Asian Journal of Water, Environment and Pollution. 2026;23(2):025220174.
doi: 10.36922/AJWEP025220174

ORIGINAL RESEARCH ARTICLE

Pollution governance through eco-industry integration: Implementing China's Eco-environment Oriented Development planning model

Yayuan Zhang[1], Guoying Dong[1], Wenjia Song[1], Zechen Song[2], Xiuhong Li[1]*, Rongjin Yang[3]*, Le Zhang[3], and Meiying Sun[3]

[1]State Key Laboratory of Remote Sensing and Digital Earth, Faculty of Geographical Science, Beijing Normal University, Beijing, China

[2]School for Environment and Sustainability, University of Michigan, Ann Arbor, Michigan, United States of America

[3]State Key Laboratory of Environmental Criteria and Risk Assessment, Chinese Research Academy of Environmental Sciences, Beijing, China

***Corresponding authors:** Xiuhong Li (lixh@bnu.edu.cn); Rongjin Yang (yangrj@craes.org.cn)

Received: May 28, 2025; Revised: July 13, 2025; Accepted: July 28, 2025; Published online: December 3, 2025

Abstract: In recent years, the eco-environment-oriented development (EOD) model has emerged as a novel approach in China's ecological and environmental governance. This model integrates ecological restoration with industrial development, creating a virtuous cycle in which ecological improvements drive industrial growth, and industrial returns are reinvested to support environmental initiatives. This integration aims to enhance ecological, economic, and social outcomes in a holistic manner. The interrelation between ecological restoration and industrial development is central to the EOD model and is crucial for achieving value-closed-loop systems, financial sustainability, and long-term ecological–industrial synergy. For example, in some regions, restored ecosystems have attracted high-value industries through improved environmental quality and regulatory services, while industrial revenues have been redirected to fund further ecological projects. Despite its potential, research on such interrelations remains limited, with a lack of systematic frameworks for analysis and evaluation. To address this gap, this study focuses on the interrelation between ecological and industrial components within EOD projects, aiming to provide a comprehensive understanding of their mechanisms and practical implications. Through case study analysis, the study first clarifies the conceptual connotation and defining characteristics of these interrelations and establishes a preliminary theoretical framework for understanding ecological–industrial interrelation under the EOD model. It then explores two key dimensions—spatial interrelation and industrial chain interrelation—by analyzing their mechanisms and manifestations. The study further proposes evaluation approaches for each dimension and integrates them into EOD project planning processes to support interrelation-oriented planning and design. The findings offer a systematic methodology and theoretical basis for identifying, evaluating, and designing ecological–industrial interrelations, thereby enriching the theoretical foundation of the EOD model and facilitating its scientific planning and practical implementation.

Keywords: Eco-environment-oriented development model; Interrelation; Ecological–industrial relationship; Pollution governance

1. Introduction

In Asia, particularly in China, pollution remains one of the central challenges in regional environmental governance.[1] With the ongoing processes of urbanization and industrialization, pollution-induced ecological degradation has emerged as a key constraint on sustainable regional development.[2] Although significant progress has been made in pollution control over the past decade, primarily through the implementation of stricter emission standards and the adoption of advanced pollution treatment technologies, these efforts have largely focused on end-of-pipe solutions.[3] Such conventional governance approaches, dominated by engineering-based control measures, have proven inadequate in addressing the growing demand for ecosystem conservation, spatially coordinated planning, and industrial transformation.

Against the backdrop of ecological civilization construction, China has explored a novel approach that integrates ecological protection with high-quality development, namely the Eco-environment-oriented Development (EOD) model.[4] Centered on ecosystem conservation and restoration, the EOD model seeks to establish sustainable pollution control mechanisms by introducing green and low-carbon industries, optimizing spatial layouts, and promoting the synergy between industrial development and ecological functions.[5,6] Unlike traditional governance approaches that treat environmental protection and economic development as separate domains, the EOD model emphasizes multidimensional interrelations between ecological and industrial systems.[7] This integration not only channels the benefits of ecological governance into industrial development but also facilitates the transformation of ecological value into economic value, thereby enabling the recovery of governance costs.[8] The EOD model has demonstrated great potential in China's ecological transition and has become one of the most prevalent project implementation approaches in the field of environmental protection, particularly in water pollution management.[9]

This study focuses on the eco-industry interrelations within the EOD model and proposes a pollution governance pathway based on interrelational mechanisms. First, it reviews the development trajectory and research progress of the EOD model to establish a conceptual and empirical foundation. Second, it defines the connotation of interrelation through case analysis and constructs a pollution governance framework grounded in these interrelations. Finally, it summarizes transferable model components and puts forward policy recommendations and strategic insights applicable to water pollution control in other developing regions of Asia. By drawing on China's experience, this study offers a systematic reference for the exploration of region-specific sustainable governance pathways. Its findings provide a theoretical basis and practical implications for fostering cross-disciplinary and cross-sectoral environmental governance.

2. Literature review

2.1. Research progress on the EOD model

Influenced by global ecological thinking, China began exploring eco-cities as early as the 1980s. Since the 18th National Congress of the Communist Party of China, ecological civilization has been elevated to a national strategy, accelerating the localized development of the EOD model.[10] In response to real-world challenges, such as financing difficulties for ecological projects, unclear pathways for value transformation, and low conversion efficiency, the EOD model has emerged as an innovative approach aiming to establish a positive feedback loop between ecological protection and industrial development—namely, "promoting ecological restoration through industry, and enhancing industry through restoration."[11]

The model's evolution can be divided into four stages: policy initiation, pilot implementation, project pipeline inclusion, and national-level promotion. Under the combined impetus of top-down policy guidance and bottom-up local experimentation, a relatively mature theoretical framework and implementation mechanism have gradually taken shape.[12,13]

Early academic attention to the EOD model focused on theoretical construction and policy analysis. These studies primarily examined the basic logic of eco-industry coordination, the model's applicability, and risk mitigation strategies, with an emphasis on the financial feasibility of ecological projects and the effective transformation of ecological value into economic value.[14] As pilot projects progressed, research expanded to operational dimensions—such as classification of project types, revenue structure analysis, and the design of investment-financing mechanisms—seeking to develop replicable and scalable implementation models.[15]

