Research on the Application of Ecosystem-based Disaster Risk Reduction (Eco-DRR) in Resilience Assessment for Industrial Parks in Taiwan

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1. Introduction

Climate change has intensified the frequency and severity of extreme weather events, posing unprecedented challenges to industrial infrastructure worldwide. In Taiwan, the industrial sector is the backbone of the national economy, yet many industrial parks are located in areas highly susceptible to flooding, typhoons, and other climate-related hazards. Traditional disaster risk reduction strategies have historically relied heavily on "grey infrastructure," such as concrete levees and drainage systems. However, as the limitations of engineering solutions become apparent in the face of escalating climate risks, there is a growing consensus on the need for more sustainable and resilient approaches.

Ecosystem-based Disaster Risk Reduction (Eco-DRR) has emerged as a critical paradigm, advocating for the sustainable management, conservation, and restoration of ecosystems to reduce disaster risk and achieve sustainable and resilient development. Despite its growing recognition, the application of Eco-DRR within the specific context of "industrial parks"—areas characterized by high impervious surfaces and intensive economic activity—remains under-researched.

This study aims to bridge this gap by establishing a comprehensive Eco-DRR assessment framework tailored for Taiwan's industrial parks. The research objectives are threefold: (1) to clarify the existing autonomous adaptation capabilities of industrial parks; (2) to construct a scientifically rigorous evaluation indicator system using the Fuzzy Delphi Method (FDM); and (3) to determine the relative weight of these indicators using the Fuzzy Analytic Hierarchy Process (FAHP) to propose a portfolio

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2. Theoretical Framework and Methodology

To ensure the assessment framework is both theoretically sound and practically feasible, this study employs a mixed-methods approach involving a two-stage expert consultation process.

2.1 Study Scope and Context

The research focuses on industrial parks under the jurisdiction of manufacturing authorities in Taiwan. These zones are critical to the global supply chain but often lack integrated ecological planning. The study reviews literature on disaster resilience, green infrastructure, and industrial ecology to propose an initial set of evaluation dimensions and indicators.

2.2 Phase I: Indicator Selection via Fuzzy Delphi Method (FDM)

The first phase of the study utilized the Fuzzy Delphi Method to screen and validate the proposed indicators. FDM was chosen to address the ambiguity and subjectivity inherent in expert opinions.

• Expert Panel Composition: A panel of seven experts was convened, representing a balanced mix of the public sector (government officials managing industrial parks and net-zero policies), the private sector (engineering consultants with experience in urban disaster prevention and park development), and academia (professors specializing in urban planning, spatial design, and climate adaptation).

• Screening Criteria: The experts assessed the importance of potential indicators. The study established strict thresholds for indicator retention: an indicator was rejected if its "test value" was less than 0 (indicating a lack of convergence) or if the "expert consensus value" (G_i) was less than 6.

2.3 Phase II: Weighting via Fuzzy Analytic Hierarchy Process (FAHP)

Following the establishment of the indicator system, the study applies the Fuzzy AHP method. This phase aims to calculate the specific weights of the dimensions and indicators. By using triangular fuzzy numbers to represent expert judgments, FAHP allows for a more nuanced understanding of the relative importance of each criterion, addressing the uncertainty often present in decision-making processes regarding environmental resilience. (Note: The FAHP analysis is currently in the final computation stage, and the final weighted model will be presented at the congress).

3. Empirical Results: Construction of the Assessment Framework

The most significant finding of this study to date is the rigorous refinement of the Eco-DRR assessment framework through the Fuzzy Delphi analysis.

3.1 Screening of Indicators

The initial framework comprised five dimensions and 22 indicators. Post-FDM analysis, the framework was refined to 17 key indicators across five dimensions. The screening process yielded critical insights:

• Deleted Indicators: Five indicators were removed due to low consensus or lack of convergence. These included "Transaction prices of factories around green spaces" (C1), "Regional joint defense organizations" (D1), "Police and fire units" (D2), "Medical units" (D3), and "Disaster relief supplies" (D4). The exclusion of these items suggests that experts view external support systems and market values as secondary to the intrinsic resilience features of the park itself.

