Exploring the Application and Challenges of Urban Planning Legal Systems Guided by Nature-Based Solutions: A Case Study of Kaohsiung City, Taiwan

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Abstract
This study focuses on examining Nature-Based Solutions (NbS) within urban planning across different spatial scales in Kaohsiung City, Taiwan, particularly evaluating the content of planning regulations and their implementation strength. By constructing an NbS relevance matrix and integrating the Strategic Environmental Assessment (SEA) framework, the study conducts regional risk and potential analyses to assess the feasibility of planning strategies in each area. The findings indicate that the incorporation of NbS in spatial planning regulations remains insufficiently systematic. Therefore, the study recommends promoting the mainstreaming of NbS through institutional reforms and enhancing climate adaptation and sustainable urban transformation by referencing international case studies and strengthening multi-level governance.

Keywords: Nature-based Solutions (NbS), Urban Planning, Climate Adaptation, Sustainable Urban Development

1. Introduction

1.1 Global Context and the Importance of the Issue

In recent years, as global warming intensifies, the frequency of extreme weather events increases, and ecosystems continue to degrade, urban areas worldwide are facing unprecedented pressure on sustainability and resource availability, particularly in terms of land, water, and infrastructure. According to the United Nations Environment Programme (UNEP, 2024), countries must commit, in the next round of Nationally Determined Contributions (NDCs), to reducing emissions by 42% by 2030 and 57% by 2035; otherwise, the Paris Agreement's 1.5°C target will be unattainable, with global temperatures potentially rising to between 2.6°C and 3.1°C(United Nations Environment Programme, 2024), leading to severe impacts on human society, ecosystems, and the global economy. The IPCC (2023) similarly highlights that cities are not only major sources of carbon emissions but also at the frontline of climate impacts, particularly vulnerable to risks such as biodiversity loss. Future climate scenarios must incorporate irreversible risks such as ecosystem collapse, limits to species adaptation, and social tipping points, while also addressing the unequal impacts of climate change across different social groups. The report further calls for interdisciplinary and multi-level cooperation to develop adaptation strategies that are inclusive and locally grounded, in order to effectively respond to increasingly complex environmental challenges.

1.2 The Rise and Multiple Benefits of Nature-based Solutions (NbS)

Drawing on insights from both international reports, it is increasingly evident that traditional engineering-dominated solutions are reaching their limitations and are no longer sufficient to address today's complex environmental and social challenges alone. This has prompted cities around the world to shift towards more sustainable and resilient strategies. In recent years, Nature-based Solutions (NbS)—offering multiple co-benefits in climate adaptation, carbon reduction, ecological restoration, and human well-being—have gained significant global attention.

NbS has been formally integrated into international frameworks such as the United Nations Framework Convention on Climate Change (UNFCCC) and the Convention on Biological Diversity (CBD), and is closely aligned with Natural Climate Solutions (NCS), the Sustainable Development Goals (SDGs), and net-zero strategies. Overall, NbS has evolved from a traditional ecological tool into a multi-level, multi-objective governance strategy, playing an increasingly important role across environmental, social, and economic dimensions.

Environmentally, NbS contributes to carbon sequestration, alleviates the urban heat island effect, regulates the water cycle, and reduces flood risks. Socially, urban green spaces enhance mental well-being, strengthen community interaction, and build resilience. Economically, NbS stimulates green investment, creates employment opportunities, and reduces infrastructure maintenance costs (Raymond et al., 2017; UNEP, 2024).

2. Theoretical Background

2.1 The Importance of NbS for Cities and Urban Planning

Nature-based Solutions (NbS) are increasingly recognised as context-specific and adaptive urban policy tools that can respond to particular societal needs while delivering multiple co-benefits. Cities such as Rotterdam, Copenhagen, and Singapore have already incorporated NbS into spatial planning, climate risk management, and urban design frameworks (Frantzeskaki, 2019).

Recent research also highlights the close relationship between NbS and urban planning and land-use systems, demonstrating their potential to enhance urban resilience, public health, and social inclusion (de Luca et al., 2021). Practical applications such as permeable green spaces, green walls, and green roofs serve as illustrative examples. NbS has also been embedded within the Sustainable Development Goals (SDGs), no longer serving solely as a conservation tool but evolving into a comprehensive strategy that integrates spatial planning, social policy, and infrastructure development.

