison of NbS implementation pathways.

The theoretical framework integrates ecosystem services with urban governance theories to analyze how spatial interventions translate into socio-ecological benefits [7, 8, 9, 10, 11, 13] . To systematically dissect the implementation pathways, the comparison evaluates three core analytical pillars:

- Institutional governance structures: Examining the degree of local government backing and formal policy integration.
- Community co-design involvement: Assessing how local citizens and civil society are engaged in the life-cycle of the NbS.
- Property-ownership dynamics: Evaluating how land-tenure fragmentation and transitional legislative frameworks impact spatial execution.

3. CASE STUDIES: NBS IMPLEMENTATION IN THE URBAN REGENERATION OF MULTIFAMILY HOUSING AREAS

To evaluate the empirical pathways of nature-based urban regeneration, this study analyzes two dynamic implementation models developed within the international *proGIreg* framework [12]. Executed between June 2018 and 2023 under the European Commission's Horizon 2020 programme, this research-driven initiative focused on developing self-sustaining and market-ready business and governance setups for NbS. Rather than treating blue-green infrastructure as isolated spatial elements, the project was anchored in an integrated co-design methodology that brought together local citizens, local governments, academic institutions, businesses, and non-governmental organizations. The following sub-sections examine how this standardized European methodology materialized under two contrasting socio-political planning environments: Turin and Zagreb.

3.1. Mirafiori Sud, Turin: Exemplifying the western European pathway

The implementation of NbS in Turin focused on the post-industrial residential district of Mirafiori Sud within the *proGIreg* initiative [12, 14, 15, 16] . This area, characterized by social housing estates and adjacent degraded industrial plots, suffered from the urban heat island effect, social vulnerability, and a lack of functional green infrastructure.

The regeneration strategy prioritized a highly structured, co-design approach involving local governments, research institutions, and citizens. On a structural level, the interventions included the installation of green walls on public school and residential buildings, which acted as thermal buffers and local climate regulators. Simultaneously, the project introduced innovative urban gardens on contaminated soils by applying safe, human-made technosols (Fig. 1).

From a governance perspective, Turin established a top-down institutional framework that legally integrated local citizen associations into the long-term management and maintenance of these spaces [14].



Figure 1. Mirafiori Sud. a) Co-design activities displaying five implemented proGIreg NbS in Turin Living Lab (RWTH); b) Community-based urban garden, Source: https://progireg.eu/turin/

Quantifiably, these NbS interventions resulted in a microclimate cooling effect, reducing local peak summer temperatures by up to 3.5 °C through enhanced evapotranspiration [16] . More importantly, the institutional model successfully prevented green gentrification by ensuring that the primary beneficiaries of the new green amenities remained the low-income residents of the existing public housing stock. The Turin experience therefore illustrates that the long-term success of NbS depends not only on the quality of the spatial interventions themselves, but also on the institutional capacity to ensure their long-term implementation and maintenance.

3.2. Sesvete, Zagreb: Exemplifying the post-socialist transitional pathway

Representing the post-socialist transitional context, the settlement of Sesvete in Zagreb served as a "front-runner" site within the same *proGIreg* framework [12, 17, 18, 19]. Sesvete possesses a spatial morphology shaped by a combination of mid-to-late 20th-century residential blocks, generous but unmaintained open spaces, and abandoned industrial complexes.

This morphological entanglement is not a product of deliberate socialist spatial synthesis, but rather a consequence of transitional planning collapse. Originally

established on the urban periphery in accordance with the CIAM principles of functional segregation, the 'Sljeme' meat-processing complex became landlocked inside a dense matrix of multifamily and individual housing blocks due to uncontrolled post-1990s residential sprawl.

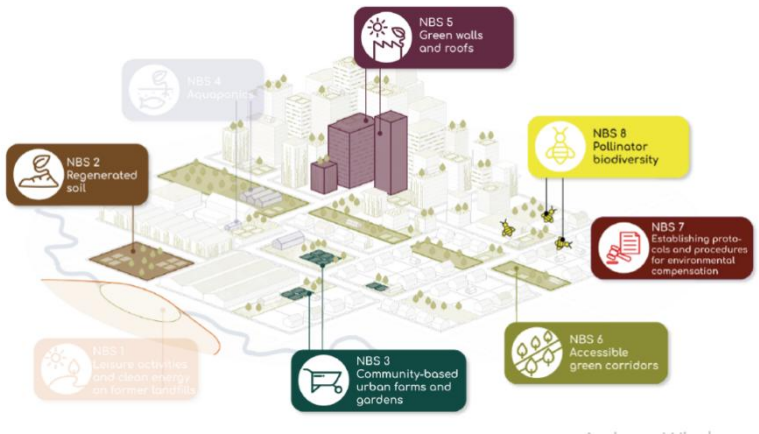






Figure 2. Sesvete. a) Co-design activities displaying four implemented proGIreg NbS in Zagreb Living Lab (RWTH), b) Green wall as a part of the modular urban farm; c) Urban gardens next to the former meat processing factory 'Sljeme', Source: https://progireg.eu/zagreb/

Unlike Turin's institutional approach, the driving force in Zagreb was bottom-up, led by local NGOs and civil society organizations that promoted the ecological transformation of the neighborhood. Physical interventions focused on utilizing unpaved open spaces through therapeutic gardens, restored water corridors, and urban micro-forests for storm-water management (Fig. 2).