In recent years, as pilot projects have revealed issues such as uneven design quality, industrial project homogeneity, and weak eco-industrial coupling, research has gradually transitioned from broad, exploratory approaches to more refined, mechanism-oriented topics.[16,17] Specifically, this shift involves a deeper investigation into the underlying mechanisms and processes that drive eco-industrial interactions, rather than merely describing general phenomena. Among these topics, the evaluation of eco-industrial interrelations has emerged as a central focus. The current research now explores multidimensional coupling mechanisms across temporal, spatial, industrial, and value domains. The goal is to construct comprehensive evaluation indicator systems that integrate ecological, economic, and social metrics. These systems are designed to assess the synergies and trade-offs between ecological conservation and industrial development at multiple scales. These efforts aim to enhance the scientific rigor and practical effectiveness of EOD planning, implementation, and post-project evaluation.[18]

At the same time, there has been growing interest in aligning the EOD model with broader Chinese pathways to ecological civilization—such as the "Two Mountains" theory (i.e., "lucid waters and lush mountains are invaluable assets"), mechanisms for realizing the value of ecological products, and the Public–Private Partnership (PPP) model.[19] For example, in Zhejiang province, the "Two Mountains" theory has been implemented through initiatives promoting ecotourism and sustainable agriculture, transforming previously degraded areas into valuable ecological and economic assets. In addition, mechanisms for realizing the value of ecological products have been developed in regions like Jiangsu, where payments for ecosystem services schemes reward farmers for adopting environmentally friendly practices. The PPP model has also been applied in infrastructure projects, such as wastewater treatment plants, where private investment complements public funding to enhance environmental outcomes. Such integration is driving the evolution of the EOD toward a more systematic, integrated, and adaptive governance paradigm.[20] For instance, in the context of urban planning, adaptive management frameworks are being adopted to dynamically adjust land use policies based on real-time environmental and economic data, ensuring continuous alignment between ecological and economic goals.[21]

2.2. Advancements in research on eco-industry interrelations

Against the backdrop of the widespread application of multivariate analysis, the interrelation between ecological and industrial systems has gradually emerged as a key research focus.[22] The current studies primarily concentrate on three aspects: (i) the coupling coordination of ecological–economic systems, which employs system dynamics and multi-scale models to reveal patterns of co-evolution;[23] (ii) the synergistic relationship between the ecological environment and industries, evolving from analyses of single-sector interactions to more complex multi-sectoral couplings through the development of integrated evaluation models;[24,25] and (iii) the interrelated effects between ecological efficiency and industrial agglomeration, utilizing tools such as principal component analysis (PCA)–data envelopment analysis (DEA) and Tobit models to identify underlying mechanisms and regional heterogeneity.[26,27]

For example, in the coupling coordination of ecological–economic systems, models analyze how land use changes, such as urban expansion versus green space preservation, impact long-term economic and ecological health, identifying critical tipping points. In examining the synergistic relationship between the ecological environment and industries, studies have shifted from single-sector analyses to evaluating multi-sectoral interactions.[28] For instance, integrated models assess the combined impact of industrial emissions and agricultural runoff on regional water quality, offering a holistic view of environmental pressures. Regarding interrelated effects between ecological efficiency and industrial agglomeration, PCA–DEA models are used to evaluate the ecological efficiency of industrial clusters, revealing that higher levels of agglomeration often correlate with both increased productivity and heightened environmental pressures. The evolution of the EOD model toward a more systematic, integrated, and adaptive governance paradigm is exemplified by adaptive management frameworks in urban planning. For instance, cities like Singapore implement dynamic zoning policies that adjust land use based on real-time environmental and economic data, ensuring continuous alignment of ecological and economic goals.

Despite advancements in methodology and analytical dimensions, most existing research remains focused on the coupling of localized factors, lacking a framework that treats ecology and industry as components of a complex and integrated system.[29] Under the EOD model, multidimensional coordination between ecological and industrial components has yet to be structured into a unified theoretical framework or supported by robust quantitative methodologies, thus limiting its ability to guide high-quality integrated project design.[30]

At present, research on eco-industrial interrelations still faces issues such as theoretical fragmentation, unclear mechanisms, and insufficient practical guidance.[31] Theoretical fragmentation is evident in the diverse and often disconnected approaches used to study eco-industrial interactions, ranging from economic modeling to ecological assessments, making it difficult to integrate findings across studies. Unclear mechanisms are highlighted by the complex relationships between industrial activities and ecological outcomes, such as the difficulty in quantifying how specific industrial practices impact local biodiversity. Insufficient practical guidance is reflected in the limited availability of actionable tools for policymakers, exemplified by the lack of standardized methods for assessing the ecological footprint of industrial zones. Collectively, these challenges undermine the effective implementation of EOD projects.[32]

3. Methods

3.1. Identification of eco-industry interrelations

To systematically examine the interrelation between ecological and industrial systems, this study adopts the principles of typicality, diversity, and representativeness to select 15 exemplary EOD project cases. Specifically, the principle of typicality ensures that the selected cases reflect common patterns and challenges observed in EOD projects, allowing for generalizable insights. The principle of diversity ensures that the cases cover a range of geographical locations, project scales, and industrial sectors, capturing the variability inherent in EOD initiatives. Finally, the principle of representativeness ensures that the cases are reflective of broader trends and experiences in the field, providing a balanced view of the interrelation dynamics.[33] The selection of the 15 cases was guided by a preliminary scoping review of existing EOD projects, which identified a pool of potential candidates. From this pool, we applied the following indicators to ensure that the cases met the study's criteria: (i) geographical coverage: projects were selected from different regions to capture regional variations; (ii) project scale: projects of varying sizes were included to reflect different implementation contexts; (iii) industrial sector: projects involving various industrial sectors (e.g., manufacturing, agriculture, and tourism) were chosen to ensure sectoral diversity; and (iv) project maturity: projects at different stages of development were selected to capture both emerging and established practices.