For urban planners, NbS represents not only a means for adaptation and carbon reduction, but also a critical strategy for ecological restoration, social equity, and sustainable development. It enables the integration of multiple urban challenges and supports transformative change in cities (Liu, Jay & Chen, 2021).

2.2 Practical Applications and Classifications of NbS in Urban Spaces

The European Union has actively promoted Nature-based Solutions (NbS) through major initiatives such as Horizon 2020 and Horizon Europe, applying them widely across urban renewal domains including green corridor development, water system integration, biodiversity enhancement, and brownfield regeneration. Among these efforts, the Naturvation project's development of the Urban Nature Atlas (UNA) stands out for systematically collecting empirical NbS cases from European cities, serving as a key reference for public authorities and planners worldwide (Almassy, Maia & Pinter, 2022).

Bona et al. (2023) analysed 24 NbS projects across European cities, categorising them by spatial scale into micro (buildings and plots), meso (communities and neighbourhoods), and macro (cities and regions), thus facilitating multi-level integration. Liu, Jay, and Chen (2021) classified NbS based on urban planning terminology, including interventions such as green roofs, vertical greening, and river restoration. Pirouz et al. (2024) further emphasised that systematically embedding NbS into planning frameworks helps reduce dependence on natural resource consumption while promoting the integration of ecological services and social well-being.

NbS can achieve multiple objectives—including climate adaptation and resource circularity—by combining green infrastructure interventions such as urban forests and rain gardens across different spatial scales. Its advancement also depends on cross-sectoral collaboration, policy incentives, and financial instruments to transition from pilot initiatives to institutionalised models. As such, NbS should not be viewed merely as a spatial intervention tool, but rather as a core institutional strategy for urban development (Pirouz et al., 2024).

2.3 Challenges in Implementing NbS in Urban Planning Policies

According to the UNDP Ukraine (2021) report, although certain policy documents in Ukraine have begun to reference Nature-based Solutions (NbS), the term is still largely absent from most urban planning, environmental protection, and climate adaptation legislation. While the current legal framework offers potential support, it lacks specific provisions and implementation guidelines. The report calls for the urgent formal integration of NbS into legal statutes, planning documents, and technical standards, alongside the enhancement of institutional, financial, and educational support systems to meet the demands of sustainable urban governance.

Even in countries where NbS has reached a more advanced stage of development, its application in urban planning often encounters conceptual stagnation, a lack of operational frameworks, and the absence of monitoring mechanisms. Moreover, the role of urban planning departments remains unclear, highlighting the persistent gap between academic discourse and practical implementation (Dumitru et al., 2020). As a result, effectively integrating NbS into urban plans and infrastructure strategies has become a key priority for many nations seeking to advance sustainable and climate-resilient development (Xie & Bulkeley, 2020; Wickenberg et al., 2021).

2.4 Development Trends and Research Gaps in Taiwan

Taiwan's complex spatial characteristics and governance structures differ significantly from those of European countries, resulting in a comparatively late start in developing and applying Nature-based Solutions (NbS). Relevant research has only recently gained traction, initially assessing ecological impacts and effectiveness in rural contexts to establish localised guidelines and models. Responding to the NbS principle of triple social, environmental, and economic benefits, studies emphasised enhancing urban resilience (Chen, 2020; Chiu et al., 2024). Subsequently, Taiwan's academia and policymakers clarified and deepened NbS definitions, core concepts, and practical frameworks (Li, 2022), increasingly focusing on urban spatial governance and climate change adaptation through policy frameworks that emphasise spatial re-naturalisation and integrated multi-benefit approaches (Chou et al., 2023). Further studies explored opportunities from spaces released by building setbacks for NbS implementation, such as green infrastructure, permeable pavements, and tree canopy expansion, noting green infrastructure design as key to urban effectiveness (Tsai, Hsu & Lin, 2023).

Policy-wise, Taiwan initiated action through drafting the 2012 "National Climate Change Adaptation Policy Framework" (Shih, 2024). Responding to growing global emphasis on NbS, the National Development Council in 2022 led cross-ministerial meetings, resulting in consensus to integrate NbS into climate adaptation policies, with the Forestry and Nature Conservation Agency of the Ministry of Agriculture coordinating cross-sectoral implementation. Recently, the Executive Yuan formally approved the "National Climate Change Adaptation Action Plan (2023–2026)", embedding NbS strategically within national climate governance and promoting cross-departmental collaboration. This plan positions NbS as a pivotal tool and core policy philosophy.