The governance architecture in Zagreb faced significant friction due to the rigid administrative legacy of the post-socialist transition. The project encountered unresolved land-ownership disputes and a lack of flexible municipal protocols for co-managing public land with citizens. Despite these barriers, bottom-up initiatives stimulated a gradual adaptation of local planning tools. Environmentally, the interventions transformed paved surfaces into active green sinks, increasing local pluvial storm-water retention by more than 60% and demonstrating the potential of community-led green infrastructure.

4. RESULTS AND DISCUSSION

The key similarities and differences between the Turin and Zagreb case studies are synthesized in Table 1, providing a comparative overview of their governance structures, spatial characteristics, and ecological outcomes.

Table 1. Comparative Matrix of NbS Implementation Pathways

Analysis Criteria	Western European context: Mirafiori Sud,Turin	Post-Socialistc context: Sesvete, Zagreb
Socio-Political Context	Established planning system; mature welfare state; stable public-private-civic partnerships.	Post-socialist transition; fragmented institutional management; legacy bureaucratic inertia.
Origin of Spatial Entanglement	Deliberate capitalist synthesis: Planned expansion of social housing (FIAT) in close structural proximity to the industrial complex.	Transitional anomaly: Rigid socialist functional zoning encroached and "swallowed" by post-1990s unregulated residential sprawl.
Scale and Type of Urban Vacancy	Post-industrial brownfield undergoing continuous, state-led structural economic restructuring.	Landlocked industrial brownfield (Sljeme factory) trapped within an un-amenitied residential matrix.
Dominant Spatial Scale & NbS	Building and block scale; highly localized interventions (green walls, technosol urban gardens).	Neighborhood and district open spaces (therapeutic gardens, urban forestry, water corridors).
Governance Architecture	Institutionalized top-down support fully integrated with structured citizen co-design frameworks.	Bottom-up NGO-led initiatives (e.g., Zelene i plave Sesvete) driving gradual, reactive planning adaptation.
Primary Implementation Barrier	Long-term social equity management; preventing green gentrification and displacement.	Complex land-ownership disputes; legislative gaps; lack of municipal protocols for public-land co-management.
Key Ecological KPI	3.5 °C reduction in local peak summer temperatures via enhanced evapotranspiration.	60% increase in local pluvial storm-water retention capacity through unpaved zones.

The empirical evidence synthesized from Turin and Zagreb demonstrates that nature-based urban regeneration is fundamentally a socio-political and managerial challenge, rather than a purely technical one. While both front-runner sites successfully deployed blue-green infrastructure under the same European framework, their institutional pathways diverged significantly based on their legacy planning cultures.

4.1. Comparative analysis of governance pathways

The quantitative and qualitative indicators [14, 15, 16] show that the Turin case illustrates a Western European planning pathway characterized by institutional predictability, whereas the Zagreb case [17, 18, 19] reflects a post-socialist planning pathway operating within a more fragmented administrative and institutional landscape.

The systemic divergence between these two implementation pathways is deeply rooted in the historical genesis of their spatial and institutional configurations. In the case of Turin (Mirafiori Sud), the proximity of the industrial giant (FIAT) and social housing blocks was a product of deliberate, state-backed capitalist synthesis designed to optimize production and labor welfare. Consequently, when the deindustrialization phase arrived, the mature institutional planning machinery of Turin was structurally capable of orchestrating a top-down, continuous regeneration strategy. By embedding NbS into long-term municipal protocols and public-private-civic partnerships, the local government acted as the primary risk-mitigator. This top-down integration enabled stable citizen co-management agreements, ensuring that building- and block-scale interventions (such as green walls and technosol gardens) were systematically protected from real estate speculation and green gentrification.

Conversely, the post-socialist transitional model in Zagreb (Sesvete) demonstrates a reverse spatial logic. The landlocked presence of the 'Sljeme' industrial brownfield within a dense multifamily housing environment does not reflect intentional socialist mixed-use design, but rather a transitional phenomenon. Following the collapse of rigid socialist functional zoning in the 1990s, an institutional vacuum allowed unregulated, market-driven residential sprawl to encroach upon and eventually 'swallow' the industrial periphery. Operating within this fragmented administrative and legislative landscape, the local municipality lacked the flexible, formalized protocols required to co-manage public assets with citizens.