These indicators were chosen to ensure that the selected cases provide a comprehensive and balanced representation of the EOD model in practice. The number 15 was determined based on the need to balance analytical depth with the feasibility of managing a large dataset, ensuring that each case could be thoroughly examined while still providing a broad overview of interrelation dynamics.[34] Through in-depth case analysis, the study identified the connotation, dimensions, attributes, characteristics, and mechanisms of interrelation, thereby laying the foundation for constructing a preliminary theoretical framework of eco-industrial interrelation.[35,36]

To enhance the scientific rigor and systematic nature of the analysis, grounded theory was employed as the core methodological approach. A three-level coding process—open coding, axial coding, and selective coding—was applied to relevant policy documents and project case texts. This process enabled the extraction of key concepts, the establishment of logical linkages, and the identification of critical variables and mechanism pathways shaping interrelation formation. The empirical orientation, iterative structure, and capacity for variable abstraction make grounded theory a highly effective tool for theory building in the EOD context, particularly at this stage when theoretical foundations remain underdeveloped.

3.2. Principles for framework design

To transform theoretical research findings into practical application tools, it is necessary to further analyze interrelations and integrate them with EOD project practices, thereby guiding projects in a more scientific and systematic manner. Therefore, this section develops a planning framework for EOD projects based on interrelations, following a systematic analysis of their characteristics across different dimensions.[37]

The framework pursues two main objectives. First, it conducts an in-depth analysis of interrelations across dimensions such as time, space, industrial chain, and value, refining the understanding of interrelations from general to specific, from macro to micro, and from qualitative to quantitative.[38] Second, it introduces interdisciplinary methods and models to provide feasible tools for identifying and designing interrelations in EOD projects. Ultimately, this approach aims to enhance the alignment of planning schemes with regional development needs and to enable the planning and design of EOD projects based on interrelation-driven insights.[39,40] The framework is developed based on the following four key principles:

(i) Scientific rigor and systematic structure

The framework is grounded in robust theoretical foundations and incorporates multidimensional interrelation theories. It integrates qualitative analysis with quantitative evaluation methods to ensure logical coherence and structural integrity.

(ii) Multidimensionality and multi-level structure
Aligned with the full-cycle planning process of the EOD model, the framework adopts a stratified approach to analyzing interrelations across spatial, temporal, industrial chain, and value dimensions. Each dimension is matched with appropriate evaluation methods and planning stages to support comprehensive analysis.

(iii) Practical operability
With a strong orientation toward real-world application, the framework balances theoretical depth with operational feasibility. It considers data availability, methodological complexity, and implementation costs to select suitable models and enhance applicability.

(iv) Contextual adaptability
In response to regional heterogeneity, the framework is designed to be both generalizable and flexible. It incorporates both universal variables alongside region-specific factors to enable tailored adaptation and precise evaluation of EOD projects.

3.3. Methodological approach to framework development

In developing a planning framework for pollution-oriented EOD projects based on eco-industrial interrelation, this study followed a structured approach comprising three main steps. First, it conducted an in-depth analysis of interrelation across multiple dimensions—spatial interrelation and industrial chain interrelation—by examining representative case studies to clarify conceptual definitions and observable patterns, and by tracing theoretical foundations to establish a sound academic basis.[41,42] Second, this study introduced relevant models and methodologies from corresponding fields to enable systematic quantification and assessment of interrelation. Specifically, it employed system dynamics modeling to simulate long-term interactions and identify tipping points; multi-criteria decision analysis to evaluate trade-offs between ecological and economic objectives; PCA to reduce dataset complexity and identify key factors; and DEA to assess project efficiency. These approaches collectively provide a comprehensive framework for analyzing interrelation dynamics and ensuring reproducibility.[43,44] Finally, drawing on the inherent characteristics of EOD projects, particularly their integrated "industry-for-ecology and ecology-for-industry" logic, the study synthesized a practical and structured planning framework grounded in interrelation.

4. Results

4.1. Theoretical framework of eco-industry interrelations under the EOD model

Through extensive grounded theory analysis of numerous EOD practice cases and policy documents, this study developed a theoretical system of eco-industrial interrelation (Figure 1). Interrelation is defined as the interactive relationship between ecological and industrial components within the EOD model, characterized by varying intensities, positive or negative effects, and diverse forms. Ecological governance transmits the external ecological value generated through remediation to industrial activities through interrelation, thereby enhancing industrial development value. Conversely, industrial operations reciprocate by reinvesting profits to support ecological governance, underpinning sustainable ecological restoration.

The study found that interrelation manifests across multiple dimensions, including spatial, industrial chain, temporal, and value aspects, with spatial and industrial chain interrelations being the most critical, shaping the spatial layout and project content of EOD initiatives, respectively. The manifestations and functional forms differed across these dimensions. During EOD project planning, it is essential to identify, evaluate, and design for interrelations across these dimensions, pairing ecological governance projects with industrial development projects that exhibit strong positive interrelations, thereby promoting deeper integration between the two. This fosters the maximization of ecological, economic, and social benefits.

Further analysis clarified the core attributes of the interrelation between ecology and industry in the EOD model, namely strength, direction, manifestation, and sustainability. Strength indicates the degree of mutual dependence, ranging from strong interrelations—where ecological functions and industrial development are deeply integrated and mutually reinforcing—to weak connections, where the two systems function largely independently with minimal feedback or cross-impact. Direction distinguishes between synergistic and restrictive interactions—the former generates positive feedback loops in which ecological improvement enhances industrial returns and industrial output supports further ecological investment; the latter implies that one domain hinders the other, disrupting systemic balance.

