

Research Paper

Environmental Assessment as Catalyst for Sustainability

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지속가능발전의 촉매로서의 환경영향평가

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요약: 본 연구는 환경영향평가(Environmental Assessment, EA)를 단순한 절차적 안전장치가 아닌, 유엔 지속가능발전목표(UN SDGs)에 부합하는 지속가능발전(Sustainable Development, SD)을 추진할 수 있는 거버넌스 기반 제도로 재정립하는 것을 목적으로 한다. 이를 위해 2015년부터 2024년까지의 선행연구를 대상으로 한 구조화된 문헌고찰, 국내외의 다양한 비교사례연구, 그리고 EA 기능과 지속가능성의 세 축을 연결하는 새로운 분석틀인 EA-SD 매트릭스를 활용하였다. 분석 결과, EA가 지속가능발전의 촉매로 작동하기 위해서는 과학적 엄밀성, 제도의 독립성, 실질적인 참여, 그리고 SDGs(특히 SDG 13: 기후변화 대응, SDG 15: 육상생태계 보전, SDG 16: 제도·정의·참여)와의 명확한 연계가 필수적임이 드러났다. 또한 국내외 사례비교는 EA가 지속가능성을 강화하거나 약화시키는 조건을 동시에 보여주며, 성공·실패의 교훈을 도출하였다. 본 연구는 EA-SD 매트릭스를 제시함으로써 학문적으로는 새로운 이론적 분석틀을 제공하고, 실무적으로는 EA를 지속가능성 거버넌스의 핵심 도구로 전환하기 위한 정책적 지침을 제시한다. 이는 기후변화, 생물다양성 손실, 사회적 불평등 등 21세기 전 지구적 도전에 대응하는 데 중요한 의의를 갖는다.

주요어: 환경영향평가, 전략환경평가, 지속가능발전, 지속가능성 평가, 환경정의, 주민참여, 지속가능발전목표, 기후 거버넌스, 기후중립, 제도적 거버넌스, 비교사례연구

Abstract: This study aims to reframe Environmental Assessment (EA) not merely as a procedural safeguard but as a governance-based institution capable of advancing Sustainable Development (SD) in line with the UN SDGs. To achieve this, the research integrates a structured literature review (2015–2024), comparative case study analysis (domestic and international), and the construction of the EA–SD Matrix as a novel analytical framework. The findings demonstrate that EA's catalytic potential depends on scientific rigor, institutional independence, genuine participation, and explicit alignment with SDGs 13, 15, and 16. Comparative case studies reveal both successful and failed practices, highlighting conditions under which EA strengthens or undermines sustainability outcomes. By introducing the EA–SD Matrix, this study contributes an original theoretical framework and practical guidance for transforming EA into a central instrument of sustainability governance in the era of climate change, biodiversity loss, and social

justice. The conceptual framework of this study is summarized in Table 1, which visualizes the intersection between EA functions and the three sustainability dimensions.

Keywords: Environmental Assessment, Strategic Environmental Assessment, Sustainable Development, Sustainability Assessment, Environmental Justice, Public Participation, SDGs, Climate Governance, Climate neutrality, Institutional governance, Comparative case study

I. Introduction

Since the enactment of the United States National Environmental Policy Act (NEPA) in 1970, Environmental Assessment (EA) has spread to more than 100 countries and evolved into diverse institutional forms, including Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA). The institutionalization of EA represented a watershed moment in governance by mandating that environmental consequences be systematically evaluated prior to major project approval. In Korea, the EA system began with the 1993 Prime Ministerial Directive on environmental review and was further consolidated through the 2006 amendment of the Environmental, Transportation, and Disaster Impact Assessment Act, which introduced SEA.

Globally, EA has played a key role in shaping development planning and decision-making. In the European Union, the 1985 EIA Directive established uniform requirements for environmental assessments, later expanded by the 2001 SEA Directive. In Canada, EA has been instrumental in balancing development with the rights of Indigenous peoples, though not without controversy. In Brazil, EA processes for large-scale projects such as the Belo Monte Dam have attracted international criticism for failing to safeguard biodiversity and social equity.