Thus, the entire operational burden of NbS deployment was shifted onto bottom-up civil society organizations (e.g., 'Zelene i plave Sesvete'). Consequently, the grassroots implementation of NbS in Sesvete functions as a reactive, ad-hoc remedial mechanism. Instead of unfolding within a continuous, state-backed urban strategy, these green interventions represent a civic reclamation of a brownfield vacancy trapped inside a residential zone by the institutional failures of the transition era. However, this institutional inertia inadvertently fostered high grassroots agility. Bottom-up initiatives proved capable of reclaiming and transforming large, unpaved urban vacancies at a neighborhood scale much faster than rigid bureaucratic structures, turning vulnerable, paved surfaces into active green sinks that increased local pluvial storm-water retention capacity by over 60%, even though their long-term legal security remains fragile.

4.2. Applicability to the Serbian planning paradigm

The structural realities of Serbian multifamily housing estates such as Novi Beograd, Liman in Novi Sad, or Bulevar Nemanjića in Niš, possess immense spatial capital due to their modernist, generously dimensioned open layouts [4,5,20]. However, domestic professional practice continues to operate within a narrow building-level energy-efficiency framework, focusing almost exclusively on partial facade thermal insulation measures [21].

The comparative analysis offers two critical directions for the Serbian paradigm:

The strategic value of public open spaces: Serbian estates' morphology is ideally suited for neighborhood-scale, unpaved ecosystem interventions similar to the Zagreb model. Reclaiming degraded public open spaces, parking lots or transit areas into active

green sinks and rain gardens represents a highly cost-effective way to boost local pluvial storm-water retention by up to 60%.

The institutional bottleneck: To prevent these interventions from falling into decay, Serbia cannot rely solely on the financial resources of fragmented housing communities. It requires the introduction of flexible municipal protocols—inspired by the Turin model—that legally and financially support co-management models between local authorities and residents. Crucially, this institutional shift should leverage recent domestic legislative tools, such as the amendments to the Serbian Law on Planning and Construction, which formally introduce the framework for 'Green Infrastructure'. Aligning local governments' protocols with these statutory mechanisms is essential for anchoring community-led initiatives within a stable, institutionalized framework.

This study has certain limitations that should be acknowledged. The analysis is based on two case studies developed within the same European project framework and therefore does not aim to generalize the findings to all Western European or post-socialist planning contexts. Rather, the selected cases illustrate contrasting implementation pathways that provide transferable insights for comparable urban environments. Future research could expand the comparative sample by including additional cities and quantitative performance indicators to further validate the identified governance patterns.

5. CONCLUSION AND RECOMMENDATIONS FOR THE SERBIAN PLANNING PRACTICE

The comparative analysis of Mirafiori Sud in Turin and Sesvete in Zagreb demonstrates that the successful urban regeneration of inherited multifamily housing areas through NbS is fundamentally a governance and legislative challenge, rather than a purely spatial or technical one [22]. While the Turin case highlights the benefits of institutionalized co-design and secure land-tenure frameworks, the Zagreb case illustrates how post-socialist transitional contexts rely heavily on vulnerable bottom-up community dynamics that must continuously navigate structural, administrative, and property-ownership constraints.

These findings offer highly actionable lessons for contemporary urban planning practice in Serbia, which shares a comparable post-socialist spatial and institutional legacy. To successfully integrate NbS into the regeneration of Serbian multifamily housing estates, three strategic recommendations are proposed:

- Institutionalization of co-design protocols: Serbian local governments must transition from purely formal public hearings to binding, long-term co-design frameworks, legally recognizing civil society organizations as legitimate partners in the co-management of public spaces to ensure the long-term spatial and economic viability of NbS.
- Addressing ownership and governance barriers: Planning instruments must develop flexible legal mechanisms that enable temporary or permanent ecological interventions within fragmented ownership

structures, overcoming barriers that commonly hinder regeneration efforts in post-socialist housing estates.

- Diversification of funding and policy integration: Future urban regeneration projects in Serbia must move away from ad hoc, project-dependent financing, explicitly integrating NbS into local strategic documents, capital investment plans, and urban planning regulations.

Ultimately, this study confirms that cross-border model adaptation is not a matter of copy-pasting technical blueprints, but of re-engineering local governance structures. For Serbian cities to become climate-resilient, the planning paradigm must evolve to support eco-social performance, ensuring that the regeneration of post-WWII multifamily neighborhoods directly empowers and protects the communities that inhabit them.

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