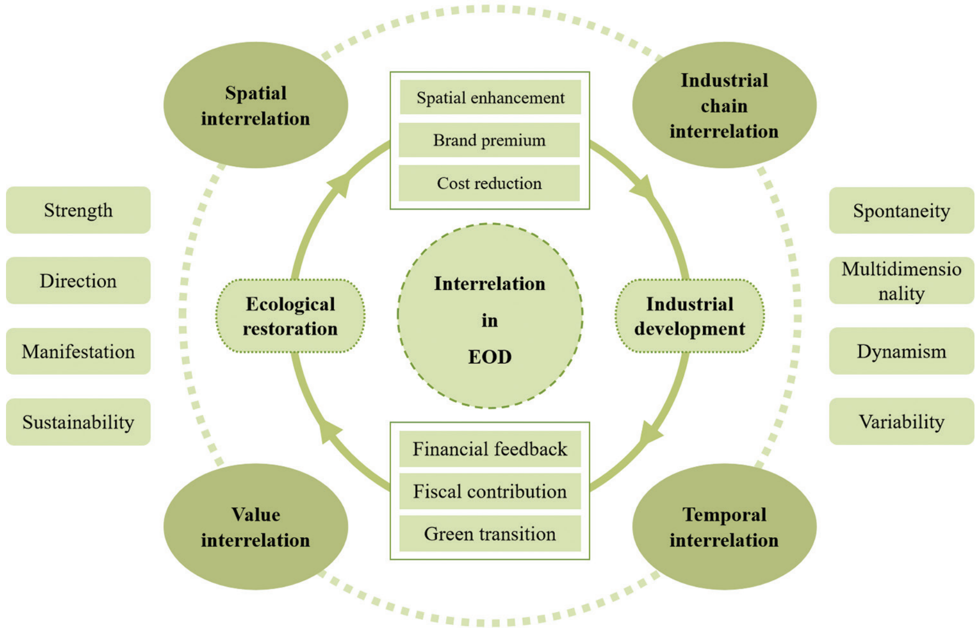

Figure 1. Theoretical framework of interrelation in the eco-environment-oriented development model

Manifestation refers to whether the interrelation is direct—with clear, immediate causal chains, such as ecological restoration stimulating tourism—or indirect, realized through multi-level transmission mechanisms like industrial chain upgrading, value premium, or regional brand influence. Sustainability reflects the capacity for long-term coordination between ecology and industry, influenced by factors such as policy alignment, market orientation, project design robustness, and risk adaptability. These attributes form the analytical foundation for evaluating the functional relationship between ecological systems and industrial development under the EOD framework.

In addition to these core attributes, interrelation also exhibited several inherent characteristics—spontaneity, multidimensionality, dynamism, and variability—that further complicate its evaluation and design. Spontaneity emphasizes that such interrelations are not artificially imposed but organically embedded within EOD systems, emerging naturally from spatial, functional, and policy interactions. Thus, project planning should aim to identify and strengthen these latent linkages. Multidimensionality captures the fact that interrelations unfold across multiple planes—including spatial proximity, temporal coordination, value transformation, and industrial chain integration—requiring a composite lens for analysis. Dynamism reflects the fluid nature of these interactions, which evolve in response to changes in resource allocation, governance capacity, market demand, and technological advancement. Variability highlights that interrelation pathways, mechanisms, and intensities differ significantly across projects and regions, making it essential to adopt adaptive, context-sensitive evaluation methods rather than relying on static or universal frameworks. Together, these characteristics shaped both the analytical challenges and the planning implications of constructing effective ecology–industry linkages within the EOD model.

The interrelation mechanism between ecology and industry in the EOD model captures the ways in which ecological restoration enhances industrial value and, conversely, how industrial development reinforces ecological governance, forming a virtuous cycle aimed at transforming and closing the loop between ecological and economic value. Ecological improvements elevate industrial potential by enhancing environmental quality and spatial functionality, thereby increasing land value and facilitating the regeneration of underutilized assets into viable development zones. At the same time, a high-quality ecological environment strengthens regional branding, attracting investment and high-value industries through green premium effects embedded across the value chain. Restored ecosystems also provide regulatory services that reduce environmental management costs for enterprises while encouraging cleaner technologies under stricter ecological governance standards.

In return, industrial systems offer critical financial and structural support to ecological governance. Revenues generated by industrial activities can be reinvested into ecological projects, offsetting the high costs and long timeframes associated with restoration. Moreover, industrial development contributes to fiscal revenues, which governments can channel into environmental governance through targeted budgeting and financial instruments. The green transition of industries further reduces ecological stress at the source while feeding advanced technologies and sustainable practices back into the ecological domain. This dynamic and reciprocal mechanism serves as the operational foundation for realizing the co-evolution of ecological integrity and industrial prosperity under the EOD paradigm.

4.2. Pollution status analysis framework based on spatial interrelations

Spatial interrelation refers to the geographic connection between ecological governance and industrial development (Figure 2). Its core lies in optimizing regional resource allocation through rational spatial planning, leveraging the spillover effects of ecological governance to enhance industrial added value and overall benefits. Within the EOD model, the spatial coupling relationship between ecology and industry determines whether ecological benefits can be efficiently transformed into industrial value addition. The rationality of spatial layout directly impacts the system performance and sustainability of projects. In analyzing spatial interrelation in EOD, a key task is to identify spatial zones within a region that simultaneously meet ecological governance demands and support industrial development, thereby enabling the linkage between ecological benefits and industrial value enhancement.

The theoretical foundation of spatial interrelation primarily includes Tobler's First Law of Geography and the theory of regional division of labor. The former emphasizes that spatial proximity correlates with stronger interactions, while the latter advocates for efficient division and cooperation between regions based on differential resource endowments. Given that spatial relationships between ecosystems and industrial layouts usually preexist before EOD intervention and are often accompanied by resource misallocation and functional conflicts, it is essential to identify and diagnose spatial interrelations during the baseline assessment phase. By analyzing existing spatial patterns and potential conflicts, ecological and industrial elements can be reorganized and optimized, promoting transitions from weak to strong interrelations and from negative to positive ones. The analysis of spatial interrelation can be conducted following the procedure below:

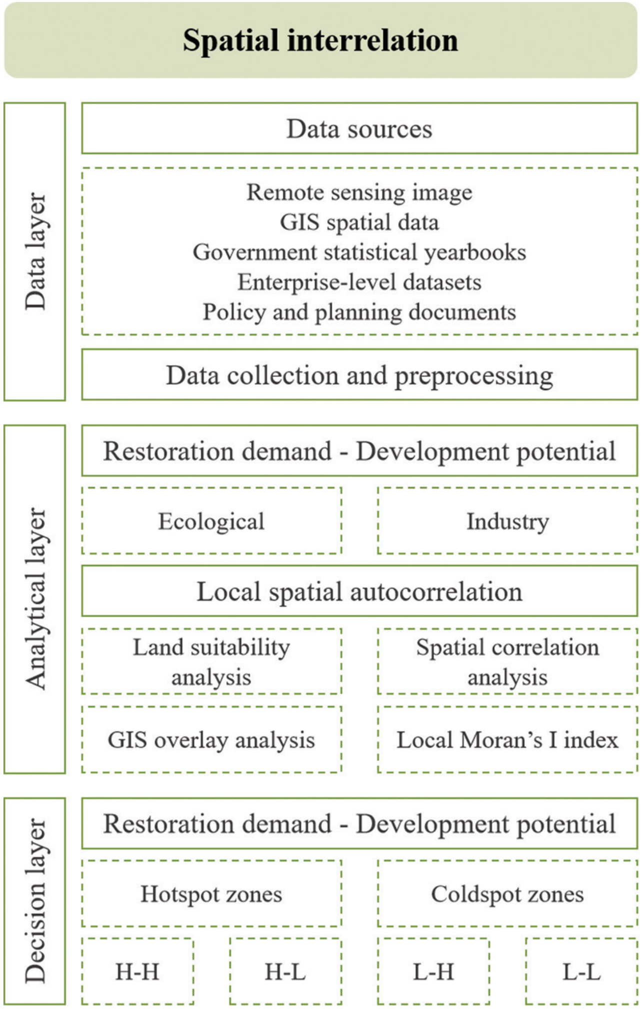

Figure 2. Framework and process of pollution status analysis based on spatial interrelation

Notes: H-H: High demand, high potential areas: These are regions with strong ecological protection needs and outstanding development conditions, suitable for coordinated ecological conservation and high-quality development with ecologically friendly industries. H-L = High-demand, low-potential areas: These are ecologically fragile or pollution-concentrated areas that require prioritized ecological restoration and restricted development intensity. L-H = Low-demand, high-potential areas: These areas have low environmental pressure but favorable conditions for development, making them suitable for expanding green industries. They can be linked with ecological governance areas through planning and design, such as by introducing green supply chains or eco-product processing. L-L = Low-demand, low-potential areas: These areas have neither prominent ecological restoration demands nor development potential and are suitable as conservation and observation zones, with their functions dynamically adjusted based on actual conditions.
Abbreviation: GIS: Geographic Information System.

(i) Evaluation of ecological governance demand–industrial development potential

The study initially screened 16 evaluation indicators from policy documents, project cases, and relevant literature to construct an ecological governance demand and industrial development potential evaluation system. Governance demand was assessed across three dimensions: pollution control, risk prevention, and potential improvement. Industrial potential was evaluated based on transportation accessibility, economic vitality, and development suitability (Table 1). Subsequently, the results of the governance demand and development potential assessments were overlaid and subjected to local spatial autocorrelation analysis to examine the clustering patterns and characteristics of geographic factors at the local scale.

(ii) Bivariate local spatial autocorrelation analysis

To further identify the spatial distribution and clustering characteristics of geographic factors, a local bivariate spatial autocorrelation analysis was conducted at the raster level based on the results of ecological governance demand and industrial development potential. GeoDa software was employed to construct spatial weight matrices, calculate local Moran's I, and analyze ecological and industrial hotspots and cold spots, providing a basis for subsequent spatial functional zoning.

(iii) Spatial zoning and layout strategy

Based on the above results, the project area was further clustered into five spatial combination types: high-high (H-H), low-low (L-L), high-low (H-L), low-high (L-H), and not significant (NS) (Figure 3). Specifically, the H-H zones, characterized by both high ecological demand and high development potential, represent key EOD implementation areas where governance and development should be promoted simultaneously. H-L zones, characterized by high governance pressure but insufficient development conditions, are suitable for restoration-focused efforts with strict control on development. L-H zones, with high development potential but low governance demand, can expand green industries through spatial guidance linked with governance areas. L-L and NS zones, where ecological and development values are insignificant, serve as conservation observation areas with functions adjusted dynamically based on conditions.

The zoning and clustering results support land use and layout optimization in EOD projects, aiding the formulation of pollution control, development intensity, and ecological compensation strategies. Early identification of the spatial interrelation between ecology and industry during the baseline assessment phase enhances the systemic coherence and coordination of overall spatial planning.

Table 1. Evaluation index of ecological governance demand–industrial development potential

Goal level	Criterion level	Indicator level
A1 – Ecological restoration demand	B1 – Pollution management	C1 – Load intensity of major pollutants
		C2 – Density of pollution sources
		C3 – Ecologically sensitive areas
	B2 – Risk prevention	C4 – Geological hazard risk
		C5 – Key ecological function zones
		C6 – Biodiversity hotspots
	B3 – Potential for improvement	C7 – Proportion of special ecosystem areas
		C8 – Degree of land degradation
A2 – Industrial development potential	B4 – Transportation accessibility	C9 – Road network density
		C10 – Distance to central urban area
		C11 – Travel time accessibility
	B5 – Economic vitality	C12 – Population density
		C13 – GDP per unit land area
		C14 – Proportion of tertiary industry
	B6 – Functional suitability	C15 – Available land resources
		C16 – Spatial regulation constraints

Abbreviation: GDP: Gross domestic product.

Theoretical connotation and application of EOD

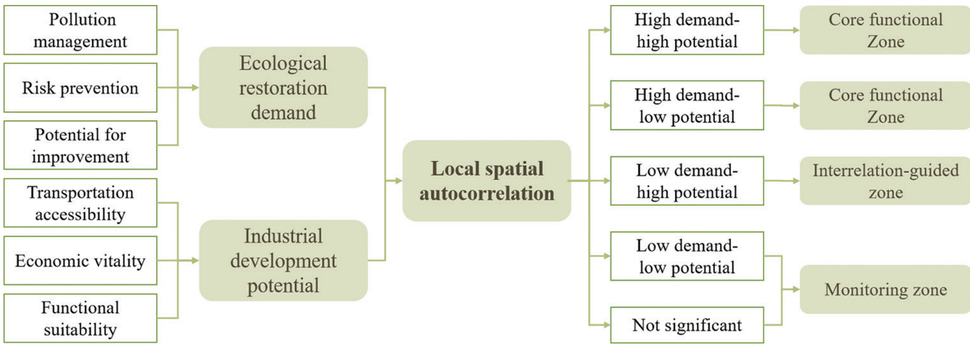

Figure 3. Zoning strategy based on analytical results

4.3. EOD scheme design framework based on industrial chain interrelations

Interrelation within the industrial chain refers to the connections between ecological restoration and industrial development through upstream–downstream linkages (Figure 4). In the context of the EOD model, this interrelation serves as a key pathway for value transmission and transformation. Outputs from ecological projects often provide fundamental resources or enabling conditions for industrial sectors. Through upstream resource integration, midstream value enhancement, and downstream feedback mechanisms, ecological governance can drive and support industrial development.