Despite active promotion, a gap remains between NbS theory and practice. While individual case studies have yielded valuable insights, comparative analyses across urban or regional contexts remain limited, confining applications to specific scenarios (Chou et al., 2023). Public and professional awareness of NbS remains vague, with institutionalised planning methods and technical guidelines still lacking. Moreover, NbS has yet to be systematically integrated into urban planning and building regulations, restricting effective implementation. At the local government level particularly, improvements in technical capacity, budgets, and access to reference cases are urgently needed.

2.5 Kaohsiung City as a Case Study: Opportunities and Challenges

Against this backdrop, Kaohsiung City—one of Taiwan's six special municipalities—stands out as a potential demonstration site for implementing Nature-based Solutions (NbS), owing to its industrial transformation and high-density urban development. However, it also faces distinct challenges compared to other international contexts. In recent years, Kaohsiung has actively sought to transition from a heavy industrial city to a smart, low-carbon, and sustainable green metropolis, developing locally adaptive strategies to address climate risks, enhance ecological resilience, promote social equity, and drive green economic development.

According to the 2024 Kaohsiung Voluntary Local Review, the city government has aligned its policy framework with the Sustainable Development Goals (SDGs) and has actively advanced sponge city initiatives and green infrastructure construction. To date, 36 stormwater retention ponds have been completed within development sites, along with 25 publicly constructed retention ponds. The total area of urban green space has reached 2,536 hectares. Furthermore, the Kaohsiung House 4.0 programme promotes vertical greening and energy-efficient building design. A dedicated Sustainable Development and Climate Change Response Council has been established to coordinate cross-departmental resources, strengthen urban resilience, and expand the deployment of nature-based infrastructure.

Nonetheless, current discussions and policy initiatives remain fragmented. The key challenge now lies in how to systematically incorporate NbS into urban planning frameworks and effectively integrate natural elements into spatial strategies.Accordingly, this study adopts an urban planning perspective to examine the feasibility and obstacles of integrating NbS in Taiwan, using Kaohsiung City as a case study. It focuses on two distinct areas: Aozihdi, a newly developed zone transitioning from agricultural use; and Gushan, an older district vulnerable to flooding. By reviewing planning documents and spatial strategies, the study assesses the potential and limitations of NbS implementation in these contexts and offers locally grounded integration proposals.

Drawing on international experience, it aims to provide concrete strategies to strengthen Kaohsiung's resilience and guide its sustainable transformation, while also serving as a policy reference for other cities seeking to pursue NbS as a dual pathway toward climate adaptation and long-term sustainability.

3. Methodology

3.1 Research Design

Many studies have employed NbS matrix systems to examine relevant indicators and the approaches and status of policy integration (Goličnik Marušić, Dremel and Ravnikar, 2023), viewing them as strategies tailored for different urban contexts (Zwierzchowska et al., 2019). Researchers have combined matrix systems with Strategic Environmental Assessment (SEA) frameworks to promote the legal integration of NbS into urban planning, enabling comprehensive environmental and regulatory assessments at early policy stages, thereby reducing future implementation risks and improving environmental outcomes (Figueiredo Gallardo et al., 2022). Consequently, this research aims to develop an integrated conceptual framework, systematically embedding NbS into each primary stage of SEA to enhance the overall resilience of urban land-use planning in response to climate change. By systematically aligning diverse NbS strategies with SEA planning phases corresponding to climate impacts, the study seeks to facilitate climate adaptation-oriented urban planning practices (San Jose et al., 2025).

This research uses Kaohsiung City, Taiwan, as a demonstration case, selecting detailed plans corresponding to primary urban plans for analysis. This approach allows a consistent and clear analytical framework and comparative benchmarks, as detailed plans typically reflect the spatial strategies and land-use implementation from primary plans. By excluding specific, case-oriented detailed plans such as redevelopment or special development zones, the study avoids heterogeneity issues arising from differences in regulations and planning objectives, ensuring more generalisable and representative results.

To further assess NbS applicability and challenges in varying urban contexts, the research focuses on two representative spatial types: (A) Gushan District's detailed plan, an early-developed urban area with high flood risk, whose drainage systems and topography are sensitive to climate impacts, suitable for exploring NbS resilience strategies in built environments; and (B) Aozihdi area's detailed plan, transformed recently from agricultural land to urban uses, representing one of Kaohsiung's key urban expansion zones(Table 1). Its recent development and planning flexibility facilitate examining NbS as a proactive development tool. These two areas reflect different phases of Kaohsiung's urban development, addressing diverse climate risks and governance needs, thus providing valuable comparative insights and policy implications.

