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Article

From Airfield Morphologies to Nature-Based Regeneration: A Proto-Ontological Framework for an AI-Assisted, Design-Oriented Analysis of Post-Airfield Projects

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Abstract

Decommissioned airfields are increasingly recognized as strategic sites for ecological regeneration, climate adaptation, and the creation of new public spaces. However, research on their transformation has predominantly focused on the environmental performance of Nature-based Solutions (NBS), often overlooking the role of inherited spatial morphology in structuring regeneration processes and outcomes. This paper proposes an AI-assisted, morphology-based proto-ontological framework for analyzing and designing post-airfield architecture. The framework was developed through the inductive and comparative analysis of a corpus of 32 urban post-airfield regeneration projects, from which recurrent inherited morphologies, transformation actions, spatial devices, and NBS were identified and structured into a relational sequence. The framework was then applied to two contrasting case studies: Maurice Rose Airfield Park (Frankfurt) and Xuhui Runway Park (Shanghai); these were selected for their different transformation logics. The results show that similar airfield morphologies can generate markedly different climatic, ecological, social, and memory-related outcomes depending on how they are transformed and linked to NBS. The study demonstrates that inherited airfield morphologies are not passive remnants but operative spatial structures, and that NBS should be understood as spatially embedded and form-generating design components. The proposed proto-ontology offers a transferable analytical model and a basis for future computational and generative design applications.

Keywords: post-airfield regeneration; climate-adaptive design; nature-based solutions landscape urbanism; ecological performance; cultural identity; infrastructural reuse



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1. Introduction

Over the last century, the rapid expansion of aviation has produced an extensive network of airports and airfields embedded within metropolitan regions, peri-urban fringes, and former military territories. As mobility systems, aeronautical technologies, and territorial economies have evolved, many of these facilities have become obsolete, underutilized, or fully decommissioned. In Europe alone, more than 750 airfields are estimated to be abandoned or awaiting transformation [1], with similar patterns observable across North America and parts of Asia. This condition has generated one of the largest stocks of dormant infrastructural landscapes in contemporary cities.

At the same time, urban territories are increasingly confronted with converging climatic, environmental, and social challenges, including rising temperatures, intensified rainfall and flooding, biodiversity loss, and growing demand for accessible and inclusive public space. Within this context, former airfields have gained strategic relevance. Their large scale, relative openness, and urban or peri-urban locations position them as critical sites for experimenting with ecological regeneration, climate adaptation and resilience [2], and new forms of urban commons [3]. As a result, post-airfield landscapes have become key testing grounds within landscape architecture, urban design and architecture.

In recent years, two major conceptual frameworks have shaped the discourse on such transformations. On the one hand, theoretical approaches such as Landscape Urbanism [4,5] and Ecological Urbanism [6,7] have reframed large infrastructural sites—including airfields—as dynamic territorial systems capable of supporting hydrological regeneration, habitat formation, and new forms of public life. On the other hand, Nature-Based Solutions (NBS) have emerged as a dominant paradigm in European and international policy and design for urban regeneration [8–10], including post-industrial landscapes [11,12], promoting the integration of ecological processes to improve environmental and climate resilience, social well-being and public space.

Despite this growing body of work, the regeneration of post-airfield landscapes remains both conceptually and operationally contested. Many projects oscillate between two contrasting tendencies. One approach seeks to erase or radically transform existing aeronautical infrastructures in favor of new ecological and climate-resilient landscapes, like in Phase Shifts Park, Taiwan [13]. A second approach prioritizes the preservation and reinterpretation of inherited forms, treating runways and other airfield spaces as carriers of collective memory and cultural heritage, like in the Tempelhof airfield process [14,15]. These divergent strategies reflect broader tensions between ecological transformation and the conservation of spatial and material legacies.

Existing research on nature-based urban regeneration of post-industrial landscapes has made significant contributions by evaluating the ecological performance, microclimatic benefits of NBS [16–19]. However, these studies tend to privilege performance-based metrics—such as temperature reduction, stormwater retention, or biodiversity indices—while paying limited attention to the role of spatial form. Consequently, the specific morphologies of airfields (e.g., runways as linear megastructures, aprons as horizontal plates, or perimeters as rigid boundaries) are frequently treated as passive background conditions, rather than as active agents shaping ecological processes, climatic behavior, and socio-spatial outcomes.

This paper argues that a more comprehensive understanding of post-airfield regeneration requires a shift in perspective, from evaluating what NBS achieve, to examining how they operate through the transformation of inherited airfield morphologies. By foregrounding spatial form, the study positions morphology as a mediating structure linking ecological processes, climate adaptation, social use, and memory. In doing so, it proposes a relational approach that bridges design, environmental performance, and cultural continuity.

To address this gap, the study develops a morphology-based analytical framework derived from an inductive and comparative analysis of approximately 32 international post-airfield regeneration projects. Through an iterative process, recurrent inherited morphologies, transformation actions, spatial devices, and NBS are identified and structured into a relational sequence. This structure is conceived as a proto-spatial ontology, enabling a systematic interpretation of how spatial transformations generate climatic, ecological, social, and cultural outcomes.

The framework is then applied to two contrasting case studies: Maurice Rose Airfield Park (Frankfurt, 2004) and Xuhui Runway Park (Shanghai, 2020); selected for their comple-

mentary transformation logics. While the former emphasizes preservation and ecological reinterpretation of existing airfield structures, the latter foregrounds extensive spatial reconfiguration through climate-responsive design. This comparison allows the methodology to be tested across diverse design conditions and to evaluate its transferability.

The main aim of the paper is therefore to provide a transferable analytical methodology that links inherited spatial form, transformation processes, Nature-Based Solutions, and multidimensional outcomes.

By integrating morphology-based analysis, comparative reasoning, and AI-assisted interpretation within a low-code workflow, the study also opens pathways toward future computational and generative design applications in the regeneration of post-airfields.

2. Literature Review: Post-Airfields as New Commons

Research on the transformation of decommissioned and underused airfields has expanded significantly in recent years, reflecting broader debates on ecological regeneration, climate adaptation, infrastructural reuse, and the production of new public landscapes. Foundational frameworks such as the European Landscape Convention have emphasized the role of residual and transformed landscapes in supporting sustainable development, ecological connectivity, and cultural identity [20]. Within this perspective, former airfields cannot be understood simply as obsolete technical grounds, but as spatial reserves whose large scale, openness, and infrastructural traces can be reactivated through landscape design.

Among the most relevant contributions to this field, Favargiotti's work, particularly *The Airfield Manual*, provides a design-oriented framework for the transformation of former airfields, focusing on soil regeneration, hydrological systems, vegetation strategies, and the reinterpretation of aeronautical infrastructures as active components of landscape projects [21]. This approach is particularly important because it shifts attention from land reuse as functional replacement to transformation as a spatial and ecological process. In parallel, recent scholarship has framed post-airfield landscapes as fragile socio-ecological systems, where abandonment and infrastructural obsolescence reveal latent ecological and spatial potentials rather than merely conditions of decline [22]. This interpretation aligns with the European Commission's framework on Nature-Based Solutions, which has positioned ecological processes, water management, climate mitigation, and social well-being as integrated objectives of contemporary spatial design [23].

These approaches are closely connected to theoretical perspectives developed within Landscape Urbanism and Ecological Urbanism. Waldheim's field-based understanding of urbanism [24] and Corner's process-oriented design methodologies [25] have been fundamental in interpreting large infrastructural terrains as dynamic, ecological, and performative systems rather than as residual voids. Girot's research on airport topographies further reinforces this view by describing airfields as "landscape reserves" capable of supporting new hydrological, ecological, and territorial structures [26]. Cipriani's notion of "Airport Urbanism" expands the discussion by showing how airport territories generate complex urban–natural hybrids, in which runways, buffer zones, landscape interfaces, and mobility infrastructures can become the basis for new spatial configurations [27].

Within this conceptual background, studies on post-airfield regeneration have increasingly emphasized resilience, biodiversity, and adaptive management. Wang et al. highlight the role of urban green infrastructure as a bridge between biodiversity conservation and sustainable development, stressing the need for adaptive approaches to govern these evolving landscapes [28]. Design manuals such as *The Airfield Manual* by Favargiotti and Yang further translate these principles into operational strategies, including soil renaturalization, vegetation systems, hydrological interventions, and spatial transformations specifically tailored to airfield morphologies [29]. At a broader territorial scale,

policy-oriented frameworks on airport infrastructure development have underlined the need for long-term planning models capable of addressing the persistent spatial footprints produced by transport infrastructures beyond their operational life cycle [30].

Current experimental applications confirm that post-airfields are increasingly treated as design laboratories where climatic, ecological, social, and cultural dimensions are intertwined through Nature-Based Solutions [31–33]. Phase Shift Park in Taichung exemplifies a climate-adaptive approach based on cooling stations, vegetative filtration, hydrological systems, and differentiated microclimatic zones [34]. Tempelhofer Feld in Berlin offers a different model, where the extensive runway surface, grassland restoration, public participation, and heritage interpretation coexist within a politically and socially contested open landscape [35,36]. Other cases, including Downsview Park in Toronto, Northerly Island in Chicago, and several former airfields across Europe and Asia, demonstrate recurrent strategies of ecological reconnection, diversification of native vegetation, and reinterpretation of aeronautical heritage as a civic and cultural asset [37–39]. Contemporary research further emphasizes airports as hybrid testing grounds for climate adaptation and nature-based infrastructure, where ecological performance and social accessibility are co-produced through integrated design systems [40].

At the same time, computational and data-driven approaches are beginning to influence the analysis and design of large-scale infrastructural transformations. AI-assisted and model-based methodologies are increasingly explored to support ecological simulation, spatial classification, morphological interpretation, and decision-making in complex territorial contexts [41]. These tools are relevant for post-airfield regeneration because they can support the organization of heterogeneous sources, the comparison of spatial patterns, and the construction of structured analytical vocabularies. However, their usefulness depends on their integration within a design-oriented methodology: AI can support classification and consistency checking, but it cannot replace expert interpretation of spatial form, historical continuity, and projective design logic.

Across this literature, a shared understanding emerges: former airfields are not only technical remnants of aviation infrastructures, but potential “new commons,” where public accessibility, ecological restoration, collective memory, and social inclusivity can intersect [3,4,42]. Recent studies on sustainable urban renewal, including transit-oriented development frameworks, similarly show how large infrastructures can act as catalysts for spatial and environmental transformation, often supported by GIS-based and AI-driven analytical tools [43]. Although these approaches focus primarily on mobility, density, and accessibility, they also implicitly confirm the structuring role of spatial configurations in shaping environmental and social outcomes.

Identification of Research Gap

Despite these contributions, four critical gaps remain in current research on post-airfield regeneration.

- First, morphological analysis remains underrepresented. Former airfields are characterized by a specific spatial grammar—runways, taxiways, aprons, drainage systems, perimeters, and open infields—yet these inherited forms are often treated as background conditions rather than as operative spatial structures. This limits the understanding of how airfield morphologies actively shape ecological processes, climatic behavior, public use, and cultural continuity.
- Second, Nature-Based Solutions are still predominantly interpreted through performance-based indicators. Metrics such as temperature reduction, stormwater retention, biodiversity enhancement, and carbon sequestration are essential, but they do not fully explain how NBS operate spatially. In post-airfield landscapes, NBS are not simply

environmental components added to a site; they become form-generating design elements whose effects depend on the inherited morphologies they transform.

- Third, climate adaptation, ecological restoration, social accessibility, and cultural memory are often addressed as separate dimensions. However, post-airfield regeneration shows that these dimensions are spatially interdependent. A preserved runway may function simultaneously as a memory device, a public promenade, a thermal surface, or an ecological edge, depending on the actions and NBS associated with it. Existing research still lacks an integrated framework capable of reading these dimensions together.
- Fourth, transferable analytical methodologies remain limited. Many studies rely on individual project narratives or descriptive case analyses, making it difficult to compare how different post-airfield projects transform inherited forms into spatial devices, NBS configurations, and multidimensional outcomes. What is missing is a shared analytical vocabulary capable of linking inherited morphology, transformation action, spatial device, Nature-Based Solution, and spatial outcome across multiple cases.

In response to these gaps, this paper proposes a morphology-based and proto-ontological framework for the design-oriented analysis of post-airfield regeneration. Rather than evaluating only what NBS achieve in environmental terms, the study examines how they operate through the transformation of inherited airfield morphologies. The framework therefore links inherited morphology, spatial action, spatial device, Nature-Based Solution, and spatial outcome, providing a structured method to connect ecological performance, spatial form, public use, and cultural continuity. In doing so, it also establishes a basis for future AI-assisted analytical workflows and, potentially, generative design applications in the regeneration of post-airfield landscapes.

3. Materials and Methods

This research adopts a morphology-based and comparative methodology to investigate how decommissioned airfields are transformed into climate-adaptive, ecologically performative, and socially inclusive landscapes through Nature-Based Solutions (NBS), while addressing the preservation and reinterpretation of aeronautical memory.

Rather than evaluating NBS through conventional performance metrics, the methodology assumes that airfields' spatial form is not a passive background condition, but an active structure shaping ecological processes, climatic behavior, and patterns of public use. In this sense, airfield morphologies are understood as operative spatial structures that mediate the integration of ecological processes, climate adaptation strategies, and socio-spatial dynamics. The approach combines inductive analysis, cross-case comparison, spatial analysis, and AI-assisted interpretation within transferable workflow. This methodological configuration allows the integration of qualitative design knowledge with structured analytical procedures, enabling both interpretative depth and reproducibility across heterogeneous case studies.

The research is structured into two phases. Phase I consists of developing the proto-ontological analytical framework through the inductive comparison of the 32-project corpus. In Phase II, the framework is then applied through two selected case studies. (Figure 1).