The theoretical foundation for industrial chain interrelation lies in both industrial synergy theory and input–output theory. Industrial synergy emphasizes the efficiency gains achieved through resource sharing and coordination between ecological and industrial systems, resulting in reduced transaction costs and enhanced competitiveness. From a systems perspective, input–output theory highlights how ecological and industrial subsystems interact via flows of materials, technologies, capital, and information, forming a coupled and mutually reinforcing structure.

In practical EOD applications, industrial interrelations manifest in two primary forms. The first is direct, or strong, interrelation—where ecological governance directly supplies inputs for industrial production, such as clean water from restored water bodies serving downstream beverage industries. The second is indirect, or weak, interrelation—where environmental improvements enhance the added value and market competitiveness of industries, such as ecotourism development benefiting from restored landscapes. Evaluating these interrelations involves assessing the degree of dependency, integration, and synergy between ecological outputs and industrial inputs along the value chain.

Establishing robust industrial chain interrelations is essential for achieving both ecological industrialization and industrial ecologicalization. This entails aligning ecological outputs with industrial demands across different stages of the value chain. Upstream, ecological resources must be transformed into tradable ecological assets through governance, property rights clarification, and ecological valuation. Midstream, integration is achieved via technological innovation and value-added services. Downstream, ecological products and services need market mechanisms to translate ecological benefits into economic returns, thereby completing the value chain loop.[45]

Effective EOD planning requires a structured assessment of local industrial foundations and ecological conditions to identify key industries that align with ecological governance outputs. Applying input–output frameworks can help map the supply–demand relationships of ecological factors along the chain. Priority should be given to industries with high growth potential, strong ecological feedback capacity, and solid market prospects. By clarifying the industrial selection logic and identifying critical linkages and feedback loops, planners can prevent disruptions or bottlenecks in the industrial chain and ensure a resilient, synergistic development model.

5. Discussion

5.1. Discussion of research results

The current EOD model is undergoing rapid promotion; however, its development remains immature, with the systemic interrelation between ecological governance and industrial development insufficiently addressed and studied.[42] To address this gap, this study systematically analyzed the interrelation between ecology and industry within the EOD framework by reviewing its developmental trajectory, conceptual foundations, and existing research. The findings indicate that although

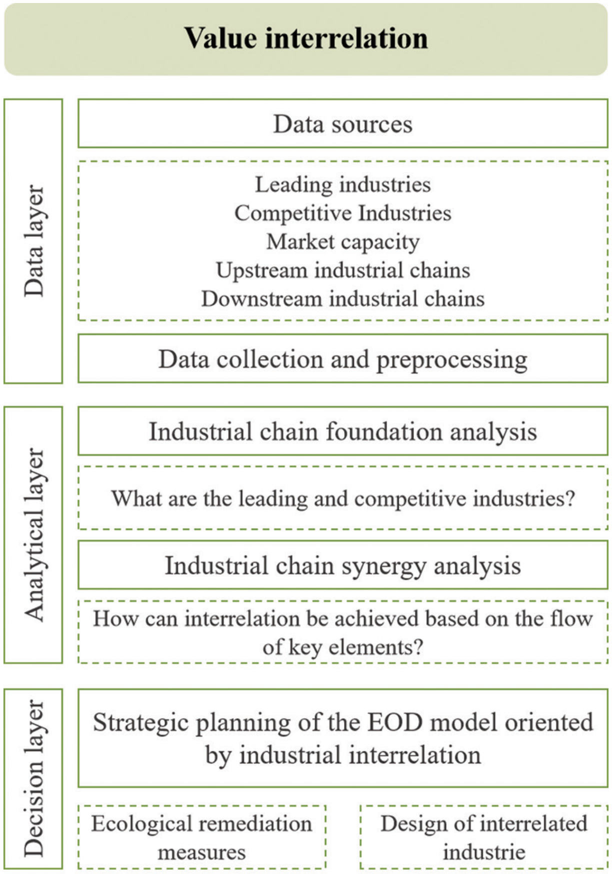

Figure 4. Framework and process of the eco-environment-oriented development scheme design based on industrial chain interrelation

Notes: (i) Industrial chain foundation analysis = Review the regional industrial base to identify the conditions and potential for related industries; analyze dominant, characteristic, and potential industries, focusing on their current status, position in the industrial chain, resource endowments, market capacity, and policy alignment; identify advantageous industries with significant growth potential, strong market expectations, and high ecological feedback capacity. Industrial selection should prioritize industries that can form reasonable interrelations with ecological governance in the EOD model.[46] (ii) Industrial chain synergy analysis = Match factor supply and demand to identify synergies between ecology and industry, clarify the content and pathways of ecological governance, and analyze its outputs and value-enhancing effects on key industries; determine whether ecological governance can facilitate industrial chain integration or create new green chains; propose possible synergy pathways to guide industrial selection in the EOD model.