At the same time, EA has been criticized for becoming overly bureaucratic, reactive rather than proactive, and vulnerable to political capture. Many scholars argue that EA has too often been reduced to a box-ticking exercise rather than serving as a transformative tool for

sustainability. Yet, as the urgency of climate change, biodiversity loss, and social inequities intensifies, the need to reimagine EA's role has become more pressing. This paper therefore asks: under what conditions can EA serve as a catalyst for sustainable development (SD)? What institutional reforms and practical innovations are necessary to realize EA's transformative potential?

This introduction frames EA's evolution within the broader trajectory of sustainability discourse. Following the Brundtland Report's (WCED, 1987) definition of SD, scholars and practitioners have sought to align environmental policy with economic and social goals. The Millennium Development Goals (MDGs) of 2000 and the Sustainable Development Goals (SDGs) of 2015 provided further impetus for integrating sustainability principles into governance. Against this backdrop, EA has increasingly been examined not only as a procedural safeguard but as an institutional mechanism with the potential to advance SD in practice. The originality of this study lies in reframing EA through the EA-SD Matrix, which for the first time cross-references EA's institutional functions with sustainability's environmental, social, and economic dimensions. By doing so, this paper moves beyond descriptive critique and offers a structured framework that clarifies how EA can evolve into a true catalyst for sustainable development.

II. Literature Review and Recent Research Trends

This study adopted a structured literature review (SLR) rather than a traditional narrative review. The review

period (2015–2024) and the databases used—Scopus, Web of Science, and the Korea Citation Index—were systematically defined. A qualitative synthesis was performed using content analysis and thematic coding to identify recurring themes across the reviewed literature. The literature on EA has developed across several distinct phases. In the 1970s and 1980s, scholarship focused on the procedural foundations of EA, emphasizing scientific rationality and predictive modeling. Glasson, Therivel, and Chadwick (1994) provided a foundational introduction to EIA, while Ortolano (1997) analyzed regulatory frameworks and institutional dynamics. During this period, EA was primarily understood as a technical process designed to predict biophysical impacts.

The 1990s and early 2000s saw the emergence of critiques highlighting EA's limitations. Cashmore (2004) framed EA within applied and civic science paradigms, emphasizing tensions between technocratic expertise and participatory legitimacy. Scholars also criticized EA for its failure to adequately address cumulative impacts, long-term sustainability, and social equity.

From the mid-2000s, the discourse shifted toward EA's contribution to sustainability. Bond and Morrison-Saunders (2011) argued that EA practice often failed to align with sustainability visions. Pope et al. (2013) reconceptualized sustainability assessment as a broader integrative framework encompassing EA, social impact assessment (SIA), and health impact assessment (HIA). Sánchez and Mitchell (2017) advanced the idea of EA as a learning process, emphasizing its potential to foster adaptive governance.

Recent research (2015–2024) has further repositioned EA within global sustainability governance. Morrison-Saunders and Retief (2020) reflected on EA's evolution and potential role in addressing climate change. Sánchez, Morrison-Saunders, and Bond (2021) examined lessons from practice in strengthening sustainability outcomes. Bina (2022) analyzed the evolution of EA as a tool linking practice to sustainability, while other studies explored EA's

role in environmental justice, digital participation, and climate governance. The adoption of the SDGs in 2015 further spurred scholarship connecting EA with SDG 13 (Climate Action), SDG 15 (Life on Land), and SDG 16 (Peace, Justice, and Strong Institutions).

Overall, the literature reflects a trajectory from viewing EA as a narrow procedural requirement to recognizing it as a governance institution with the potential to foster sustainability. Yet gaps remain: EA often struggles to move beyond procedural compliance, to address cumulative and transboundary impacts, and to integrate emerging challenges such as climate adaptation and digital governance.

This study employs a mixed qualitative methodology combining a systematic literature review, case study analysis, and the construction of the EA–SD Matrix. First, a systematic literature review was conducted to capture the evolution of Environmental Assessment (EA) research within the context of sustainability. Articles published between 2015 and 2024 were identified and analyzed using major international databases such as Scopus and Web of Science, as well as Korea Citation Index (KCI) to ensure inclusion of domestic perspectives. The search employed key terms such as 'Environmental Assessment,' 'Sustainability,' 'SDGs,' and 'Governance.' This systematic approach ensured both breadth and depth in capturing the most recent academic discussions.