3.1. Phase I: Structuring the Proto-Ontological Framework

The construction of the proto-ontological framework is based on an inductive and comparative methodological process aimed at identifying, abstracting, and organizing recurrent spatial patterns in post-airfield regeneration projects. Rather than relying on predefined categories, the framework emerges progressively from the analysis of the 32-project corpus. The process translates heterogeneous empirical material—including aerial imagery, project

documentation, plans, photographs, and descriptive texts—into a structured set of analytical categories and relationships. Through cross-case comparison and iterative refinement, the methodology identifies transformation logics linking inherited airfield morphologies, spatial actions, spatial devices, Nature-Based Solutions, and spatial outcomes.

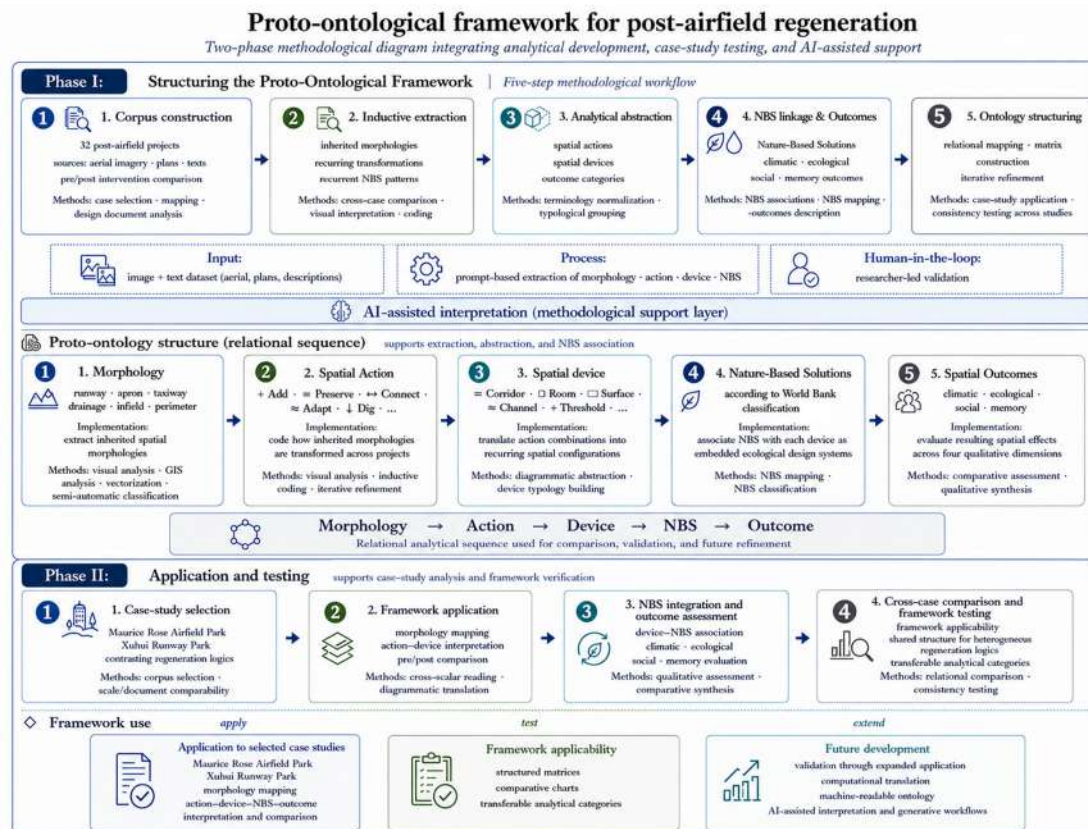


Figure 1. Proto-ontological framework for post-airfield regeneration (credit: A. Raffa, M. Moscatelli).

Phase I unfolds through five interconnected methodological steps (Figure 2): (i) corpus construction; (ii) inductive extraction of spatial patterns; (iii) analytical abstraction into spatial actions and spatial devices; (iv) association with Nature-Based Solutions and outcome definition; and (v) proto-ontological structuring. Together, these steps establish a reproducible workflow that supports both the interpretation of individual projects and comparison across multiple cases.

A central output of Phase I is the construction of a morphology-based vocabulary composed of the recurrent analytical terms used to describe post-airfield transformations: inherited morphologies, spatial actions, and spatial devices. This vocabulary provides the basic language of the framework, allowing heterogeneous projects to be compared through shared categories. However, the vocabulary is only one component of the framework. The framework emerges when these categories are organized into a relational sequence and connected to Nature-Based Solutions and spatial outcomes. For this reason, the 32-project corpus is not intended to provide a complete project-by-project assessment of NBS implementation or spatial outcomes. Its role is to ground the vocabulary and relational structure of the framework in a broad comparative sample.

To improve clarity and reproducibility, the key terms used in the analytical framework are summarized in Table 1.

The glossary provides a concise reference for the vocabulary used throughout the study and clarifies the role of each term within the relational sequence. These terms do not describe isolated design elements, but different levels of the same analytical process:

inherited spatial condition, transformation actions, resulting spatial devices, nature-based integration, and spatial outcome.

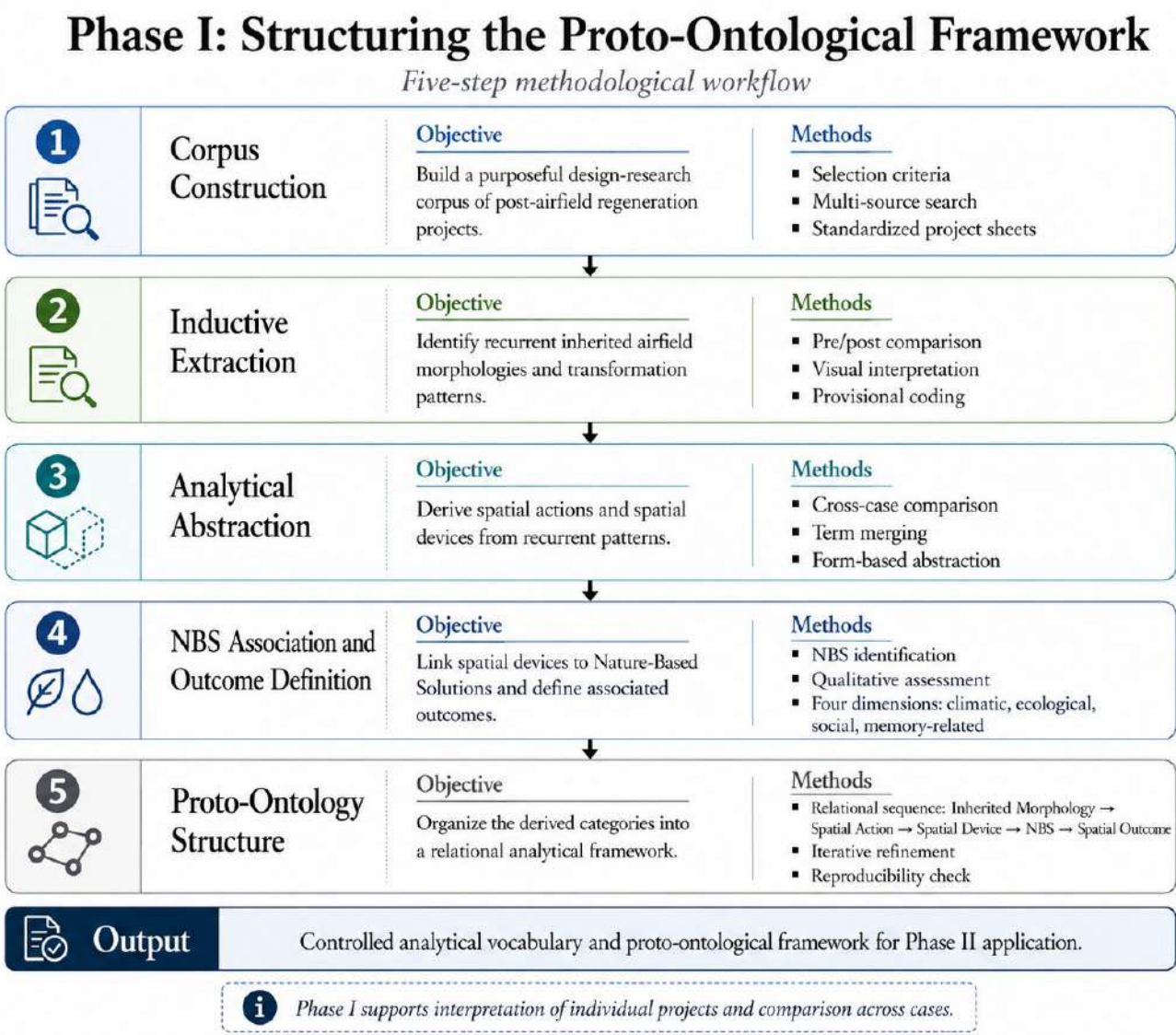


Figure 2. Phase I: Five-step methodological workflow (credit: A. Raffa, M. Moscatelli).

Table 1. Glossary of key terms used in the analytical framework.

Term	Definition	Role in the Analytical Sequence
Inherited morphology	The pre-existing spatial structure inherited from the former airfield, such as runways, taxiways, aprons, drainage systems, perimeters, open infields, etc.	Defines the starting spatial condition of the analysis.
Spatial action	The transformation operation applied to an inherited morphology, such as preserve, fragment, subtract, connect, soften, reveal, reinterpret, or densify.	Describes how the inherited morphology is modified.
Spatial device	The resulting spatial configuration produced by one or more spatial actions, such as corridor, hybrid surface, threshold, field, edge, channel, room, or gradient.	Describes the spatial form through which the transformation becomes operative.

Table 1. *Cont.*

Term	Definition	Role in the Analytical Sequence
Nature-Based Solution (NBS)	The Nature-Based components embedded within a spatial device are borrowed from [44].	Explains how Nature-Based Solutions are spatially integrated.
Spatial outcome	The effect generated by the relation between morphology, action, device, and NBS, assessed across climatic, ecological, social, and memory-related dimensions.	Describes what the spatial transformation produces in environmental and socio-cultural terms.
Proto-ontology	A structured but not yet fully machine-readable relational model that organizes the links between inherited morphologies, spatial actions, spatial devices, NBS, and outcomes.	Provides the overall framework for comparing projects and supporting future computational development.

3.1.1. Corpus Construction

The first step consisted of constructing a corpus of post-airfield regeneration projects. Cases were selected according to five criteria: (i) projects at design or implementation stage; (ii) location in urban or peri-urban contexts; (iii) prioritization of green open-space transformation; (iv) development by professional design firms; and (v) realization or design within the last three decades. Based on these criteria, a corpus of 32 case studies was identified (Table 2).

Projects were identified through a multi-source search process. The sources consulted included professional landscape architecture and architecture office websites; competition and masterplan documents; project databases and design platforms such as Landezine, ArchDaily, and Dezeen; academic publications on airport landscape regeneration; reports and public documents produced by local authorities; Google Earth historical imagery; OpenStreetMap; and, where available, GIS or aerial mapping platforms. Documentation was retained only when it allowed the reconstruction of at least the basic pre- and post-intervention spatial condition of each project.

For each project, the authors compiled a project sheet including: former airport or airfield name, park or regeneration project name, location, former airfield type, approximate airfield and park area, decommissioning date where available, project completion or design date, design office, available aerial imagery, project plans or masterplans, published descriptions, photographs, and relevant secondary literature. The same template was used across the corpus to ensure comparability and reduce inconsistencies between heterogeneous cases.

The corpus was constructed as a purposeful design-research corpus aimed at capturing documented and relevant examples of post-airfield transformation across different geographical contexts, scales, and design approaches, with particular attention to the relationship between inherited airfield morphologies and landscape regeneration strategies.

3.1.2. Inductive Extraction

The second step consisted of extracting recurrent spatial patterns through cross-case comparison, visual interpretation, and coding. The analysis began with the systematic observation of pre-intervention conditions, through which recurrent inherited airfield morphologies were identified. These included runways as linear megastructures, taxiways as branching networks, aprons as horizontal plates, drainage systems as latent hydrological structures, perimeters as hard boundaries, and open infields as extensive low-vegetation fields. These elements formed the spatial baseline of the analysis.

Table 2. The 32 selected case studies arranged in ascending order of park area (credit: A. Raffa, M. Moscatelli).

No.	Airport Name	Airport Area (Ha) (App.)	Park Name	Park Area (Ha) (App.)	Location	Typology	Decommission Date	Completion Date	Studio
1	Maurice Rose Airfield	7.7	Maurice Rose Airfield Park	7.7	Frankfurt a. M-Bonames	Military	1992	2004	GTL landschaftsarchitektur
2	Longhua Airport	14	Xuhui Runway Park	10	Shanghai	Civil	2013	2019	Sasaki
3	Oslo International Airport	340	Nansen Park	20	Bærum, Oslo	Civil	1998	2008	Bjørbeek & Lindheim
4	Johannisthal/Adlershof Airfield	26	Landscape Park Johan-nisthal/Adlershof	26	Berlin	Military	1952	2010	Büro Kiefer
5	Crissy Field Airfield	40.5	Crissy Field	40.5	San Francisco	Military	1974	2001	Hargreaves Associates
6	Meigs Field Airport	48	Meigs Field Park	48	Chicago	Civil	2003	2015	Studio Gang and SmithGroupJJR
7	Vicenza Airport	120	Peace Park	65	Vicenza, Italy	Civil	2008	2024	PAN Associati + Estudi Martí Franch
8	Taichung Shuinan Airport	250	Phase Shift Park	70	Taichung, Taiwan	Civil	2004	2020	Mosbach Paysagistes + Philippe Rahm architects, Ricky Liu & Associates
9	La Carlota Airport	103	Parque Metropolitano la Carlota *	103	Caracas	Military		2012 comp.	Enlace Arquitectura
10	Mariscal Sucre International Airport	125	Parque Bicentenario	125	Quito	Civil	2013	2016	Ernesto Bilbao + Robert A. Sproull
11	Malmi Airport		Airport Park	140	Helsinki	Civil		2020 comp	Maanlumo
12	Downsview Airport	150	Downsview Park	147	Toronto	Military	2024	2025–ongoing	Henning Larsen
13	Munich-Riem Airport	500	Munich Riem Landscape Park	210	Munich	Civil	1992	2025	Latitude Nord
14	Tegel Airport	500	Tegeler Landscape Park *	210	Berlin	Civil	2020	2019	Weidinger Landschaftsarchitekten
15	Hellinikon Airport	620	Hellinikon Metropolitan Park	243	Athens	Civil	2001	2021–ongoing	Sasaki

Table 2. Cont.