Abbreviation: EOD: Eco-environment Oriented Development.

prior studies have made progress in understanding the model's conceptualization, risk assessment, and case analyses, the interactive relationship between ecology and industry still lacks a systematic theoretical framework and quantitative analysis. Moreover, it has yet to become a core consideration in project planning and design.[43]

Despite advancements in theoretical construction and framework design, this study has certain limitations. First, in terms of evaluation models, the analysis was constrained by data availability and thus unable to employ more complex and precise evaluation methods. Future research could adopt approaches such as shadow pricing, hedonic models, and system dynamics to achieve a more accurate quantification of the ecological–industrial interrelation. Second, regarding the analytical perspective, the study primarily focused on the design phase of EOD projects and does not fully capture the interrelation between ecology and industry in other phases. Future research could incorporate a full life cycle dynamic assessment and management approach to explore the long-term evolution and adaptive mechanisms of this interrelation. Finally, in terms of empirical cases, the study tested the framework only through the EOD project in Mazhuang district, Jiaozuo city, Henan province. Future research could conduct horizontal comparative analyses across various EOD project types to further verify the framework's adaptability in multiple contexts. With the ongoing advancement of ecological civilization construction in China, the EOD model is poised for broader development prospects, facilitating the deep integration and synergistic development of ecology and economy.

5.2. Practical implications

To further advance the deep integration of ecology and industry within the EOD model and enhance its systemic performance in ecological restoration[46] and environmental governance,[45] particularly in pollution risk prevention and control, it is essential to establish a systematic support framework spanning theoretical research, policy design, and market mechanisms. Although EOD projects have demonstrated synergistic benefits in pollution remediation, land rehabilitation, and ecological restoration, the collaborative mechanisms between ecology and industry remain unclear. There is an urgent need to develop replicable, scalable, practical pathways and systematic evaluation tools. Constructing an interrelation-based planning and design framework for the EOD model will not only improve the scientific rigor and specificity of ecosystem function restoration but also promote regional industrial green transformation and optimize resource allocation efficiency. To address these practical challenges and enhance the effectiveness of EOD implementation, the following strategies are proposed:

(i) Strengthen theoretical research on ecology-industry interrelation: Leverage leading research platforms to systematically review foundational theories such as the "Two Mountains Theory" and the ecological product value realization mechanism; focus on key issues including pollution control, ecosystem service supply, and the enhancement of industrial synergy to develop a multidimensional interrelation framework tailored to China's EOD development pathway; emphasize the identification of interrelation pathways, analyze coupling mechanisms, and establish feedback regulation systems.

(ii) Enhance top-level design and policy guidance: Formulate unified evaluation standards and operational guidelines focused on the synergy between ecological–environmental projects and industrial development, especially in areas such as pollution prevention, ecological restoration, and industrial integration and incorporate interrelation assessments throughout the entire EOD project lifecycle—from initiation and approval to supervision—thereby establishing a closed-loop policy system that covers planning, implementation, and evaluation to improve systemic integrity and normative governance.

(iii) Develop diversified market incentive mechanisms: Fully utilize platforms such as the "Two Mountains Bank," ecological product trading, and green finance to facilitate the value conversion of ecological restoration outcomes and ecological assets and integrate ecology–industry interrelation into the evaluation criteria for green credit, green bonds, and other financing instruments. This approach will guide social capital toward high-quality projects that foster deep ecology–industry integration, thereby enhancing the sustainability and scalability of the EOD model.

6. Conclusion

This study focused on the interrelations between ecological and industrial elements in EOD projects. Key findings are clarifying the conceptual connotations and characteristics of these interrelations, building a basic theoretical framework, exploring spatial and industrial chain interrelations, and proposing relevant evaluation methods for project planning. For the future, research could refine the evaluation methods considering EOD projects' dynamic nature in different scenarios. Furthermore, expanding the research scope to diverse regions with various economic and ecological conditions is needed. These findings are significant for the public. The systematic methods and theory enrich the EOD model, enabling more scientific project planning and implementation and thus bringing comprehensive ecological, economic, and social benefits to the public.

Acknowledgments

None.

Funding

None.

Conflict of interest

Xiuhong Li is an Editorial Board Member of this journal but was not in any way involved in the editorial and peer-review process conducted for this paper, directly or indirectly. Separately, other authors declared that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

Author contributions

Conceptualization: Yayuan Zhang, Xiuhong Li, Rongjin Yang
Formal analysis: Wenjia Song
Investigation: Le Zhang, Meiying Sun
Methodology: Yayuan Zhang, Zechen Song
Writing–original draft: Yayuan Zhang
Writing–review & editing: Yayuan Zhang, Guoying Dong

Availability of data

Data from this study are available from the corresponding author upon reasonable request.