Table 1: Strategic Environmental Assessment Matrix

region	Assessment Aspects (Key Risks/Challenges)	
A	Key Risks	• Located near the mouth of the Love River, the area faces dual flood risks from tidal surges and heavy rainfall. • Dense development has resulted in a lack of green space connectivity, undermining ecosystem functions and urban resilience.
	challenge	• Hydrological Risks – Water Resource Management • Ecological Conservation – Green Spaces, Habitats and Biodiversity, Climate Adaptation and Restoration, and Mitigation Actions.
B	Key Risks	• The area was formerly rezoned from agricultural land and has undergone extensive residential and commercial development, resulting in high development pressure and population concentration. • The area is low-lying and prone to flooding during heavy rainfall.
	challenge	• Hydrological Risks – Water Resource Management • Warming Risks – Climate Adaptation and Restoration, Mitigation Actions, and Environmental Quality

3.2 Data Collection

Literature indicates that Taiwan has actively explored and developed NbS primarily within the last five years Systematic promotion of Nature-based Solutions (NbS) in Taiwan only began to take shape in the past five years, approximately since 2020 (Lin, Chan, and Hsu, 2021). This study uses detailed urban plans completed in Kaohsiung between 2020 and 2025 as its core dataset, with a particular focus on cases from the most recent two years that contain NbS-related provisions or spatial strategies. Selected samples include three detailed plans from the Gushan District and eight from the Aozihdi area. All materials are sourced from officially published planning documents and maps by the Kaohsiung Urban Development Bureau, encompassing a wide range of spatial typologies and enabling analysis of NbS application potential.

3.3 Analytical Process and Methods

This study adopts a mixed-methods approach, combining qualitative and quantitative techniques to systematically assess the representation and spatial appropriateness of NbS within urban planning texts (Sarabi et al., 2022). The process begins with a literature-based compilation of keywords related to NbS and green infrastructure, as well as the corresponding environmental and social challenges they address, forming the basis of an evaluation indicator list. The NbS matrix method is then applied to conduct clause-by-clause analyses of the Gushan and Aozihdi plans, identifying the frequency and proportion of relevant keywords to quantify the extent of NbS integration.

Further analysis is carried out using the Strategic Environmental Assessment (SEA) framework to evaluate each area's capacity to respond to key challenges such as hydrological risks and the urban heat island effect. From a regulatory perspective, the study assesses the potential environmental impacts of the plans and the depth of NbS integration. A scoring system is employed to identify implementation gaps, based on which targeted recommendations for improvement are proposed.

3.4 NbS Typologies and Scope of Analysis

This study draws on the policy framework "Building a Resilient Greater Bay Area through Nature-based Solutions", along with other scholarly sources (Debele et al., 2019), to adapt the classification of NbS for urban environments in Asian cities. The classification is structured into three main categories:

(1) **Blue Infrastructure:** Centred on water resource management, this includes riverside and waterfront systems and coastal wetland systems. Key functions encompass flood adaptation, water purification, and aquatic habitat maintenance.

(2) **Green Infrastructure:** Focused on terrestrial ecosystems and urban greening, it includes open spaces (e.g., parks, greenbelts) and ecological spaces (e.g., protected areas, habitats), providing recreational services and enhancing biodiversity.

(3) **Hybrid Infrastructure:** Combining green infrastructure and grey engineering to create synergistic benefits, this category includes detention ponds, permeable pavements, vertical greening on buildings, and ecological corridors.

To ensure statistical accuracy and analytical consistency, the study applies a set of exclusion criteria: repeated mentions from the same source are counted only once; interventions lacking ecological functionality or those that are purely engineering-oriented are excluded; vague or non-specific terms (e.g. references to "greening" without classification) are not included; existing infrastructure that has not undergone retrofitting is excluded; and appendices or procedural documents are disregarded unless they contain specific NbS design descriptions.

4. Results

4.1 Distribution of NbS Types

From the distribution of NbS types in urban planning documents over the past five years, both Gushan and Aozihdi districts primarily emphasise green open spaces (e.g., urban parks, greenery), representing the most frequently mentioned NbS measures. Gushan had 17 occurrences(Table 2), while Aozihdi had 56(Table 3), highlighting urban greening as the current priority NbS strategy. In mixed NbS categories, Aozihdi notably shows greater diversity and frequency of application compared to Gushan. Although Gushan also mentions permeable paving and

green corridors, these appear less frequently, and ecological conservation-oriented NbS are entirely absent, indicating a stronger emphasis on landscape enhancement and spatial reuse. However, the frequency of NbS mentions, while indicative of strategic preferences, is insufficient to reflect actual implementation effectiveness or institutionalisation.