No.	Airport Name	Airport Area (Ha) (App.)	Park Name	Park Area (Ha) (App.)	Location	Typology	Decommission Date	Completion Date	Studio
16	Oldenburg Air Base	300	Peninsula Park *	300	Oldenburg	Military	1994	2022	Dumpelmann + Waldheim
17	Tempelhof Airport	386	Tempelhof Field *	320	Berlin	Civil	2008	2010 comp.	Gross Max
18									Topotek 1
19								2025 comp.	Some Place Studio + FWD Landscape Architecture
20									bbz landschaftsarchitekten
21									De Zwarte Hond + Grieger Harzer Dvorak L.
22									Franz Reschke L.
23									Schönherr
24									Raumlabor+Klaus Overmeyer
25	Floyd Bennet Field	526	Floyd Bennet AirField *	526	New York	Military	1970	2007 comp.	Ashley Scott Kelly + Rikako Wakabayashi
26									North Design Office
27									Virginia Polytechnic
28									Archipelago
29									Christopher Marcinkoski, Andrew Moddrell
30									Frank Gesualdi, Hayley Eber
31	Marine Corps Air Station El Toro	1900	Orange County Great Park	545	Irvine, Los Angeles	Military	1999	2011–ongoing	Studio MLA
32	King Salman Air Base	5700	King Salman Park	1660	Riyadh	Military	2020	ongoing	Gerber Architekten

* Projects at a design stage.

The cross-case comparison followed the same sequence for each project. First, the pre-intervention airfield layout was examined to identify inherited morphologies. Second, the post-intervention condition was compared with the former airfield condition to determine how each element had been preserved, modified, removed, fragmented, reinterpreted, or ecologically transformed. Third, these transformations were described through provisional spatial actions and devices. Fourth, recurring actions and devices were compared across the corpus, merged when redundant, and refined into a controlled analytical vocabulary.

The spatial patterns were not predefined. They emerged through repeated comparison across the corpus. Not every pattern observed in individual projects was included in the final framework. Patterns were retained only when they met the following criteria: recurrence across multiple projects; clear relation to inherited airfield morphology; capacity to describe a transferable transformation process; and usefulness in linking spatial form, design operation, NBS integration, and outcomes. Highly site-specific features, isolated design solutions, or elements not directly connected to airfield morphology were excluded from the core framework, although they were retained in the individual project notes.

The resulting categories therefore emerged from an iterative process of observation, comparison, coding, consolidation, and verification. This procedure allowed the framework to remain grounded in empirical project analysis while avoiding an excessive proliferation of isolated or non-transferable terms.

3.1.3. Analytical Abstraction

The extracted patterns were abstracted into two linked analytical categories: spatial actions and spatial devices. This step is explicitly form-based and design-oriented. The study does not separate design analysis from the analysis of form; rather, it examines how inherited airfield forms are transformed through specific design operations and how these operations generate recognizable spatial configurations.

For each project, the authors identified inherited airfield morphologies in the pre-intervention condition—such as runways, taxiways, aprons, drainage systems, perimeters, and open infields—and compared them with the post-intervention configuration. The aim was to understand how each inherited morphology had been maintained, altered, removed, fragmented, reconnected, ecologically transformed, or reinterpreted.

These transformations were initially described through provisional action verbs. Through repeated comparison across the 32 projects, similar verbs were merged, overly specific terms were eliminated, and recurring operations were consolidated into a controlled vocabulary of spatial actions. These actions describe transferable modes through which inherited airfield morphologies are modified in post-airfield regeneration processes.

The analysis does not treat resulting forms as isolated design outcomes. Instead, it interprets them as relational spatial configurations produced by the transformation of inherited airfield morphologies. These recurring configurations are conceptualized as spatial devices: form-based design structures through which spatial actions become legible, operative, and connected to Nature-Based Solutions and spatial outcomes. This approach adapts previous research on climate-adaptive, nature-based streetscape regeneration to the specific open-space morphologies of former airfields [44,45].

The association between spatial actions and spatial devices is grounded in an analytical–synthetic understanding of design, in which complex spatial systems are interpreted through processes of decomposition and recomposition [46,47]. Decomposition refers to the analytical disaggregation of post-airfield regeneration projects into morphologies, actions, and devices in order to reveal their spatial logic. Recomposition refers to the interpretation of these elements as part of an integrated design system linking inherited forms, transformation operations, spatial configurations, NBS, and outcomes.

Spatial actions are intentionally formulated as elementary design operations. Their specificity in this study does not derive from the terms in isolation, but from their application to the morphological condition of former airfields. For example, “fragment” becomes specific when it describes the breaking of runway or apron surfaces; “preserve” when it refers to the maintenance of runway continuity, aeronautical geometry, or infrastructural legibility; “soften” when it concerns the transformation of rigid airport perimeters into permeable ecological or public edges; and “reveal” when it concerns latent drainage systems, buried infrastructures, or residual aeronautical traces.

The relationship between spatial actions and spatial devices is not one-to-one. The same action may generate different devices depending on the inherited morphology to which it is applied and on the spatial role that the transformed element assumes within the regenerated landscape. Devices were therefore assigned through a combined reading of three criteria: the geometry and material condition of the inherited morphology; the transformation action applied to it; and the resulting spatial role of the element after intervention.

For example, “preserve” may generate a corridor when applied to a linear runway that continues to organize movement, ecological continuity, or visual orientation; a surface when applied to an apron that remains legible as an extensive horizontal plane; an edge when applied to a perimeter that continues to structure boundary or transition conditions; or a field when applied to an open infield that remains as a broad ecological or flexible public space. Similarly, “fragment” may generate a hybrid surface when applied to impervious runway or apron pavements, but a threshold or gradient when applied to boundary conditions or transitional zones.

Operational distinctions were also used to reduce overlap between terms. “Remove” indicates the elimination of an element; “subtract” refers to the selective extraction of portions of a morphology; and “reduce” indicates a decrease in scale, extension, or intensity while retaining partial legibility. Similarly, “connect” refers to establishing continuity between elements or systems, whereas “open” refers to increasing accessibility or permeability by weakening or removing barriers.

This clarification avoids treating spatial actions as deterministic categories. Spatial actions describe the mode of transformation, while spatial devices describe the spatial configuration resulting from the interaction between inherited morphology, transformation action, and post-intervention role. The assignment of devices was therefore based on observable spatial evidence, including geometry, continuity, material configuration, accessibility, ecological function, and relation to surrounding spaces.

3.1.4. NBS Association and Outcomes Definition

In a subsequent step, spatial devices were linked to Nature-Based Solutions. The analysis asked three questions: which NBS components are embedded in the device; how they modify or activate the inherited airfield morphology; and which spatial outcomes they generate.

Within this framework, NBS are understood not merely as environmental interventions, but as operative design components [48] that contribute to the spatial articulation of each device. The study does not introduce an autonomous NBS taxonomy, since the classification of Nature-Based Solutions follows the categories and terminology of A Catalogue of Nature-Based Solutions for Urban Resilience [49]. This choice was made to avoid duplicating an already established classification system and to ensure comparability with existing international frameworks. Within the present methodology, however, these NBS categories are not treated as isolated environmental measures. They are systematically associated with the spatial devices identified through the morphology-based analysis. In

this way, each NBS category is interpreted according to the spatial configuration through which it becomes operative. For example, vegetation-based solutions may function differently when embedded in a runway corridor, a softened perimeter, a reconfigured apron, or a hydrological channel. The analytical focus is therefore not the creation of a new NBS classification, but the relational linkage between spatial actions, devices and outcome.

Each NBS was then evaluated in relation to associated outcomes across four dimensions. Climatic outcomes refer to shading, cooling potential, surface permeability, stormwater retention, and microclimatic improvement. Ecological outcomes refer to habitat creation, biodiversity support, vegetation succession, soil regeneration, and ecological connectivity. Social outcomes refer to accessibility, public use, flexibility, movement, informal activity, and inclusivity. Memory-related outcomes refer to the preservation, reinterpretation, or perceptual legibility of aeronautical traces.

The evaluation does not claim to provide instrumental measurement of environmental performance. Instead, it provides a structured qualitative assessment based on spatial evidence, project documentation, aerial imagery, visual interpretation, and the relationship between morphology, spatial action, device, NBS, and outcome. The purpose is therefore not to measure NBS performance quantitatively, but to explain how NBS become spatially embedded within inherited airfield morphologies.

While the 32-project corpus informs the identification of recurrent spatial devices and actions, the systematic association between actions, devices, NBS, and outcomes is developed in detail in the two selected case studies. This methodological choice reflects the different role of the corpus and the case study analysis: the former supports category generation, while the latter tests the complete relational framework.

3.1.5. Proto-Ontology Structure and Iterative Refinement

The final step consisted of organizing the analytical categories into a relational framework. The categories—*inherited morphologies*, *spatial actions*, *spatial devices*, *Nature-Based Solutions*, and *spatial outcomes*—were not predefined, but emerged through iterative comparison, testing, and refinement across the corpus. Through this process, relationships between spatial conditions, transformation processes, ecological strategies, and outcomes were structured into the sequence: *Inherited Morphology* → *Spatial Action* → *Spatial Device* → *Nature-Based Solution* → *Spatial Outcome*.

For each project, the authors recorded the relationship between five elements: the inherited airfield morphology, the spatial action applied to it, the spatial device generated by this action, the NBS associated with the device, and the spatial outcomes produced. This procedure made it possible to move from individual project descriptions to comparable analytical units. Each unit was treated not as an isolated design feature, but as a relationship between form, operation, configuration, ecological strategy, and outcome.

These relationships were then compared across the 32-project corpus to identify recurring combinations. For instance, the sequence *runway* → *preserve/reinterpret* → *corridor* → *meadow or ecological corridor* → *memory continuity and ecological connectivity* was identified in projects where the linear continuity of the former runway remained legible and became part of the regenerated landscape structure. Similarly, the sequence *apron* → *fragment/subtract* → *hybrid surface* → *permeable surface and spontaneous vegetation* → *soil regeneration and flexible public use* was identified where impervious surfaces were broken, partially retained, and ecologically transformed.

The term “proto-ontology” is used because the framework organizes entities and relationships in a structured and repeatable way, but does not yet constitute a fully formalized machine-readable ontology. Its function in this paper is analytical: to make the relationships between morphology, transformation, NBS, and outcomes explicit, comparable, and poten-

tially extensible. The framework remains grounded in qualitative spatial interpretation and cross-case comparison, while remaining compatible with future computational applications, including knowledge graphs and AI-assisted generative design systems [50,51].

The iterative refinement of the proto-ontology followed three criteria. First, each category had to be traceable to observable spatial evidence, such as aerial imagery, project drawings, published descriptions, or photographic documentation. Second, each relationship had to be transferable across more than one case, avoiding categories based only on exceptional or isolated design solutions. Third, the sequence had to clarify how inherited airfield morphologies were transformed into operative spatial configurations through which NBS could produce climatic, ecological, social, or memory-related outcomes. Categories that were too generic, redundant, or not clearly connected to airfield morphology were merged, reformulated, or excluded from the core framework.

In this sense, the proto-ontology does not simply classify design elements. It reconstructs the operational chain through which inherited airfield forms are transformed: how a morphology becomes an action field, how an action produces a spatial device, how the device embeds NBS, and how these configurations generate spatial outcomes. This makes the framework reproducible because another researcher can follow the same sequence—morphology, action, device, NBS, outcome—to analyze additional post-airfield projects and compare them with the corpus examined in this study.

3.1.6. Diagrams as an Analytical-Synthetic Tool

Diagrams were used as analytical-synthetic tools to translate the results of the spatial analysis into comparable visual representations. Their role was not merely illustrative. They made visible the relationships between inherited morphologies, spatial actions, spatial devices, Nature-Based Solutions, and outcomes.

The diagramming process followed a consistent four-step procedure. First, the pre-intervention morphology of each selected site was reconstructed through aerial imagery, historical satellite views, available project documentation, and published plans. This step identified the inherited airfield elements that structured the original spatial condition, including runways, taxiways, aprons, open infields, drainage systems, and perimeters. Second, the post-intervention configuration was overlaid onto the former airfield structure to identify which elements persisted, which were removed, which were fragmented, and which were reconfigured or ecologically transformed. Third, the resulting spatial configurations were coded according to the vocabulary of spatial devices developed through the cross-case comparison. Fourth, the diagrams were simplified into comparable graphic abstractions, using a consistent visual logic across the analyzed cases.