• Retained Exceptions: Two indicators, "Disaster prevention training and education" (D6) and "Regional disaster prevention plans" (D7), had consensus values slightly below the threshold ($Gi = 5.91 < 6$). However, they were retained because their test values showed convergence (> 0), and literature strongly supports the necessity of soft communication mechanisms in resilience.

3.2 The Finalized Indicator System

The final validated framework consists of the following structure:

(1) Ecological Benefits: Including Green coverage rate (A1), Connectivity of green spaces (A2), and Diversity of planting structure (A3).

(2) Human Well-being: Including Drainage and flood control efficiency (B1), Smart disaster monitoring management (B2), Implementation of green manufacturing (B3), and Ambient air quality (B4).

(3) Economic Feasibility: Including Renewable energy installation (C1), Energy

demand intensity (C2), and Water demand intensity (C3).

(4) Social Participation: Including Disaster warning mechanisms (D1), Disaster education and drills (D2), and Alignment with local disaster plans (D3).

(5) Disaster Risk: Including Population exposed to risk (E1), Potential disaster impact area (E2), Shelter capacity (E3), and Emergency access/rescue accessibility (E4).

4. Discussion: The Hierarchy of Resilience

A detailed analysis of the expert consensus values reveals a profound hierarchy in what is considered essential for industrial park resilience. The arithmetic mean of the consensus values for the five dimensions resulted in the following ranking of importance:

(1) Economic Feasibility (7.22)

(2) Ecological Benefits (7.10)

(3) Disaster Risk (6.95)

(4) Human Well-being (6.88)

(5) Social Participation (6.26)

4.1 "Passive Protection" over "Active Management"

The results indicate that experts prioritize "Economic Feasibility" and "Ecological Benefits" above all else. This ranking suggests a paradigm where "passive protection" mechanisms—grounded in resource efficiency (energy/water) and robust ecological foundations (green infrastructure)—are viewed as the primary line of defense.

In contrast, "Social Participation," which represents "active disaster risk management" (such as educational drills, organizational planning, and warning systems), was ranked lowest. This does not imply that social measures are unimportant; rather, it highlights a fundamental structural logic: Effective resilience must first be built on a solid physical and ecological infrastructure. Without the "hard" foundation of efficient resource use and a healthy ecological buffer, "soft" management measures are insufficient to mitigate the impacts of climate change in high-density industrial zones.

4.2 Implications for Planning

The data suggests that future industrial park planning should prioritize the "intrinsic health" of the park. This means designing parks that are resource-efficient and ecologically connected from the outset. The high ranking of Economic Feasibility (specifically renewable energy and resource demand) aligns with the global shift towards circular economies, suggesting that resilience is economically rational.

5. Conclusion and Future Directions

This study successfully establishes a localized and expert-validated Eco-DRR assessment framework for Taiwan’s industrial parks. The application of the Fuzzy Delphi Method has filtered out less relevant indicators and highlighted a critical insight: industrial resilience is rooted first in sustainable resource management and ecological integrity ("passive protection"), and secondarily in social management systems ("active management").

The ongoing phase of this research involves the finalization of the Fuzzy AHP weighting to assign precise numerical values to these priorities. By integrating these weights, the study will conduct a quantitative resilience evaluation of selected industrial parks in Taiwan.

The ultimate contribution of this research will be a Nature-based Solutions (NbS) Strategy Portfolio. Based on the assessment results, this portfolio will offer targeted strategies for different types of industrial parks, guiding policy-makers and park managers to transition from grey-infrastructure dependence to a more resilient, hybrid Eco-DRR model. This research not only fills a gap in industrial land use planning but also provides a replicable methodological framework for other regions facing similar climate challenges.