Table 2: Quantification of Frequencies in the NbS Relevance Matrix -Gushan District

Location	Nature-based Solution (NbS) Categories Based on Nature as the Solution frequency Proportion of NbS-related provisions			Documents from Gushan District within the past five years	
city	blue	River, Riverbank	Riverside and waterfront parks	1	1. Riverbank restoration transformed into a riverside park. (100%)
		coast	Coastal wetland	0	
	green	Open space	*Urban Park, Greening (planting, tunnels)	*17	1. The establishment or expansion of parks and green spaces (an increase in quantity)(59%) 2. Land Resource Integration and Conversion (including support for greening (strategies)(29%) 3. Disaster Prevention, Evacuation, and Resilience Functions(12%)
		Ecological space	Nature/Ecological Reserve	0	
	Hybrid	Open space	Flood retention function	0	
			Permeable pavements and waterways (natural water management)	1	1. Pavement permeability improvement (basic pavement renewal)(100%)
		Architectural space	Building Greening (Green Roofs, Green Walls, etc.)	0	
		semi-open space	Atrium and Rain Garden	0	
		ecological space	Green infrastructure network, Pedestrian trail, Green corridor	10	1. Utilization of the Green Corridor after Railway Undergrounding(70%) 2. Integration of Blue-Green Infrastructure Network(30%)

Table 3: Quantification of Frequencies in the NbS Relevance Matrix-Aozihdi District

Location	Nature-based Solution (NbS) Categories Based on Nature as the Solution frequency Proportion of NbS-related provisions			Documents from **Aozihdi District** within the past five years	
city	blue	River, Riverbank	Riverside and waterfront parks	1	1. Construct a waterfront park and recreation area.(100%)
		coast	Coastal wetland	0	
	green	Open space	***Urban Park, Greening (planting, tunnels)**	***56**	1. **Establishment or expansion of parks and green spaces (quantitative increase)(50%)** 2. Ecological education and multifunctional greening (qualitative enhancement) (30%) 3. Disaster prevention, evacuation and resilience functions(13%) 4. Greening aesthetics of blocks and boundaries.(7%)
		Ecological space	Nature/Ecological Reserve	0	
	Hybrid	Open space	Flood retention function	5	1. Detention basins and stormwater retention facilities(100%)
			Permeable pavements and waterways (natural water management)	9	1. Permeable Pavement Installation (Base Pavement Upgrading)(56%) 2. Stormwater Retention and Natural Drainage Facilities(44%)
		Architectural space	Building Greening (Green Roofs, Green Walls, etc.)	3	1. Building setback greenbelt and site green coverage ratio(100%)
		semi-open space	Atrium and Rain Garden	0	
		ecological space	Green infrastructure network, Pedestrian trail, Green corridor	116	1. Utilization of the Green Corridor after Railway Undergrounding (62.5%) 2. Linking Ecological Corridors and Species Habitats(37.5%)

4.2 NbS Application Intensity and Clause Proportions

The NbS matrix analysis reveals that both areas have included a considerable proportion of NbS-related clauses in their urban planning documents, reflecting their respective emphasis and priorities at the planning stage.

In Gushan district, NbS clauses focus predominantly on 'green open spaces' (17 clauses), with new or expanded public green spaces comprising 59%, highlighting an aim to increase overall greenery. Land consolidation and adjustments to green spaces account for 29%, indicating an attempt to identify greening opportunities through spatial reorganisation in high-density settings. Greening combined with disaster prevention accounts for only 12%, suggesting a supplementary role. Mixed-type NbS mainly involve green corridors and reuse of underground spaces (70%), emphasising regeneration and spatial revitalisation, with permeable paving and waterway design at 30% (Table 2).

In Aozihdi, 'green open spaces' are central (56 clauses), reflecting a strong emphasis on green infrastructure and ecological integration during urban development. New or expanded parks and green spaces constitute the primary policy direction (50%), while multifunctional green areas combining ecological education and aesthetic landscaping comprise 30%, underlining educational and landscape values. Disaster prevention facilities represent 13%, with urban visual greening at 7%. Mixed-type NbS (16 clauses) predominantly focus on green corridors and underground space reuse (62.5%), highlighting spatial connectivity; permeable paving and rainwater management systems represent 37.5% (Table 3).