The diagrams were produced through visual tracing, comparative overlay, categorical coding, and graphic abstraction. They did not aim to reproduce the full material or experiential complexity of each project, but to isolate the spatial relationships most relevant to the framework. For example, a preserved runway could be diagrammed as a corridor when it continued to organize movement, ecological continuity, or visual orientation; fragmented concrete surfaces could be diagrammed as hybrid surfaces when they combined residual hardscape, vegetation, permeability, and informal use; softened airport boundaries could be diagrammed as edges or thresholds when they mediated between the former airfield and its surrounding urban or ecological context.

The purpose of diagramming was primarily comparative. By reducing each project to a controlled set of spatial relationships, the diagrams allowed the authors to compare how similar inherited morphologies generated different devices and outcomes depending on the transformation actions and NBS applied. In this study, diagrams should therefore be understood as part of the working process rather than as final representational outputs

only. They contributed to testing the coherence of the categories, clarifying the relationship between actions and devices, and verifying whether the same analytical vocabulary could be applied across different post-airfield regeneration projects.

Through this role, diagramming strengthened the reproducibility of the method. Another researcher could follow the same procedure—tracing the inherited morphology, overlaying the transformed condition, coding the resulting devices, and relating them to NBS and outcomes—to analyze additional cases within the same framework.

3.2. Phase II: Application and Testing of the Proto-Ontological Framework

Phase II applies the proto-ontological framework developed in Phase I to two selected case studies in order to test its interpretative capacity, internal consistency, and transferability across different post-airfield regeneration strategies. While Phase I constructs the proto-ontological framework from the 32-project corpus, Phase II examines how this framework operates in detailed case study analysis.

From the broader corpus, two cases were selected: Maurice Rose Airfield Park in Frankfurt and Xuhui Runway Park in Shanghai. They were chosen because they are comparable in scale and documentation availability but differ in transformation logic. Maurice Rose Airfield Park is primarily based on preservation, minimal intervention, and ecological succession, while Xuhui Runway Park is based on reconfiguration, hybridization, and climate-responsive redesign. This contrast makes it possible to test the framework across different design approaches.

The application followed the same relational sequence developed in Phase I: Inherited Morphology → Spatial Action → Spatial Device → Nature-Based Solution → Spatial Outcome. For each case, the analysis was conducted through four steps (Figure 3): (i) pre-intervention conditions were examined to identify inherited airfield morphologies, such as runways, taxiways, aprons, drainage systems, perimeters, and open infields; (ii) post-intervention configurations were compared with the former airfield layout to identify the spatial actions applied to these morphologies and the spatial devices generated by them; (iii) each device was associated with embedded Nature-Based Solutions; and (iv) the resulting configurations were evaluated qualitatively across climatic, ecological, social, and memory-related outcomes.

The analysis was supported by multi-temporal aerial imagery, project documentation, photographs, plans, and, where available, GIS-based interpretation. These materials allowed the authors to verify the persistence, transformation, or removal of inherited morphologies and to assess how NBS were spatially integrated into the regenerated landscape. The same procedure was applied to both cases to ensure comparability.

Through this process, Phase II tests the framework not as a predictive or quantitative evaluation model, but as a reproducible design-oriented analytical system. Its purpose is to clarify how inherited airfield morphologies are transformed into spatial devices, how these devices embed NBS, and how different transformation strategies produce distinct climatic, ecological, social, and memory-related outcomes.

3.3. AI-Assisted Data Classification, Analytical Archiving, and Comparative Workflow

The research integrated an AI-assisted workflow as a support layer for analytical archiving, data classification, cross-case comparison, and relational structuring. This integration is connected to the broader objective of translating qualitative design knowledge into structured semantic systems compatible with spatial ontology and semantic-network approaches [52,53], and responds to the increasing use of AI-assisted methods for pattern extraction, semantic organization, and comparative analysis in design and urban research [54–56]. AI was not used as an autonomous source of evidence or as a substitute

for expert spatial interpretation. Its role was limited to supporting the organization, classification, comparison, and consistency checking of curated project data according to the analytical sequence.

Phase II: Application and Testing of the Proto-Ontological Framework

Four-step methodological workflow

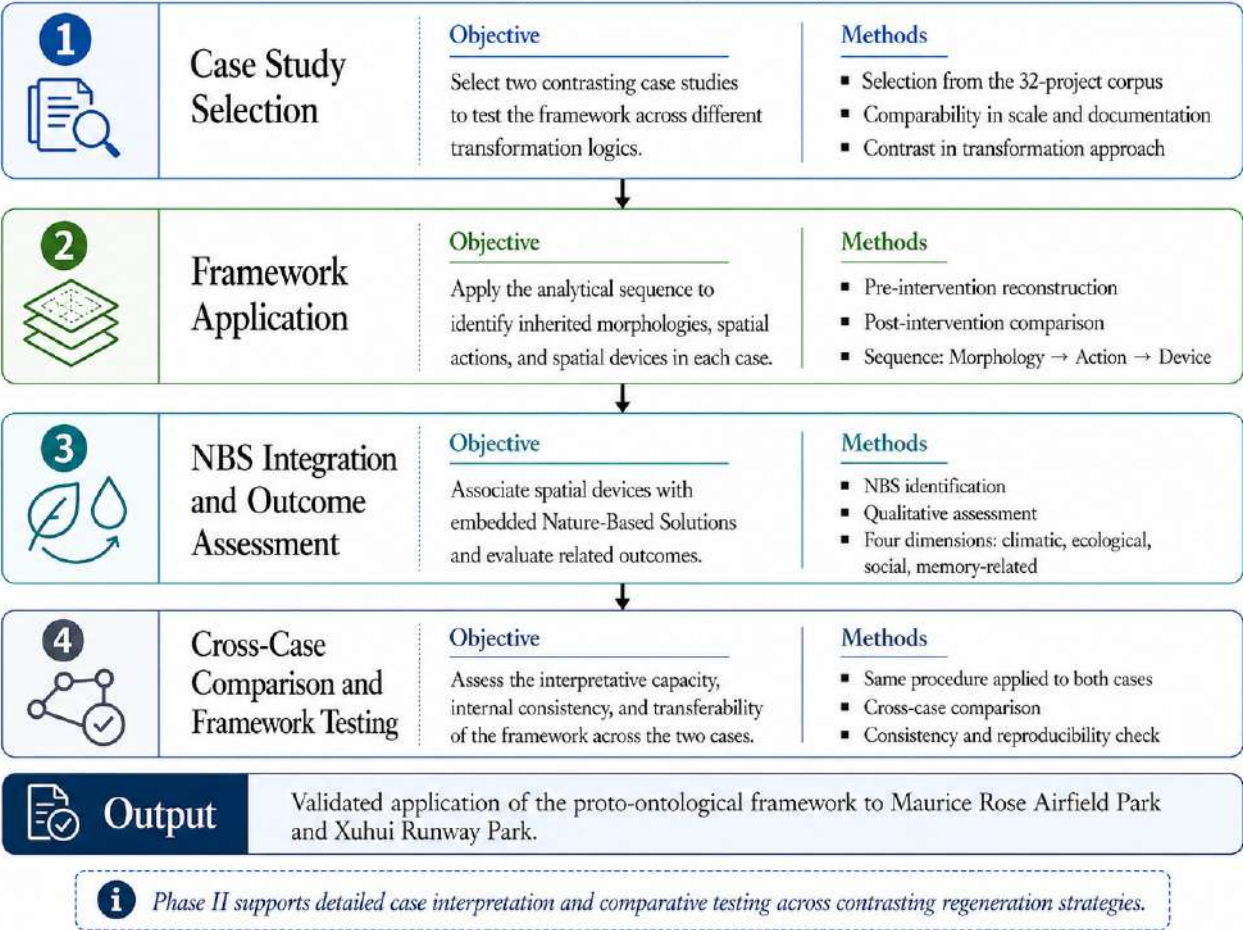


Figure 3. Phase II: Four-step methodological workflow (credit: A. Raffa, M. Moscatelli).

The workflow used a large language model (LLM) through a prompt-based interface [57]. No model was trained or fine-tuned for this research, and no automated web scraping was performed. The AI techniques used included prompt engineering, text-based information extraction, semantic classification, table-based coding, vocabulary normalization, consistency checking, and, in Phase II only, visual-recognition support for the two in-depth case studies. The model was used only after the authors had selected the projects, collected the documentation, and reorganized the material into comparable analytical records. The relevant input data were therefore not training data in the machine learning sense, but curated project materials provided by the authors for classification, comparison, and consistency checking.

In Phase I, AI supported analytical archiving, text-based classification, cross-case comparison, and vocabulary normalization across the 32-project corpus. The authors first collected documentation from professional design-office websites, municipal and planning documents, published descriptions, academic sources, project databases, aerial imagery, maps, and photographic material. AI was not used to select projects or collect sources. The material was then reorganized into comparable project sheets, each including basic project

data, available visual documentation, textual descriptions, observed inherited morphologies, transformation processes, NBS components, and visible or reported outcomes. These project sheets functioned as analytical archival units: heterogeneous documentation was curated, segmented, and transformed into a structured research archive.

The curated textual material and researcher-produced notes were processed through controlled prompts. The model was instructed to work only on the provided material, avoid unsupported external information, separate observations from interpretations, and organize outputs in comparable tables. For each project, prompts asked the model to identify candidate elements within the five categories of the framework: inherited morphology, spatial action, spatial device, NBS, and spatial outcome. The model supported text-based information extraction by identifying relevant entities and relationships, such as runways, taxiways, aprons, perimeters, drainage systems, open infields, permeable surfaces, wetlands, ecological corridors, and other recurring components described in the documentation.

The model also supported semantic classification by sorting extracted information into the analytical categories of the framework. The same prompt structure was repeated across the corpus to classify: (i) inherited airfield morphology; (ii) transformation action; (iii) spatial device; (iv) associated NBS; and (v) climatic, ecological, social, or memory-related outcome. Outputs were organized through table-based coding, allowing projects to be compared according to the same morphology–action–device–NBS–outcome sequence.

All Phase I AI-assisted outputs were checked through a human-in-the-loop validation process [58]. They were verified against available evidence, including aerial imagery, project plans, diagrams, photographs, published project descriptions, and design-office documentation. AI-generated outputs were treated as provisional classifications and were corrected, merged, rejected, or reformulated when they were unsupported, redundant, over-generalized, inconsistent with spatial evidence, or not directly related to inherited airfield morphology. In ambiguous cases, direct spatial evidence and disciplinary judgment prevailed.

The validated Phase I outputs were then used for vocabulary normalization and cross-case comparison [59]. Similar terms were merged, overlapping terms were differentiated according to their spatial effect, and recurrent categories were consolidated into a controlled analytical vocabulary. Categories were retained only when they were traceable to spatial or documentary evidence, recurrent across more than one project, and useful for explaining morphology–action–device–NBS relationships. The resulting categories were therefore derived inductively from the 32-project corpus rather than defined a priori. They were finally organized into the relational sequence [60]. AI supported this phase through consistency checking, but the proto-ontological structure was produced through the authors' interpretation, combining AI-assisted classification with manual visual analysis, diagrammatic reasoning, cross-case comparison, and design-oriented judgment.

In Phase II, the proto-ontological framework developed in Phase I was applied to Maurice Rose Airfield Park and Xuhui Runway Park [61]. AI was used in a more limited and case-specific way: to support terminology consistency, verify that the case study descriptions followed the same analytical sequence, and assist visual-recognition support for the two selected projects only. Visual material—including aerial imagery, project plans, diagrams, and photographs—was used to identify visible inherited morphologies, spatial devices, NBS components, and post-intervention configurations. When supported by the multimodal interface, the LLM assisted the recognition of visual elements such as runways, taxiways, aprons, fragmented pavements, permeable surfaces, planted areas, tree canopies, wetlands, ecological corridors, and water-management devices. These outputs were used

only as candidate observations and were verified against manual visual-spatial analysis and project documentation.

This Phase II visual-recognition support was particularly useful for identifying NBS embedded within spatial devices, such as vegetated surfaces, meadow systems, wetland areas, tree-lined corridors, permeable pavements, and water retention systems. The process did not involve training or fine-tuning the model. Rather, it supported the calibration and consistency of the analytical vocabulary when applying the framework to the two selected cases. Final recognition, classification, and interpretation remained author-led.

The workflow can be considered low-code in the limited sense that it relied on prompt-based interaction, structured tables, and manual validation rather than custom model training or automated computational pipelines. However, its reproducibility depends primarily on input curation, consistent prompts, documented coding categories, and human-in-the-loop verification.

To improve transparency, reliability, and reproducibility, four control principles were adopted throughout both phases: input curation before AI processing; consistent prompt structure across comparable tasks; human verification of every AI-assisted output; and inclusion only of categories supported by spatial or documentary evidence. The contribution of AI was therefore archival, classificatory, visual-supportive, and relational rather than generative in a strict sense. It helped transform dispersed project documentation into a structured research archive, supported the classification of heterogeneous evidence into a shared analytical vocabulary, assisted the comparison of recurring relationships across the corpus, and helped verify the visual-spatial reading of NBS in the two case studies. However, AI did not replace design interpretation, determine the final categories, evaluate the case studies autonomously, or train a model for future automatic recognition. The epistemic basis of the study remained design-oriented, visual, comparative, and interpretative.

4. Results

The results are organized according to the two-phase structure of the research. Section 4.1 presents the results of Phase I, namely the analytical vocabulary derived from the inductive comparison of the 32-project corpus. This section synthesizes the recurrent spatial actions and spatial devices identified across the corpus and formalized as the controlled vocabulary of the framework. Section 4.2 presents the results of Phase II, in which the framework is applied to two selected case studies—Maurice Rose Airfield Park and Xuhui Runway Park—to test the interpretative capacity of the proto-ontological sequence. The Results section therefore moves from framework construction to framework application: first showing what was derived from the broader corpus, and then demonstrating how it operates in detailed case study analysis.