References

1. Li X, Liu X, Luo L. Research on market-oriented models for watershed ecological governance: Challenges, cases,

difficulties, and suggestions. *Water Resour Dev Res*. 2021;21(12):32-38.
2. Huang J, Fang C. Analysis of the interaction and coupling mechanism between urbanization and ecological environment. *Geogr Res*. 2003;22(2):211-220.
3. Huang Q, Zeng Y, Jiang Q. Research progress on China's ecological civilization construction. *China Popul Resour Environ*. 2015;25(2):111-120.
4. Gu S, Hu Y, Zhou H. Scientific connotation and implementation pathways of ecological civilization construction. *Resour Sci*. 2013;35(1):2-13.
5. Jia Y, Lu Y, Jia X. Significance, challenges, and pathways of implementing EOD models in ecological environmental governance. *Environ Prot Sci*. 2023;49(1):39-43.
6. General Office of the Ministry of Ecology and Environment. *Notice on Issuing the Implementation Guidelines for Ecology-Oriented Development (EOD) Projects (Trial)*. [EB/OL]; 2023. Available From: https://www.mee.gov.cn/xxgk2018/xxgk/xxgk05/202401/t20240102_1060425.html
7. Ye Y, Zhang H, Zhou C, *et al*. Review of "ecology-oriented" urban spatial structure research. *City Plan Rev*. 2008;25(5):69-74.
8. Wang Z, Li X, Li X, *et al*. Theoretical research and applications of ecology-environment-oriented urban development concepts. *Project Manage Technol*. 2021;19(9):67-72.
9. Guo B, Wang A. Innovative research on EOD organizational models in urban renewal. *Urban Probl*. 2023;31(7):53-61.
10. Huang Z, Yang D. Review of global eco-city theories. *City Plan Rev.* 2001;22(1):59-66.
11. Register R. *Eco-City Berkeley: Building Cities for a Healthier Future*. Berkeley, CA: North Atlantic Books; 1987. p. 13-43.
12. Shi M, Chen L, Zhao Y, *et al*. Theoretical logic and practical exploration of ecology-oriented development (EOD) mode. *Chin J Environ Manage*. 2024;16(2):5-14.
13. Wei F. Research on EOD implementation pathways in China: A policy text analysis perspective. *Hubei Soc Sci*. 2023;4(12):87-95.
14. Lu Y, Zhao Y, Xin L, *et al*. Key elements and practical exploration of ecology-oriented development (EOD) implementation. *Environ Protect*. 2021;49(14):30-33.
15. Xin L, Zhao Y, Lu J, *et al*. Preliminary Exploration of Connotative Characteristics of Ecology-Oriented Development (EOD) Mode. In: *Proceedings of 2020 Annual Conference of Environmental Science and Technology of China*. Vol. 1. Chinese Academy of Environmental Planning; 2020. p. 193-196.
16. Zhao Y, Xu Z, Xin L, *et al*. Market-oriented pathways for realizing ecological product value: Evidence from national EOD pilot projects. *Ecol Econ*. 2022;38(7):160-166.
17. Zhan S. Research on EOD operation models for ecological environmental protection projects. *China Eng Consult*. 2021;12(2):70-74.
18. Wang Y, Wang S. Exploration of ecology-oriented PPP+EOD models. *Environ Protect*. 2022;50(14):44-48.
19. Sun C, Liu T. Practices and suggestions for PPP model project management. *Co-Oper Econ Sci*. 2022;3(8):140-141.
20. Wen L, Li R. Industry investment directions revealed through 94 EOD pilot projects. *Environ Econ*. 2023;48(4):52-55.
21. Su Y, Zhang F, You X. Exploration and practice of EOD mode: Case studies from hunan province. *Environ Ecol*. 2023;5(4):107-113.
22. Nie W, Song J, Liu S. EOD-driven urban renewal pathways: A case study of Meishan District, Jinzhai County. *Urban Dev Stud*. 2023;30(2):18-24.
23. Qu Q. Research on integrated EOD models for watershed ecological governance. *Technol Wind*. 2020;11(35):120-121.
24. Gao S, Yu D, Shu Y, *et al*. Reflections and suggestions on promoting EOD mode in Zhejiang province. *Recyclable Resour Circ Econ*. 2023;16(4):6-8.
25. Gao X, Ban Y, Zhu J, *et al*. EOD-based practices in mine ecological restoration. *Nat Resour Inf*. 2023;7(5):33-39.
26. Li G, Yang Z, Du B, *et al*. EOD model for mine ecological restoration based on SWOT analysis. *China Mining Mag*. 2024;33(4):132-140.
27. Liu M, Lei Z, Gao Y, *et al*. A framework for rural spatial governance based on the eco-environment oriented development mode: The case of coal mining subsidence area on the Weibei Plateau. *Front Archit Res*. 2025;14(1):224-247.
28. Liu J. Application of EOD mode in urban complex development. *Intell Build*. 2022;49(5):9-12.
29. Peng Y, Song W, Yang X, *et al*. EOD-based planning of Zhujialin rural complex. *J Beijing Norm Univ* (*Nat Sci*). 2020;56(3):462-466.
30. Yuan H, Luo P, Duan Y, *et al*. Risk evaluation system for EOD projects under ecological civilization construction. *J Chongqing Univ Technolo (Nat Sci)*. 2022;36(7):254-263.
31. Song M. *Risk Assessment of Watershed Management Based on EOD Mode*. Master's Thesis, Beijing University of Civil Engineering and Architecture; 2023.
32. Luo S. *Performance Evaluation of Watershed Ecological Governance Projects Under EOD Mode*. Master's Thesis, Xihua University; 2023.
33. Zhang J. Influencing factors of EOD project investment risks based on dematel. *Fortune Life*. 2022;13(24):13-15.
34. Qiu S, Zhou Z. Shapley-TOPSIS model for multi-party benefit distribution in EOD projects. *Henan Sci*. 2022;40(10):1712-1720.
35. Peng C, Xie H. Behavioral strategies of stakeholders in mine ecological restoration under EOD mode: An evolutionary game perspective. *J Fujian Norm Univ (Nat Sci Ed)*. 2025;41(2):125-132.

36. Shi M, Chen L. Theoretical foundations and core principles of EOD mode. *Environ Protect*. 2025; 53(Z1):21-25.
37. Ma Q, Zhang Q, Zhao C, *et al*. Value capture mechanisms in EOD projects: Principles, influencing factors, and applications. *Environ Protect*. 2025;53(Z1):26-29.
38. Jin S, Wang Y. Public governance value of EOD applications. *Environ Protect*. 2025;53(Z1):30-34.
39. Zhao Y, Wang J. Value chain-based innovation mechanisms in EOD implementation. *Environ Protect*. 2025;53:12-16.
40. Liu C, Yan Q, Luo J. System dynamics simulation of economic-resource-environment coupling in Wuhan metropolitan area. *Geogr Res*. 2013;32(5): 857-869.
41. Wang B. *Coupling Model-Based Study on Regional Economic-Ecological Coordination in China*. Doctoral Dissertation, Hunan University; 2014.
42. Ren B, Du Y. Coupling relationships among economy, industry, and ecology in Yellow River Basin. *China Popul Resour Environ*. 2021;31(2):119-129.
43. Zhou C, Feng X, Tang R. Coupling coordination analysis and prediction of regional economy-ecology-tourism: Evidence from Yangtze River Economic Belt. *Econ Geogr*. 2016;36(3):186-193.
44. Zhao Y, Wang Z. Theoretical framework and value chain model of EOD mode. *China Environ Protect Ind*. 2024;35(8):17-19.
45. Zhang H, Pu M, Li H, *et al.* Progress and prospects for remediation of soil potentially toxic elements pollution: A state-of-the-art review. *Environ Technol Innov*. 2024;35:103703.
doi: 10.1016/j.eti.2024.103703
46. Chen Y, Yu X, Xu D, *et al*. A spatial machine learning approach to exploring the impacts of coal mining and ecological restoration on regional ecosystem health. *Environ Res*. 2025;264:120379.
doi: 10.1016/j.envres.2024.120379