4.3. SEA Analysis: Spatial Potential and Strategic Evaluation for NbS Integration

The evaluation mainly covers three core dimensions: strategic focus, implementation strength, and site-specific identification. The scoring criteria reference Fischer & Gazzola's (2006) SEA implementation study, which employs a three-level rating (high, medium, low) to compare institutional effectiveness, as well as the IPCC Fourth Assessment Report (AR4), which uses likelihood scales such as 'very likely (>66%)', 'likely (33–66%)', and 'unlikely (<33%)' for quantifying scientific evidence strength. This approach, recognised internationally for semantic grading, continues to be applied in IPCC's Sixth Assessment Report (AR6), thereby forming a combined assessment standard(Table 4).

When assessing the focus of urban-plan provisions or design elements, one judges whether a clause explicitly addresses a specific risk or challenge—such as flooding or ecological crises. If the wording directly and concretely corresponds to such challenges, it is deemed "high focus," indicating a clear, purpose-driven strategy. If it only partially addresses the challenge, leaving ambiguity or lacking full implementation detail, it is classified as "medium focus," showing that policy intent is emerging but still open to refinement. Conversely, if a clause makes no explicit reference to any risk or response and remains at the level of abstract vision, it is regarded as "low focus," signifying that the strategy lacks specificity and actionable guidance.

When evaluating implementation strength, clauses with high strength (≥ 66 %) are typically expressed in unequivocal, legally binding language—common terms include "shall," "must," "may not," "in accordance with...," or "only if," for example: "New buildings shall incorporate permeable paving over at least 30 % of the site." Medium strength clauses (33–66 %) combine mandatory and encouraging language—terms such as "encourage," "recommend," "should" or "may" appear, some with legal effect and others merely advisory, for instance: "The site may include an ecological detention basin" or "Developments should retain native planting." Low-strength clauses (≤ 33 %) are largely optional, lacking legal compulsion and reliant on developer discretion; wording such as "may," "encourage," "recommend" or "subject to conditions" is used, for example: "It is encouraged to adopt low-impact development principles" or "The site may consider a retention basin to improve runoff."

Site-specific identification is judged by whether a clause clearly specifies applicable locations and spatial design requirements. High identification (≥ 66 %) occurs when clauses explicitly name districts, plots or zoning categories and provide concrete spatial standards. Medium identification (33–66 %) applies where clauses mention applicable types or spatial approaches but remain vague or lack detailed criteria (e.g. "applicable to development zones" or "may include ecological spaces"). Low identification (≤ 33 %) is when clauses are purely conceptual—merely referring to "enhancing green amenity" or "developing green spaces" without specifying any location, type or method—indicating low site specificity.

By applying these criteria, one can systematically gauge a planning policy's strategic focus, enforcement efficacy and on-the-ground feasibility, thereby informing subsequent policy diagnosis and optimisation.

Table 4: SEA Scoring Criteria

Evaluation Dimension	Definition	Evaluation Criteria
Priority Dimension (Strategic Focus)	Assess whether the urban planning regulations or designs explicitly address this risk or challenge.	1. Fully addresses the challenge with appropriate and clearly defined measures → High 2. Partially addresses the challenge, but with room for improvement. → Medium 3. Fails to address any challenges → Low
Implementation strength (Legal Mandate of Provisions)	Assess whether the provisions in the planning documents are 'optional' or 'mandatory'.	1. ≥ 66 % of clauses are explicit and mandatory with non-compliance affecting planning approval → High implementation strength 2. 33 - 66 % of clauses blend compulsory and encouraging language, indicating a middle-age of enforcement → Medium implementation strength 3. ≤ 33 % of clauses are framed as encouragement, guidance or optional, relying on developer discretion → Low implementation strength
Site-specific Identification (Implementation Potential)	Assess whether the applicable location is clearly specified and whether spatial design conditions are provided.	1. ≥ 66 % of clauses explicitly specify applicable locations and operational conditions → High site specificity 2. 33 - 66 % of clauses mention locations or spatial conditions but remain partly vague → Medium site specificity 3. ≤ 33 % of clauses make no concrete reference to locations or conditions → Low site specificity