4.1. Phase I: Spatial Action and Devices from the 32-Project Corpus

The first result of the research is the construction of a controlled analytical vocabulary derived from the inductive comparison of the 32-project corpus. As clarified in the Methodology section, the corpus was not used as a background repository of examples, but as the empirical basis from which the framework was developed. Through the repeated comparison of pre- and post-intervention conditions, recurring inherited morphologies, transformation processes, NBS strategies, and outcome dimensions were identified, coded, compared, and progressively refined. In this sense, the analysis of the 32 projects constitutes Phase I of the research, while the two selected case studies constitute Phase II, where the framework is applied and tested in greater detail. Tables 3 and 4 present the main outputs of Phase I.

Table 3. Airfield regeneration spatial actions with definitions (credit: A. Raffa).

Spatial Action	Symbol	Definition
Adapt	≈	To modify an existing morphology through limited and context-sensitive interventions, enabling new functions while maintaining its overall structure.
Add	+	To introduce new spatial, ecological, or programmatic elements that were not previously present in the airfield structure.
Collect	∪	To gather and retain flows, materials, or ecological processes within a defined spatial configuration.
Connect	↔	To establish physical, ecological, or visual continuity between previously separated areas, systems, or elements.
Cross	⊥	To create transversal connections that intersect existing morphologies, enabling movement and permeability.
Delimit	□	To define or structure spatial boundaries or edges through physical or vegetative means.
Densify	•	To increase the intensity or layering of spatial, ecological, or programmatic elements within a given area.
Diffuse	~	To disperse interventions or ecological systems across a broader area, reducing concentration.
Dig	↓	To excavate or lower ground levels in order to create new topographic or hydrological conditions.
Dissolve	~	To eliminate or blur rigid boundaries, enabling spatial continuity and integration.
Enrich	*	To enhance an existing morphology through ecological or material interventions that increase diversity and performance.
Fragment	☐	To break a continuous morphology into smaller or discontinuous elements.
Hide	⊘	To conceal or reduce the visibility of elements through spatial or vegetative strategies.
Look	☉	To direct visual attention toward specific spatial elements through framing, alignment, or orientation, structuring visual relationships within the landscape.
Open	---→	To increase accessibility, porosity, or visual permeability within an existing spatial structure, without necessarily creating new connections.
Preserve	=	To maintain the geometry, materiality, or spatial continuity of an existing morphology with minimal alteration.
Redirect	↷	To reroute flows or systems toward new spatial or environmental configurations.
Reduce	—	To decrease the intensity, scale, density, or dominance of an existing element, system, or surface while keeping part of it in place.
Remove	×	To entirely eliminate an existing element or surface.
Reshape	↗	To alter the form or geometry of a morphology to generate new spatial configurations.
Reuse	↻	To repurpose existing materials or spatial traces within a new design logic.
Reveal	⊙	To expose previously hidden or latent spatial or infrastructural elements.
Reinterpret	↔	To transform the meaning or function of a morphology while retaining references to its original structure.
Separate		To distinguish or divide spatial elements or systems, enabling independent operation.
Shade	☐	To introduce cover or screening elements that provide protection from solar exposure.

Table 3. *Cont.*

Spatial Action	Symbol	Definition
Soften	≈	To reduce the rigidity of edges or surfaces, typically through vegetation or permeable materials.
Stay	•	To retain an existing element in place with minimal or no transformation.
Subtract	⊖	To operate through selective cutting or withdrawal of material to reveal latent spatial, ecological, or historical conditions.

Table 4. Airfield regeneration spatial devices with definitions (credit: A. Raffa).

Spatial Device	Symbol	Definition
Barrier		A linear or volumetric element that restricts movement, visibility, or ecological flows, often used to separate or protect areas.
Channel	≈≈	A linear spatial device, often excavated, designed to convey water, ecological flows, or movement across the site.
Corridor	=	A continuous linear space that organizes movement, ecological connectivity, or climatic flows across the landscape.
Cover	—	A horizontal or overhead element providing protection, shading, or shelter, influencing microclimatic conditions and user comfort.
Diaphragm	▤	A semi-permeable vertical or layered element that filters, mediates, or regulates flows (visual, ecological, or climatic) between adjacent spaces.
Edge	—	A transitional spatial condition marking the boundary between different zones, systems, or environments.
Field	□	A large, continuous, and relatively undifferentiated open space supporting ecological processes and flexible uses.
Gradient	▤	A spatial condition defined by gradual variation in material, density, or ecological performance, enabling transitions rather than discrete separations.
Grid	#	A regulating spatial structure that organizes surfaces, flows, and interventions through repetition and modularity.
Hybrid Surface	▤	A composite surface combining impermeable and permeable materials, enabling both ecological processes and human use.
Path	---	A linear circulation device facilitating movement across the site, often associated with accessibility and slow mobility.
Platform	—	An elevated or leveled horizontal plane that organizes access, supports activities, and mediates between different topographic or programmatic conditions.
Room	□	A defined spatial enclosure supporting specific ecological functions, programs, or microclimatic conditions.
Surface	□	A horizontal plane that supports activities, ecological processes, or material transformations.
Threshold	┌ ┐	A transitional space mediating between different spatial conditions, such as park/city, open/enclosed, or natural/constructed systems.
Volume	■	A three-dimensional spatial entity introduced or retained within the site, comprising built forms or dense vegetative masses that structure space, define enclosure, and influence environmental and perceptual conditions.

Table 3 synthesizes the recurrent spatial actions identified across the corpus, understood as the transformation operations applied to inherited airfield morphologies.

Table 4 synthesizes the recurrent spatial devices, understood as the spatial configurations generated by those actions and through which NBS become embedded within the regenerated landscape. These categories were not defined a priori; they emerged through an iterative process of observation, comparison, coding, consolidation, and verification across the corpus.

The spatial actions listed in Table 3 are intentionally formulated as elementary design operations, because they describe transferable modes of spatial transformation. Their specificity in this study derives from their application to former airfield morphologies such as runways, taxiways, aprons, drainage systems, perimeters, and open infields. For example, “fragment” becomes specific to post-airfield regeneration when it describes the breaking of runway or apron surfaces; “preserve” becomes specific when it refers to the maintenance of runway continuity or aeronautical legibility; and “soften” becomes specific when it concerns the transformation of rigid airport perimeters into permeable ecological or public edges.

The spatial devices listed in Table 4 represent the formal and operational configurations through which these actions become legible in the regenerated landscape. They are not independent typologies, but relational outcomes of a morphology–action process. For instance, a preserved runway may become a corridor when it continues to organize movement, ecological continuity, or visual orientation; a fragmented apron may become a hybrid surface when residual concrete, vegetation, permeability, and informal use coexist; and a softened perimeter may become an edge or threshold when it mediates between the former airfield and its urban or ecological surroundings.

Together, Tables 3 and 4 establish the vocabulary used in the following case study analyses. They allow the framework to move from descriptive narratives of individual projects toward a structured comparison of how inherited airfield morphologies are transformed into spatial devices, associated with NBS, and connected to climatic, ecological, social, and memory-related outcomes. The subsequent sections apply this vocabulary to Maurice Rose Airfield Park and Xuhui Runway Park in order to test the interpretative capacity and transferability of the proto-ontological sequence.

4.2. Phase II Results: Case Study Analysis and Comparison

The two selected case studies, despite being similar in scale, represent contrasting approaches and spatial strategies to post-airfield transformation, allowing the framework to be tested across diverse design conditions. Maurice Rose Airfield Park emphasizes the preservation and reinterpretation of inherited airfield morphology, while the latter foregrounds ecological transformation and climate-responsive design through extensive spatial reconfiguration. The following sections apply the three steps of the morphology-based and ontology-driven analytical structure to each case, examining how inherited morphologies are transformed through spatial actions, translated into spatial devices, and associated with Nature-Based Solutions and their related outcomes.

4.2.1. Case Study I: Maurice Rose Airfield Park (Frankfurt, 2004)

Maurice Rose Airfield Park, designed by GTL Landschaftsarchitektur and located in Frankfurt-Bonames, represents an early and emblematic example of post-airfield regeneration characterized by a strategy of selective preservation and ecological reinterpretation. Rather than erasing the existing infrastructural condition, the project maintains key elements of the former military airfield, allowing them to structure the new landscape (Figure 4).

- (1) **Inherited Morphologies.** The pre-intervention condition is defined by a clear set of airfield morphologies, including a linear runway, residual aprons, taxiways, and

extensive open infields. These elements are embedded within a largely flat and engineered topography, with minimal vegetation and strong spatial legibility. The site is further characterized by rigid boundaries and a latent hydrological system, largely concealed within the technical infrastructure of the airfield.

- (2) Transformation Processes: Actions and Spatial Devices. The transformation strategy is based on a limited number of precise spatial actions, including preservation, subtraction, and ecological enrichment. Rather than fragmenting the site, the project reinforces its existing spatial logic.



Figure 4. Satellite image comparison of the Maurice Rose Airfield Park, Frankfurt (credit: Google Earth 2026): (a) pre-intervention 2002; (b) post-intervention 2024.

- The runway is preserved as a linear corridor, maintaining its continuity and orientation while being ecologically enriched through vegetation and spontaneous succession (Figure 5).



Figure 5. The preserved runway has been transformed into a space for informal activities (credit: reproduced with permission from GTL Landschaftsarchitektur; photo: Kai Spurling).

- Impervious surfaces such as aprons and taxiways are selectively removed or fragmented, generating hybrid surfaces that combine remnants of concrete with permeable and vegetated areas (Figures 6 and 7).
- Open infields are adapted through minimal intervention, supporting grassland development and low-intensity ecological processes.
- The drainage system is reshaped, becoming a network of water spaces which contribute to create new ecosystems, improving the park's biodiversity and experience (Figure 8).
- The perimeter is softened, transforming rigid boundaries into permeable edges that reconnect the site with its surroundings.

These transformations generate a set of spatial devices—corridors, surfaces, fields, and thresholds (Figure 9)—that structure both ecological processes and patterns of use.



Figure 6. The airfield's impervious surfaces are broken up and gradually undergo spontaneous naturalization (credit: reproduced with permission from GTL Landschaftsarchitektur; photo: Werner Rose).

- (3) **Nature-Based Solutions and Spatial Integration.** Within this project, Nature-Based Solutions are embedded within the spatial devices rather than applied as separate layers. The main NBS strategies include:
- Semi-spontaneous re-naturalization processes;
 - Grassland, meadow and wetland ecosystems;
 - Ecological corridors along the runway;
 - Permeable surfaces enabling soil regeneration;
 - Edge vegetation and hedgerows.

These interventions operate at relatively low intensity, relying on ecological succession and minimal maintenance rather than engineered systems.



Figure 7. Broken fragments of the former airfield's impervious surfaces guide visitors through the evolving landscape, fostering diverse microhabitats and experiences (credit: reproduced with permission from GTL Landschaftsarchitektur; photo: Kai Spurling).



Figure 8. A flooded area connected to the new wetland system, where remnants of impervious surfaces become part of emerging ecosystems (credit: reproduced with permission from GTL Landschaftsarchitektur; photo: Ines Wodrich).

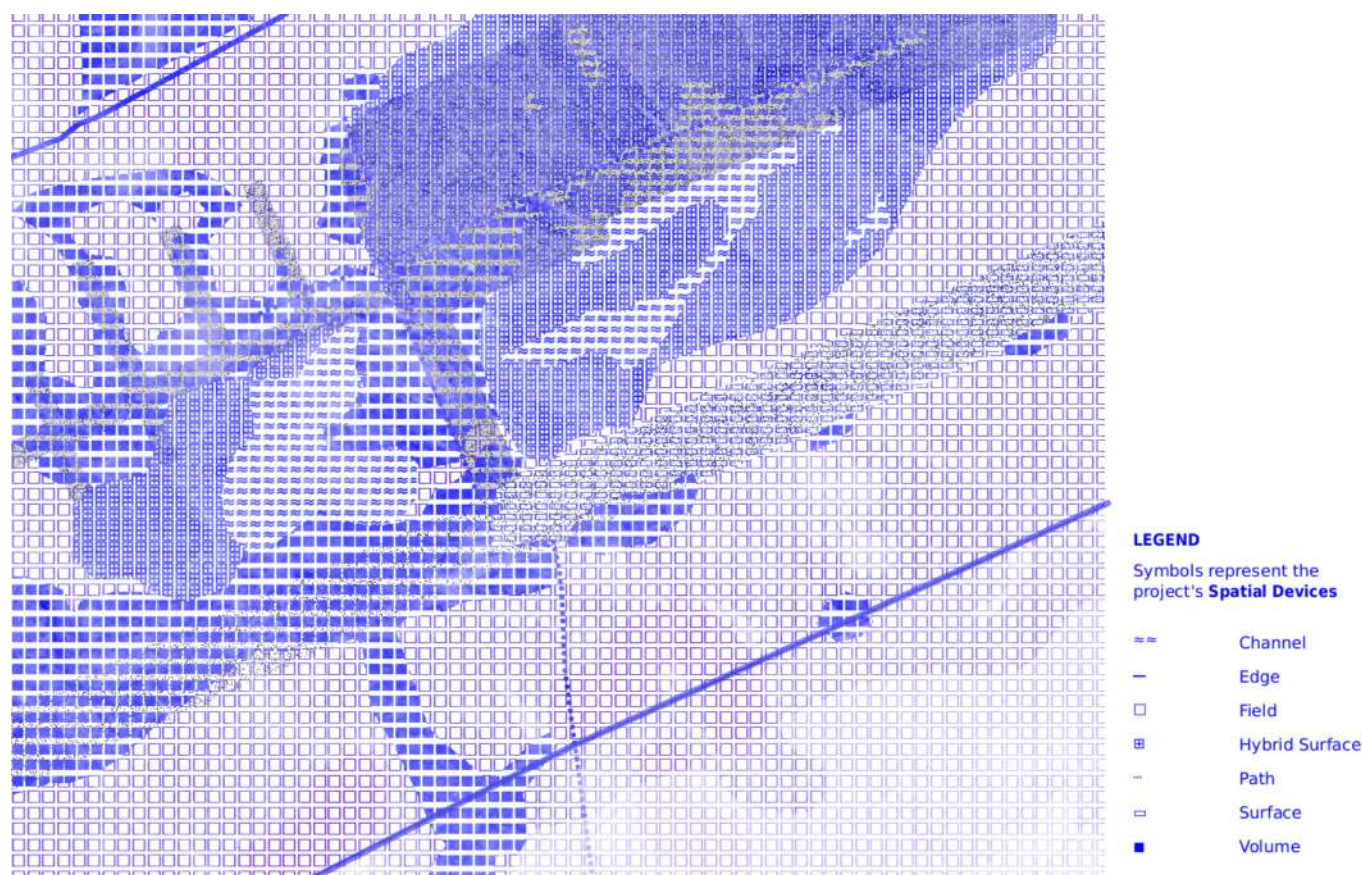


Figure 9. Diagram of spatial devices within a representative area (credit: A. Raffa).

(4) Outcome evaluation. The resulting landscape demonstrates a strong integration between inherited morphology and ecological processes.

- Climatic outcomes include moderate cooling effects through increased vegetation and reduced surface sealing, as well as improved microclimatic conditions along vegetated corridors.
- Ecological outcomes are characterized by the development of continuous grassland and wetland habitats, increased biodiversity, and enhanced ecological connectivity across the site.
- Social outcomes arise from open, flexible spaces supporting informal and low-intensity uses, such as walking, cycling, and spontaneous activities.
- Memory outcomes are particularly significant, as the preservation of the runway and infrastructural fragments maintains a strong legibility of the former airfield, allowing users to engage with the historical layers of the site.

Overall, Maurice Rose Airfield Park exemplifies a regeneration approach in which ecological enhancement is achieved through the context-sensitive transformation of inherited spatial structures (Table 5).

Table 5. Maurice Rose Airfield Park: Outcome evaluation (credit: A. Raffa).

Airfield Morphologies	Regeneration			Outcomes			
	Spatial Actions	Spatial Devices	NbS	Climatic	Ecological	Social	Memory
Runway	Preserve + Enrich + Connect	Corridor	Green corridor	Linear cooling corridor	Continuous linear habitat supporting species movement across the site; low-disturbance grassland ecology	Structured yet open-use spine for walking, cycling and informal activities	Strong legibility of original runway geometry and materiality; continuity of spatial orientation
Aprons	Subtract + Fragment + Reuse	Surface	Permeable pavement/Spontaneous vegetation	Reduction in heat island effect through de-sealing; increased evapotranspiration	Transition from sealed surfaces to heterogeneous pioneer habitats; increased soil infiltration and microhabitat diversity	Flexible, non-programmed spaces enabling adaptive and informal uses	Material traces and fragments of impervious surfaces maintain readable layers of past infrastructure
Taxiways	Adapt + Reuse	Path	Permeable pavement	Reduced surface runoff; improved microclimate along circulation paths	Enhanced ecological connectivity through vegetated path linking different habitats	Improved permeability and accessibility across the site; support for slow mobility	Reuse of original alignments preserves latent infrastructural logic within new circulation patterns
	Remove + Fragment + Reuse	Surface	Permeable pavement Spontaneous vegetation				
Graded surfaces	Adapt + Enrich	Room/Corridor	Phytoremediation Forest/Ecological Forest Corridor	Thermal buffering through vegetated surfaces; reduced soil overheating	Development of grassland mosaics and early successional habitats; soil regeneration processes	Open spaces supporting recreation and informal appropriation along the runway	Preservation of the original flatness reinforces the perception of the preserved runway, while diversifying the runway's border
	Add + Delimit	Diaphragm	Tree Canopies				
Drainage system	Reveal + Dig + Stay	Room	Constructed wetlands	Stormwater regulation; local cooling through water bodies; humidity modulation	Significant increase in wetland biodiversity; improved water retention and filtration capacity	Experiential landscapes enabling interaction with water systems; educational potential	Transformation of hidden technical infrastructure into visible ecological systems recalling river wetland ecosystem and inherited morphologies
	Reveal + Dig + Redirect	Channel	Stream daylighting/Bioengineering techniques				
	Reveal + Dig + Reinterpret	Room	Retention pond				
	Cross + look	Path	Permeable pavement				
Open infields	Adapt + Enrich	Room	Pocket Parks/Natural Playground	Large-scale cooling through evapotranspiration; air circulation zones	Expansion of continuous grassland habitats; increased ecological resilience and habitat diversity	Large commons supporting collective uses, events, and unstructured activities	Maintenance of the open-field condition subdivision
	Preserve + Enrich	Field	Natural Playground				
	Densify + Shade	Volume	Phytoremediation Forest/Ecological Forest corridor				
Perimeter	Subtract + Open + Connect	Threshold	Tree Canopies/Hedgerow	Wind modulation; shading; edge microclimate improvement	Strengthened edge ecologies and habitat gradients between park and surroundings	Improved physical and visual accessibility; integration with surrounding urban fabric	Transformation of rigid boundaries into permeable edges while partially retaining the original enclosure logic

4.2.2. Case Study II: Xuhui Runway Park (Shanghai, 2020)

Xuhui Runway Park, designed by Sasaki, exemplifies a contemporary and transformative strategy for post-airfield regeneration, in which inherited aeronautical infrastructures are preserved and extensively reconfigured to facilitate climate-responsive design, ecological enhancement, and intensive public programming. In contrast to preservation-oriented projects, this intervention employs fragmentation, addition, and re-articulation to convert the former runway into a multifunctional urban landscape system (Figure 10).

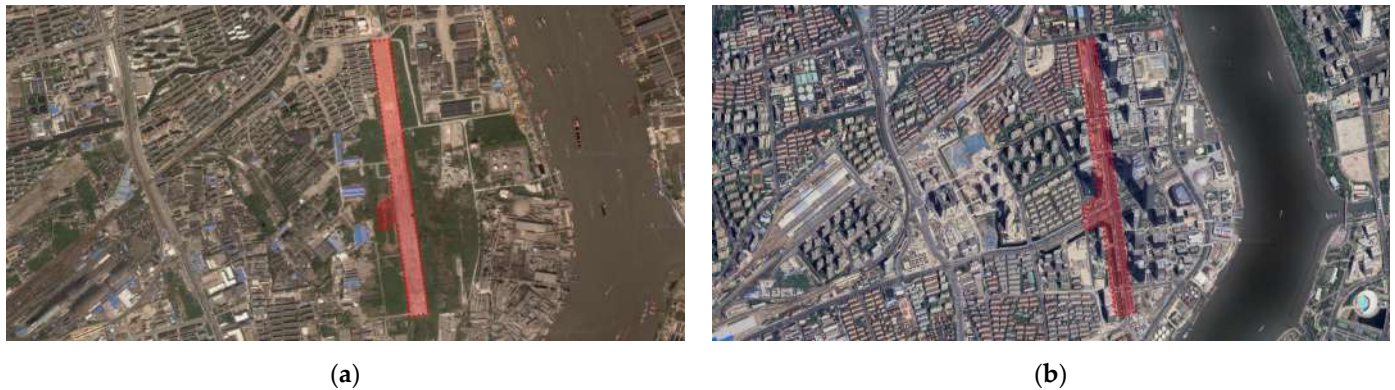


Figure 10. Satellite image comparison of the Xuhui Runway Park, Shanghai (credit: Google Earth 2026): (a) pre-intervention 2008; (b) post-intervention 2025.

- (1) **Inherited Morphologies.** The pre-intervention condition is characterized by a clearly legible airfield structure, composed of a central runway, extensive impervious surfaces, open infields, and a concealed drainage system. The site presents a highly engineered and predominantly sealed surface condition, with limited vegetation and strong geometric order. The runway acts as the primary spatial axis, while adjacent surfaces form continuous horizontal plates. The hydrological system remains largely hidden, and the perimeter is defined by infrastructural boundaries separating the site from the surrounding urban fabric.
- (2) **Transformation Processes: Actions and Spatial Devices.** The transformation strategy combines preservation and reconfiguration. Inherited morphologies are both retained and reinterpreted simultaneously.
 - The runway is partially preserved and transformed into linear corridors, rooms, and thresholds that facilitate ecological processes and accommodate intensive public use (Figure 11).
 - Impervious surfaces are completely transformed generating a system of rooms, surfaces, and pathways integrating vegetation, water; fragments are reused for paving (Figure 12).
 - The drainage system is reshaped, becoming a network of water spaces which contribute to create new urban water landscapes structuring the park (Figure 13).
 - Open infields are excavated, connected, and densified, transforming into articulated ecological and programmatic fields.
 - The perimeter is completely dissolved, creating permeable thresholds that integrate the park with the city (Figure 14).



Figure 11. The drainage system is reshaped into a network of water spaces, forming a linear green–blue structure along the river and contributing to new urban water landscapes that structure the park (credit: Reproduced with permission from Sasaki; photo: Insaw Photography).

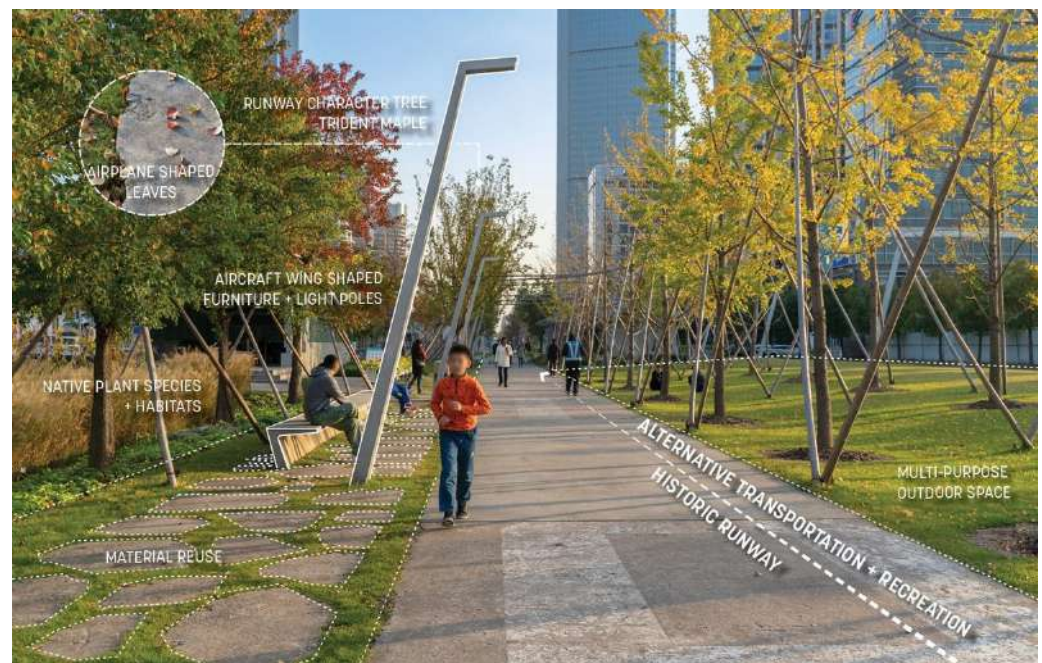


Figure 12. The runaway memory survives in the linear orientation of the park, the conservation of some portions, and the material reuse of its impervious fragments (credit: Reproduced with permission from Sasaki; photo: Insaw Photography).



Figure 13. The park operates as a green–blue infrastructure where water features create new urban water landscapes (credit: Reproduced with permission from Sasaki; photo: Insaw Photography).



Figure 14. Subtle ground movements create accelerations and decelerations that, together with the vegetation, enrich the experience of moving through the park (credit: Reproduced with permission from Sasaki; photo: Insaw Photography).

These transformations create a complex system of spatial devices, including corridors, rooms, channels, thresholds, and diaphragms (Figure 15). These elements spatially organize ecological, climatic, and social processes by reinterpreting the runaway linearity.