Justification and indicative references

1. **Priority Dimension (Strategic Focus):**
   Frantzeskaki (2019): Explores whether Nature-based Solutions (NbS) serve as a core strategy for urban transformation and identifies how they explicitly correspond to specific challenges for evaluation.
2. **Implementation Intensity (Legal Mandate of Provisions)**
   Kabisch et al. (2016): pointed out that many urban Nature-based Solutions (NbS) measures are merely recommendatory provisions, resulting in low implementation rates.
   Gómez Martín et al. (2020): encouraged planning documents to include clearly action-oriented clauses corresponding to specific risks.
3. **Site-specific Identification (Implementation Potential)**
   In the study by Xie, L. and Bulkeley, H. (2020) within the Urban Nature Atlas (UNA), it is suggested that assessing the spatial specificity of NbS design holds a certain level of importance.
   San Jose et al., (2025) and Figueiredo Cardenia et al. (2022), when applying the SEA framework, emphasize that aligning Nature-based Solutions (NbS) with specific spatial locations leads to higher implementation potential. If the spatial areas are not explicitly defined, the likelihood of effective strategy implementation is reduced.

The analysis indicates that Gushan's NbS clauses concentrate on expanding urban green spaces. While this partly addresses ecological conservation, provisions for water management, blue–green corridor connectivity and biodiversity remain underdeveloped. Only 31% of clauses explicitly tackle climate risks, and most are advisory rather than legally binding. Although 70% specify particular locations, the overall profile is "moderate focus, low enforceability, high site specificity."

In Aozihdi, green space expansion also predominates, with additional clauses on water management reflecting stronger support for both total green cover and adaptive reuse of vacant sites. However, references to hydrological or heat risk measures are still few. About 58% of its clauses address climate challenges with moderate enforceability, and 85% name exact locations, yielding a "moderate focus, moderate enforceability, high site specificity" profile.

Overall, despite Kaohsiung's green energy ambitions, regulatory and local context responses need strengthening. The gap between Gushan and Aozihdi stems largely from differing legal enforceability: Aozihdi's higher proportion of mandatory, location specific clauses establishes a firmer implementation basis, whereas Gushan's advisory approach limits its potential. Accordingly, this study stresses that successful NbS adoption depends not only on spatial suitability but also on clear, enforceable institutional design. To this end, a comparative case analysis framework will examine clause types, implementation responsibilities, spatial clarity and strategic integration to pinpoint institutional bottlenecks and inform future policy refinements.

Table 5: Strategic Environmental Assessment Matrix

region	Assessment Dimensions of NbS Implementation (Regulatory Provisions)			General Description
A	Focus area	Project Intensity	regional identification	Although the location is clearly specified, the overall legal provisions lack sufficient enforceability, and there is still room for improvement in strategic focus.
	Actively expanding green spaces, but still insufficient in flood prevention and blue-green infrastructure integration.	Only about 31% of the provisions are legally binding regulations, resulting in relatively limited enforceability.	Only 69% of the provisions explicitly specify applicable locations (such as along the Love River, Shoushan, etc.).	
	◈ Moderate potential	◈ Low potential	◈ High Potential	
B	Emphasizes the enhancement of green spaces and considers stormwater retention, but still requires improvement in addressing hydrological risks.	Approximately 58% of the provisions are legally binding regulations, but there is still room for improvement in enforcement capacity.	85% of the regulations explicitly specify applicable locations (such as Aozihdi Forest Park).	The location is clearly specified, and the regulation has a moderate level of enforceability, but there is still room for improvement in strategic focus.
	◈ Moderate potential	◈ Moderate potential	◈ High Potential	

5. Discussion

5.1 International Case-Comparison Methodology

This study uses the Urban Nature Atlas (UNA) to identify an international city—Hamburg, Germany—with spatial characteristics and climate risks akin to those of Kaohsiung. Employing a case-comparison framework, it contrasts the two contexts to pinpoint local challenges in climate adaptation and urban resilience, extract policy-implementation lessons from Hamburg's successes, and reveal gaps in Kaohsiung's spatial planning, regulatory application, inter-agency collaboration and implementation resources, thereby bolstering the prospects for institutionalising NbS locally (Dignum et al., 2020).

5.2 International Case-Comparison Methodology

Hamburg's HafenCity, situated on the banks of the Elbe and formerly an industrial and port district, has been transformed into a high density, mixed use urban quarter. Its low lying topography and extensive impermeable surfaces have long exposed it to flooding and the threats posed by extreme rainfall under climate change, while ecological restoration and infrastructure renewal remain challenging.

The proliferation of dense housing and infrastructure has dramatically increased surface runoff, overwhelming the city's drainage systems; coupled with increasingly frequent and intense downpours, this exacerbates urban inundation, surface water flooding and water pollution risks. In response, in 2009 the City of Hamburg and the municipal water utility, HAMBURG WASSER, launched the RISA (RegenInfraStrukturAnpassung) programme to establish an integrated, nature based stormwater management system. RISA's objectives are to restore the city's natural hydrological balance, boost on site rainwater retention and infiltration, enhance flood resilience, protect aquatic ecosystems and incorporate rainwater as a key element of urban design and green infrastructure. The initiative unfolded in four phases: in 2010, comprehensive risk analysis and climate scenario modelling; in 2011, the development of guiding principles to align stormwater policy with land use planning; pilot demonstrations of permeable pavements, green roofs and retention landscapes; and, in 2015, the publication of the Regenwasser 2030 Structural Plan, fully integrating stormwater policy into urban governance. A cross departmental framework brought together experts in urban planning, water engineering, transport and landscape architecture, supported by GIS based vulnerability mapping and site assessment tools to inform spatial prioritisation and policy design. Despite regulatory ambiguities, overlapping departmental responsibilities, varied site conditions and limited public engagement, RISA overcame implementation barriers through regulatory reinforcement and institutional transformation. Ultimately, the Regenwasser 2030 Plan became a milestone in Hamburg's evolution into a water sensitive city, demonstrating a systematic approach—from technical innovation and governance integration to regulatory reform and public education—that not only enhances urban climate resilience and spatial quality but also offers a highly replicable nature based water management model for other port and high density cities.

6. Institutional Comparison and Conclusions

Contrasts two institutional models for integrating NbS, focusing on governance integration, legal mandates and interdepartmental cooperation rather than spatial scale or project count. In Hamburg, the RISA system explicitly designates climate adaptation and water management as statutory, cross-departmental objectives, integrating land use, building regulations and drainage via the HafenCity Masterplan so that resilience underpins rather than merely embellishes urban planning(Table 6).

Table 6: Comparative Analysis of International Case Studies

Analytical dimension	(Aozihdi + GushanDistrict) (2019–2024)	Case: Germany RISA – Hamburg (2005-2015)
Major Types of Implemented Nature-based Solutions (NbS)	Urban parks and greening, greenway trails and corridors, permeable pavements, detention and stormwater management facilities, and building greening	Water Resource Management Green Spaces and Sustainable Urban Drainage Systems.
Implementation Instruments (Initial Institutional Arrangement)	Urban planning, urban renewal, and BOT implementation have not yet established an integrated stormwater management tool.	Project-Oriented Climate Adaptation Plan and Spatial Integration HafenCity Masterplan + RISA System (Rainwater Adaptation Platform).
Regulatory and Planning Integration	Although the concept has been incorporated into detailed plans, there is a lack of legally established NbS indicators and institutionalized financial support.	Explicitly incorporate into the Urban Planning Act and Building Act, establish a stormwater management fund and development obligation mechanism.
Implementation approach	Low level of departmental integration, primarily driven by urban development agencies; community participation is preliminary or unclear.	Establish the RISA coordination platform to enable cross-sectoral integration (including environmental protection, water resources, urban planning, real estate developers, and communities).
Key Development Priorities	Some spaces show potential (such as green buildings), but all are implemented through general green infrastructure.	Integrate data-driven engineering and land policies, and provide pilot implementations as models for other cities to follow.

In Kaohsiung, by contrast, NbS measures such as greening, retention basins and permeable paving remain at case-by-case or advocacy stages, lacking clear legal status, mandatory standards or defined responsibilities; departmental collaboration platforms (e.g. urban development, water, environment and construction) are undeveloped and agencies largely act independently, preventing systemic benefits. Kaohsiung's planning framework also lacks the technical integration and task-oriented governance exemplified by Hamburg's institutional platforms and pilot mechanisms. This analysis not only exposes Kaohsiung's governance bottlenecks but also offers transferrable lessons from international practice to inform policy innovation and deepen institutional capacity. Success will require elevating NbS from planning tool to statutory core by setting explicit targets and tasks, establishing cross-departmental governance structures, enacting regulatory frameworks and spatial instruments, and involving stakeholders at all levels, thereby enabling Taiwan's urban planning system to achieve a truly nature-based, sustainable and climate-adaptive transformation.

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