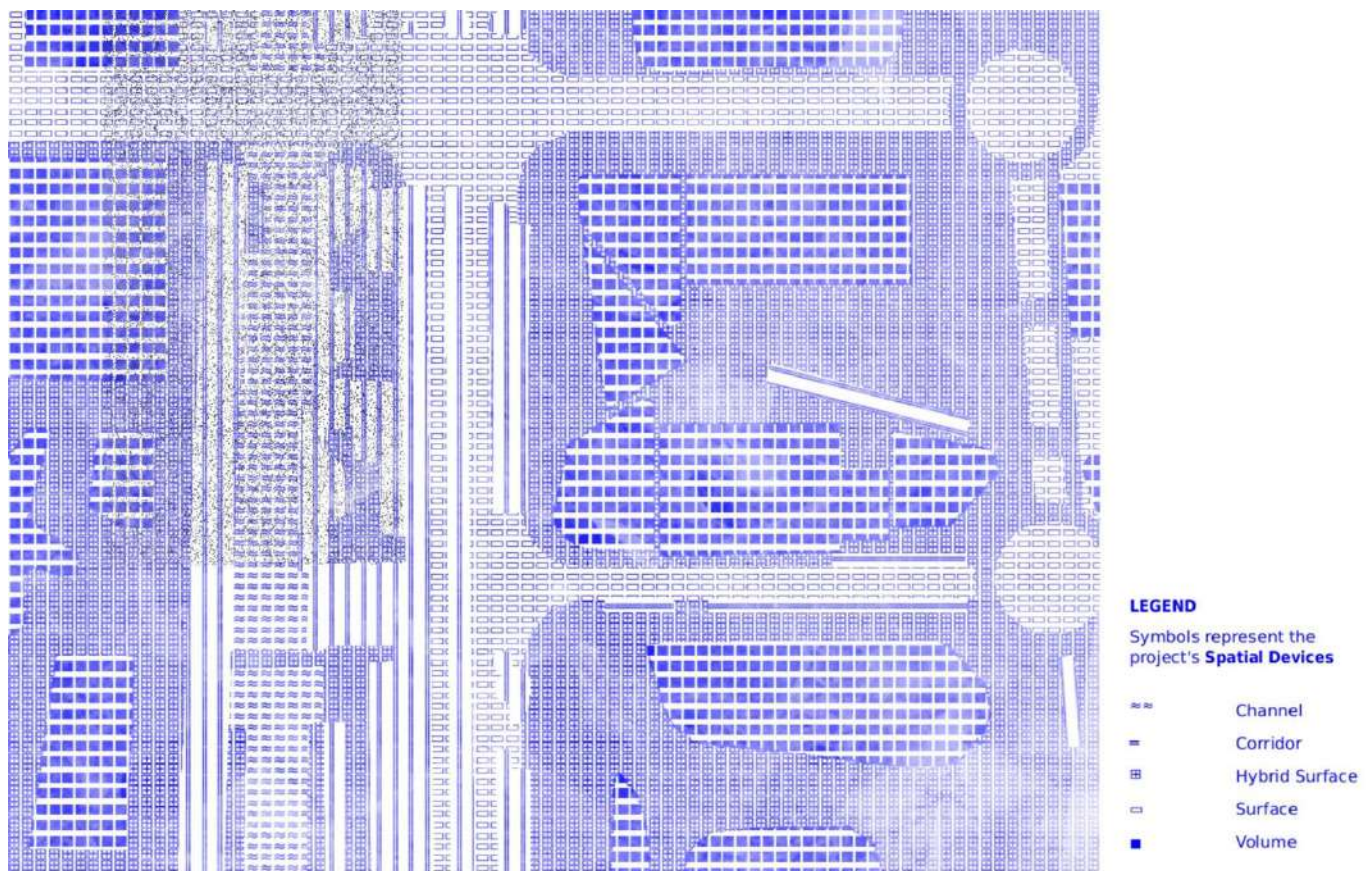


Figure 15. Diagram of spatial devices within a representative area (credit: M. Moscatelli).

(3) In Xuhui Runway Park, Nature-Based Solutions are deeply integrated into spatial design and operate at multiple scales. Rather than relying on spontaneous processes, the project deploys designed ecological systems, including:

- Urban green corridors structured by tree canopies;
- Constructed wetlands, bioswales, and rain gardens;
- Stream daylighting and water features;
- Permeable surfaces and recycled material systems;
- Bioengineered edges and floating wetland modules.

These NBS are embedded within spatial devices, functioning as both environmental infrastructure and form-generating elements.

(4) Outcome evaluation (Table 6). The transformation results in a highly articulated landscape where climatic, ecological, social, and cultural dimensions are tightly interconnected.

Table 6. Xuhui Runway Park: Outcome evaluation (credit: M. Moscatelli).

Airfield Morphologies	Regeneration			Outcomes			
	Spatial Actions	Spatial Devices	NbS	Climatic	Ecological	Social	Memory
Runway	Preserve + Reduce + Reuse + Connect	Corridor	Urban Green Corridor	Continuous linear cooling spine combining shading and evaporative effects	Continuous vegetated corridor with native plants supporting urban biodiversity, facilitating species movement	Highly programmed linear public infrastructure supporting mobility, leisure, and large-scale events	3.6 m-width portions of runaway preserved
	Stay + Reuse	Surface	Recycled Material	Improved soil permeability	Permeable pavement with spontaneous vegetation	Define spaces along the corridor for unprogrammed uses	Runway fragments reused as paving materials
	Subtract + Collect	Room	Constructed Wetland				
	Stay	Room/Surface	Pocket Parks/Natural Playground/	Significant reduction in heat island effect through de-sealing, tree shading, integration of permeable and vegetated surfaces, and water features	Transformation of impervious surfaces into heterogeneous green patches increases soil permeability and supports diverse plant communities through native vegetation layering	High-density activity zones (sports, playgrounds, plazas) enabling diverse and simultaneous uses, connected by slow mobility paths	Geometric persistence through alignment and strip subdivision; transformation into a highly programmed urban landscape
	Stay	Surface	Water features				
	Stay + Dig + Collect	Room	Rain Gardens				
	Separate + Dig	Channel	Linear Rain Gardens				
	Separate + Connect	Threshold	Green Avenues				
	Delimit + Shade	Diaphragm/Cover	Street tree canopy				
	Separate + Hide	Barrier	Vegetated hedgerows				
	Divide + Dig	Channel	Linear bioswales				
	Cross	Path	Permeable surfaces				
Aprons	Add	Volume	NA	NA	NA	NA	New volumes and open spaces erased the airfield's aprons
	Stay	Room/Surface	Pocket Parks/Natural Playground/	Reduction in heat island effect through tree shading, integration of permeable and vegetated surfaces	Transformation of impervious surfaces into heterogeneous green patches among new buildings	Multipurpose activity zones in connection with surrounding buildings	NA

Table 6. Cont.

Airfield Morphologies	Regeneration			Outcomes			
	Spatial Actions	Spatial Devices	NbS	Climatic	Ecological	Social	Memory
Taxiways	Add	Volume	NA	NA	NA	NA	NA
Water System	Subtract + Collect	Room	Constructed Wetland	Integrated stormwater management system combining retention, filtration, and evaporative cooling	Constructed wetlands and bioswales establish aquatic and semi-aquatic habitats, enhancing biodiversity while improving water quality and ecological functioning	Strong social activation through interactive water features and playable landscapes	Former hidden drainage infrastructure reinterpreted as visible and experiential water landscapes, recalling the original hydrological logic of the city
	Stay	Room/Surface	Pocket Parks/Natural Playground/				
	Stay	Surface	Water features				
	Stay + Dig + Collect	Room	Rain Gardens				
	Separate + Dig	Channel	Linear Rain Gardens				
Open infields	Reveal + Dig	Channel	Stream Daylighting	Large-scale cooling through shading and evapotranspiration; contribution to urban ventilation corridors	Restoration of fluvial and riparian habitats; increased ecological diversity and habitat complexity	Transformation into active and multifunctional public spaces supporting sports, gatherings, and events near a newly re-created water landscape	Open-field condition transformed into a programmed and urbanized landscape
	Reshape + Connect	Edge	Bioengineering techniques				
	Add + Diffuse	Surface	Floating wetland module				
	Delimit + Shade	Diaphragm/Cover	Street tree canopy				
Perimeter	Remove + Connect	Threshold	Street tree canopy/Hedgerows	Edge cooling and shading through tree canopies; buffering of surrounding urban heat and improvement of local microclimate	Tree-lined edges and vegetation support species movement and ecological connection with surrounding urban green systems	High accessibility and integration with surrounding neighborhoods; active urban frontage	Dissolution of the original boundary condition; loss of enclosure replaced by urban continuity

- Climatic outcomes include significant mitigation of the urban heat island effect through large-scale de-sealing, tree shading, and evapotranspiration, as well as improved stormwater management through integrated hydrological systems. The introduction of water bodies and vegetated surfaces contributes to localized cooling and microclimatic regulation.
- Ecological outcomes are characterized by the creation of diverse and multi-layered habitats, including grasslands, wetlands, and tree-lined corridors. The integration of aquatic and terrestrial systems enhances biodiversity, improves ecological connectivity, and supports resilient urban ecosystems.
- Social outcomes are defined by a high degree of spatial programming and intensity of use. The park functions as a multifunctional public infrastructure, accommodating sports, leisure, events, and everyday activities. The combination of linear corridors and articulated rooms supports both movement and occupation, enabling diverse and simultaneous uses.
- Memory and heritage outcomes are more ambivalent compared to preservation-oriented projects. While fragments of the runway are retained—such as the 3.6 m strips—and reused as paving elements, the original airfield morphology is largely transformed into a new urban landscape. The memory of the site persists primarily through geometric alignments and material traces, rather than through direct preservation of spatial continuity.

4.2.3. Cross-Case Comparative Analysis

The comparative analysis highlights how similar inherited airfield morphologies can generate significantly different spatial, ecological, and social outcomes when mediated by distinct transformation logics and Nature-Based Solutions (NBS). By applying the same morphology-based and ontology-driven analytical structure to Maurice Rose Airfield Park and Xuhui Runway Park, it becomes possible to systematically compare how each project interprets and transforms the same set of spatial entities—runways, impervious surfaces, open infields, drainage systems, and perimeters—through different sequences of actions, spatial devices, and NBS integrations.

- (1) **Divergent Transformation Logics.** A primary distinction between the two cases lies in their fundamentally different transformation logics. Maurice Rose Airfield Park operates through a strategy of selective preservation and ecological enhancement, where inherited morphologies are largely maintained and incrementally adapted. Spatial actions such as preservation, subtraction, and minimal ecological enrichment reinforce the existing spatial order, allowing ecological processes to emerge through low-intensity interventions. In contrast, Xuhui Runway Park is characterized by a transformative and reconfigurative approach, where inherited morphologies are fragmented, hybridized, and recomposed. Rather than reinforcing the original structure, the project reinterprets it, generating new spatial hierarchies and programmatic intensities.
- (2) **Morphology–Action–Device Relationships.** The comparison further reveals how similar morphological elements are translated into different spatial devices through distinct transformation actions.
 - The runway, in Maurice Rose, is preserved as a continuous corridor, functioning as a linear social spine open to undefined social possibilities. In Xuhui, the runway is partially preserved and re-articulated into a sequence of corridors, rooms, and thresholds, supporting a more diverse range of uses and environmental conditions.
 - Impervious surfaces (aprons and taxiways) are selectively removed and hybridized in Maurice Rose, producing permeable surfaces and semi-natural landscapes. In Xuhui,

these surfaces are extensively reconfigured into a system of programmed rooms and landscapes, integrating vegetation, water, and built elements.

- The drainage system remains largely implicit in Maurice Rose, where hydrological processes are integrated through newly constructed wetlands, soil permeability and vegetation. In Xuhui, it becomes a central design driver, transformed into visible channels, wetlands, and water features that structure the spatial organization of the park.
- Open infields are maintained as open and continuous ecological fields in Maurice Rose, while in Xuhui they are urbanized and subdivided into differentiated programmatic and ecological zones.
- The perimeter is softened in Maurice Rose, maintaining a degree of spatial enclosure, whereas in Xuhui it is dissolved, enabling full integration with the surrounding urban fabric.

These differences demonstrate how the same morphological starting conditions can produce radically different spatial configurations when mediated by distinct action–device relationships and contexts.

- (3) Integration and Role of Nature-Based Solutions. The role and intensity of NBS also differ significantly between the two cases. In Maurice Rose Airfield Park, NBS are embedded within spatial devices through low-intensity and process-based strategies, such as spontaneous renaturalization, grassland development, and permeable surfaces. These interventions rely on ecological succession and minimal maintenance, allowing natural processes to shape the landscape over time. In Xuhui Runway Park, NBS are implemented as designed and engineered systems, including constructed wetlands, bioswales, rain gardens, and tree canopy infrastructures. These systems are tightly integrated into the spatial design and operate as active environmental infrastructures, regulating water, temperature, and ecological processes at multiple scales. This comparison highlights two distinct paradigms: NBS as adaptive ecological processes versus NBS as performative design systems, both contributing to spatial transformation. This cross-case interaction between morphological heritage, spatial devices, and nature-based performances is systematically synthesized from an exclusively ecological perspective in Table 7.

Table 7. Synthesis and comparative matrix of the two case studies’ interpretative diagrams, evaluating the ecological dimension across inherited structures, spatial devices, and nature-based performances (credit: M. Moscatelli).

Inherited Morphologies	Spatial Devices	Applied NBS	Ecological Outcomes
Runways & Taxiways (Central runway and taxiway systems)	= Corridor (Runway axis) ■ Surface (Asphalt mass) ▣ Hybrid Surface (Semi-permeable eco-pavements)	• Maurice Rose Park: Partial asphalt de-construction, preserving the original infrastructural linearity while embedding eco-permeable fissures. • Xuhui Runway Park: Complete de-paving and programmatic fragmentation of the runway into a modular system of longitudinal rain gardens.	• Maurice Rose Park: Localized increase in surface permeability (+40%); preservation of the historical runway corridor as a continuous biological connectivity axis. • Xuhui Runway Park: Total restoration of the surface hydrological cycle; complete mitigation of urban peak runoff through widespread infiltration and retention.

Table 7. Cont.

Inherited Morphologies	Spatial Devices	Applied NBS	Ecological Outcomes
Open Infields (Internal lawns and inter-infrastructure gaps)	□ Field (Open grassland/Meadow matrix) --- Path (Slow mobility/Circulation network)	• Maurice Rose Park: Full preservation of the pristine grassland landscape matrix, implementing targeted low-intensity maintenance actions. • Xuhui Runway Park: Ecological fragmentation and selective urbanization of the meadow, sub-divided into micro-scale vegetative habitats and integrated natural playgrounds.	• Maurice Rose Park: Outstanding spontaneous biodiversity support; consolidation of stable protected habitats for local fauna and ruderal flora species. • Xuhui Runway Park: High long-term biomass carbon storage achieved through dense native planting schemes; ecological functionality balanced with controlled anthropogenic use.
Drainage Systems (Original technical hydraulic infrastructures)	≈≈ Channel (Ponds & Water features)	• Maurice Rose Park: Daylighted and excavated underground drainage network, successfully transformed into permanent ponds and semi-natural bio-swales. • Xuhui Runway Park: Ex novo creation of a continuous linear water axis featuring terraced constructed wetlands for urban stormwater recycling and filtration.	• Maurice Rose Park: Successful establishment of essential standing-water biotopes acting as strategic stepping stones for local amphibian and aquatic wildlife. • Xuhui Runway Park: Advanced bio-filtration of urban surface pollutants and highly efficient phytoremediation of heavy metal storm runoff.
Perimeters & Edges (Physical boundaries and buffer zones)	– Edge (Boundary lines/Fence) ■ Volume (Dense & Isolated masses)	• Maurice Rose Park: Strict retention of the historical perimeter fencing combined with the thick planting of native multi-layered vegetative shelterbelts. • Xuhui Runway Park: Dissolution of the physical site boundary, replaced by a dense urban forest buffer and continuous street canopy elements.	• Maurice Rose Park: High ecological buffering performance, effectively shielding the core sanctuary areas from external urban and anthropogenic disturbances. • Xuhui Runway Park: Strategic mitigation of the local Urban Heat Island (UHI) effect at the margins via continuous tree canopy shading and microclimatic regulation.

- (4) Comparative Outcomes. The divergence in transformation strategies and NBS integration leads to differentiated outcomes across climatic, ecological, social, and cultural dimensions.
- Climatic performance in Maurice Rose is moderate, achieved through increased vegetation and reduced surface sealing. In Xuhui, climatic performance is more pronounced and spatially structured, driven by large-scale de-sealing, water systems, and tree canopies that actively mitigate urban heat and regulate microclimates.

- Ecological outcomes in Maurice Rose emphasize habitat continuity and grassland ecosystems, supporting biodiversity through low-disturbance environments. In Xuhui, ecological outcomes are more diversified and multi-layered, but within a more controlled and designed framework.
- Social use differs significantly in intensity and structure. Maurice Rose supports flexible, informal, and low-intensity activities, reflecting its open and minimally programmed landscape. Xuhui, by contrast, functions as a highly programmed urban park, accommodating a wide range of activities, events, and user groups within a structured spatial system.
- Memory and heritage represent perhaps the most contrasting dimension. Maurice Rose maintains a strong legibility of the original airfield through the preservation of spatial continuity and material traces. In Xuhui, memory is partially retained through geometric alignments and material reuse, but is largely reinterpreted within a new urban landscape, resulting in a more abstract and mediated form of heritage.

The comparative analysis of the two case studies serves not only to highlight differences in airfield regeneration strategies, but also to test and validate the proto-ontology through its application. By systematically mapping morphologies, spatial actions, spatial devices, and nature-based solutions across both projects, the framework demonstrates its capacity to consistently structure heterogeneous transformations and reveal underlying spatial logics. It also demonstrates that post-airfield landscapes should not be understood as tabula rasa conditions, but as morphologically structured systems whose transformation can follow multiple trajectories. The application of the proto-ontology makes it possible to compare projects that, while sharing similar initial morphological conditions, diverge significantly in their transformation processes and outcomes. In the preservation-oriented case, the ontology captures a logic based on continuity, ecological enhancement, and the legibility of inherited structures. In contrast, the hybrid urban–infrastructural case reveals a more composite logic, where morphologies are reinterpreted, and integrated into a highly programmed and multifunctional spatial system. This comparison confirms the analytical robustness of the proto-ontology, which is able to accommodate both process-driven ecological transformations and more design-intensive, hybrid interventions. At the same time, it highlights its interpretative capacity, enabling the identification of recurring patterns and divergences across cases, and supporting a more nuanced understanding of how NBS operate within different spatial configurations inside airfields' regeneration.

5. Discussion

This study contributes to research on post-industrial landscape regeneration, Nature-Based Solutions (NBS), and morphology-driven design by proposing a structured method for analyzing how former airfields are transformed into climate-adaptive and socially accessible landscapes. Its main contribution is to show that inherited airfield morphologies are not passive remnants, but operative spatial structures that condition how NBS are embedded, how spatial devices are produced, and how climatic, ecological, social, and memory-related outcomes emerge. This moves the analysis of post-airfield regeneration beyond descriptive case study narratives and toward a reproducible morphology-based framework.

5.1. Contribution 1: Repositioning Airfield Morphology as an Operative Structure

The first contribution is theoretical. The study reframes airfield morphologies—such as runways, aprons, taxiways, drainage systems, perimeters, and open infields—as active spatial structures in regeneration processes. Rather than treating them as residual infrastructures to be erased or preserved as isolated heritage traces, the paper shows that

they can organize ecological continuity, public access, hydrological performance, spatial orientation, and memory.

This contribution extends landscape urbanism and airport landscape studies by making the role of inherited form more explicit. While previous research has often described former airfields as large open landscapes, ecological reserves, or potential urban commons, this paper specifies how particular morphologies shape different transformation logics. A runway, for example, may become a corridor, a path, a memory trace, or an ecological spine depending on the spatial action applied to it. In this sense, morphology becomes a design mediator between infrastructural inheritance and future environmental performance.

5.2. Contribution 2: Reframing NBS as Spatially Embedded Design Components

The second contribution concerns the interpretation of Nature-Based Solutions. The paper argues that NBS should not be understood only as technical or environmental interventions evaluated through performance indicators. They also operate as spatially embedded design components whose effects depend on the morphologies and devices through which they are articulated.

This is particularly relevant in post-airfield landscapes, where NBS rarely operate on neutral ground. Meadows, wetlands, permeable surfaces, ecological corridors, tree canopies, and water retention systems are shaped by pre-existing geometries, material conditions, and infrastructural traces. By linking NBS to spatial devices, the framework clarifies how ecological strategies become spatial form. For example, a preserved runway can support an ecological corridor, while fragmented apron surfaces can become hybrid permeable landscapes. The paper therefore contributes a design-oriented reading of NBS as both ecological and form-generating elements.

5.3. Contribution 3: Developing a Proto-Ontological Analytical Framework

The third contribution is methodological. The study develops a proto-ontological framework that links five analytical levels: Inherited Morphology → Spatial Action → Spatial Device → Nature-Based Solution → Spatial Outcome. This structure allows the analysis to move from individual project description to comparable relational chains.

The value of the framework lies in its capacity to make design transformations explicit and comparable. It clarifies which inherited morphology is present, which action transforms it, which spatial device is produced, which NBS are embedded, and which outcomes are generated. In doing so, the framework addresses a gap in existing post-airfield research, where projects are often discussed through isolated narratives rather than through transferable analytical relations. The framework is defined as “proto-ontological” because it organizes entities and relationships in a structured and repeatable way, without yet claiming to be a fully formalized machine-readable ontology. Its contribution is therefore twofold: it provides an operational tool for design-oriented analysis, and it establishes a basis for future computational development through graph-based models, semantic networks, or decision-support systems.

5.4. Contribution 4: Clarifying the Role of AI in Design-Oriented Comparative Analysis

The fourth contribution concerns the use of AI. The paper demonstrates how AI can support design-oriented research without replacing expert interpretation. In this study, AI was not used to autonomously generate findings or evaluate projects. Its role was limited to analytical archiving, text-based classification, vocabulary normalization, consistency checking, and visual-recognition support in the two in-depth case studies.

This contribution is methodological rather than technological. It shows how AI can assist the organization and comparison of heterogeneous design documentation while remaining embedded within a human-in-the-loop process. The authors retained respon-

sibility for the interpretation of spatial form, the validation of AI-assisted outputs, and the final assignment of categories. This controlled use of AI improves transparency and reproducibility, while avoiding the risks of unsupported automated classification.

5.5. Implications for Post-Airfield Regeneration

The proposed framework has implications for both analysis and design. Analytically, it allows researchers to compare post-airfield regeneration projects through a consistent relational structure rather than through descriptive narratives alone. Design-wise, it helps identify how inherited airfield morphologies can be transformed into spatial devices capable of supporting NBS, public use, ecological continuity, and memory.

The comparison between Maurice Rose Airfield Park and Xuhui Runway Park shows that similar inherited morphologies can produce different outcomes depending on the transformation strategy adopted. Preservation, fragmentation, subtraction, reconnection, or reconfiguration do not produce fixed results; their effects depend on the spatial device generated and, on the way, NBS are embedded within it. This confirms the importance of treating morphology, ecological strategy, and spatial outcome as interdependent elements of the same design process.

Overall, the paper contributes a transferable analytical framework for post-airfield regeneration. It clarifies how inherited infrastructural forms can become resources for climate adaptation, ecological regeneration, public space, and cultural continuity, and it provides a methodological basis for future comparative, computational, and design-oriented research.

5.6. Limitations and Future Research

This study has some limitations that should be acknowledged. First, the corpus of 32 post-airfield regeneration projects was constructed as a purposeful design-research corpus aimed at capturing relevant and documented examples of post-airfield transformation across different geographical contexts, scales, and design approaches. The selection was based on the availability of sufficient documentation and on the relevance of each project for open-space, ecological, and morphology-based regeneration. Future research could further extend this corpus by including additional cases from underrepresented regions, smaller or less-documented projects, and examples in which post-airfield transformation has followed non-landscape-led, informal, or incremental processes. This would strengthen the external validity of the framework and allow its categories to be tested across a broader range of urban, territorial, and historical conditions.

Second, the analysis relies primarily on qualitative spatial interpretation, aerial imagery, project documentation, and published descriptions. While this approach is appropriate for identifying morphology–action–device–NBS relationships, it does not provide direct instrumental measurement of environmental performance. Further studies should therefore integrate quantitative parameters to complement the qualitative spatial reading and to test more precisely the climatic, ecological, social, and performance-related outcomes of the framework. Future research should also broaden the analytical scope beyond spatial and ecological dimensions by incorporating governance structures, land ownership regimes, public participation processes, since these factors strongly influence institutional arrangements, stakeholder conflicts, social equity conditions, and ultimately the feasibility and outcomes of post-airfield regeneration.

A further limitation concerns the proto-ontological status of the framework. In this paper, the framework structures relationships between inherited morphologies, spatial actions, spatial devices, Nature-Based Solutions, and spatial outcomes, but it is not yet formalized as a fully machine-readable ontology. Future work will translate these relationships into

semantic-network models, allowing the framework to evolve into a computational ontology usable for knowledge graphs, decision-support systems, and AI-assisted generative design. Moreover, although AI was used as a support layer for organizing information, comparing recurring patterns, and normalizing terminology, all final classifications remained authored and interpretative. Future research should test the reproducibility of the method by involving multiple researchers in the coding process, comparing inter-coder agreement, and making the analytical templates, prompts, and coding sheets available.

Finally, the application of the framework to two case studies demonstrates its interpretative potential, but further validation is needed. The next implementation step should involve applying the framework to a larger set of cases from the 32-project corpus and developing standardized case study workflow diagrams for each project. These diagrams would make the analytical sequence more transparent. In addition, the framework could be tested in design studios, dedicated design workshops, or professional practice as a tool for guiding new post-airfield regeneration scenarios. Such implementation would shift the framework from an analytical model toward an operational design-support tool, capable not only of interpreting existing projects but also of informing future transformations of former airfield landscapes.

6. Conclusions

This paper has examined post-airfield regeneration through the relationship between inherited morphology, design transformation, Nature-Based Solutions, and spatial outcomes. The central argument is that former airfields should not be approached as generic brownfields or neutral reserves for ecological compensation. Their spatial structures continue to condition how regeneration operates after decommissioning.

The analysis shows that inherited airfield morphologies—runways, aprons, taxiways, drainage systems, perimeters, and open infields—act as operative frameworks for transformation. They influence the organization of movement, hydrological systems, vegetation, public use, and memory. However, their effects are not predetermined. The same morphology may support different outcomes depending on the spatial action applied to it, the device generated, and the NBS embedded within that device.

The comparison between Maurice Rose Airfield Park and Xuhui Runway Park makes this point explicit. In the first case, preservation, minimal intervention, and ecological succession maintain a high degree of morphological legibility. In the second, reconfiguration, hybridization, and designed green-blue systems produce a more intensive and climate-responsive urban landscape. The contrast demonstrates that post-airfield regeneration is shaped not only by the presence of inherited structures, but by the specific design operations through which they are transformed.

The proposed proto-ontological framework provides a systematic way to describe these relationships. By organizing the analysis through the sequence Inherited Morphology → Spatial Action → Spatial Device → Nature-Based Solution → Spatial Outcome, the framework makes visible the intermediate design conditions through which ecological, climatic, social, and memory-related effects are produced. Its value lies in clarifying the relational logic of transformation, rather than reducing projects to isolated typologies or performance indicators.

The study also reframes NBS as spatially embedded design components. In post-airfield landscapes, meadows, wetlands, permeable surfaces, ecological corridors, tree canopies, and water retention systems do not operate independently from form. They acquire spatial, ecological, and cultural significance through their association with inherited geometries and transformation devices. This suggests that the evaluation of NBS should

consider not only environmental performance, but also the spatial structures that enable, constrain, or amplify such performance.

Overall, the paper contributes to a more critical understanding of post-airfield regeneration as a design process situated between ecological transformation and cultural continuity. Former airfields are not simply sites to be reused, naturalized, or programmed; they are structured landscapes whose spatial grammar can become an active resource for climate adaptation, ecological continuity, public space, and memory. Future research can further develop this proto-ontological approach through broader case applications, quantitative parameters, and graph-based or semantic-network models capable of supporting knowledge graphs, decision-support systems, and AI-assisted generative design.

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