Second, a case study selection process was undertaken to provide empirical grounding for the analysis. Cases were chosen according to three main criteria: geographical diversity (including examples from Korea, Europe, the Americas, and the Asia–Pacific region), sectoral relevance (urban planning, water management, and energy infrastructure), and explicit connections to the United Nations Sustainable Development Goals, particularly SDGs 13 (Climate Action), 15 (Life on Land), and 16 (Peace, Justice, and Strong Institutions). These criteria ensured that the cases were representative of different governance contexts while directly linked to sustainability

objectives.

Finally, the analytical procedure was guided by the EA–SD Matrix. This framework systematically mapped EA functions—such as institutionalizing environmental consciousness, formulating alternatives and mitigation strategies, and facilitating public participation—against the three dimensions of sustainability: environmental, social, and economic. Through this matrix-based approach, comparative analysis was conducted across the selected cases to identify recurring patterns, critical strengths, and persistent weaknesses. This step not only highlighted commonalities and divergences across contexts but also provided a structured basis for evaluating EA's catalytic potential for sustainable development. Overall, this methodological structure transforms the review process from a conventional narrative summary into a replicable, transparent, and systematically coded qualitative synthesis, strengthening the paper's methodological rigor.

III. Critiques on Environmental Assessment and Sustainable Development

Despite its wide adoption, EA faces persistent and multifaceted critiques. First, EA has been criticized for scientific limitations, particularly in its inability to address cumulative impacts, long-term ecological risks, and climate adaptation. The Yucca Mountain nuclear repository case in the United States, for example, exposed weaknesses in predictive modeling and highlighted judicial concerns about arbitrary standards. Second, public participation has often been reduced to procedural formalities, excluding marginalized groups and reinforcing inequities. The Cypress Freeway case in California, which disproportionately affected low-income communities, exemplifies this limitation. Third, EA is vulnerable to political capture, where assessments justify predetermined outcomes rather than shape decisions. Fourth, EA tends to prioritize ecological concerns at the expense of social equity and economic

viability, leaving the integrative vision of SD unrealized.

Recent scholarship adds further critiques, pointing to EA's inadequate responses to climate change, biodiversity loss, and carbon neutrality. Additionally, EA often neglects environmental justice, failing to engage meaningfully with Indigenous and marginalized communities. Digital participation platforms and AI-assisted tools have been proposed as means of addressing some of these limitations, though challenges remain in implementation.

The concept of Sustainable Development (SD) was formally articulated by the World Commission on Environment and Development (WCED) in 1987, defining SD as development that meets present needs without compromising the ability of future generations to meet their own. This definition has been widely cited but also critiqued for its ambiguity. Subsequent scholarship has emphasized SD's three pillars: environmental integrity, social equity, and economic viability (Goodland, 1994; Lawrence, 1997).

In 2015, the adoption of the United Nations Sustainable Development Goals (SDGs) further operationalized SD, setting global targets for climate action (SDG 13), terrestrial ecosystems (SDG 15), and strong institutions (SDG 16). EA can play a critical role in achieving these goals by embedding sustainability principles into planning and decision-making. For instance, SEA can align with SDG 13 by integrating climate risk assessments into infrastructure planning. Similarly, EA can advance SDG 15 by protecting biodiversity in land-use planning, and SDG 16 by fostering transparency and inclusive governance.

However, EA's contribution to the SDGs depends on its quality and scope. If conducted as a compliance exercise, EA risks missing opportunities to contribute meaningfully to sustainability. By contrast, a transformative EA that incorporates cumulative impact assessment, environmental justice, and participatory governance can become a catalyst for achieving SDGs in practice.

Table 1. EA-SD Matrix

EA Functions / SD Dimensions	Environmental	Social	Economic
Institutionalizing environmental consciousness	Embedding ecological values in planning	Recognition of environmental rights	Awareness of sustainability trade-offs
Formulating alternatives and mitigation	Ecosystem and biodiversity conservation	Conflict mediation and inclusivity	Balancing costs and benefits
Facilitating public participation	Community-based resource management	Advancing environmental justice	Local economic resilience

IV. Analytical Framework: The EA-SD Matrix and Expanded Case Studies

To assess EA's potential role as a catalyst for SD, this paper introduces the EA-SD Matrix. The matrix cross-references three core EA functions—institutionalizing environmental consciousness, formulating alternatives and mitigation strategies, and facilitating public participation—with the three pillars of sustainability. Each intersection demonstrates a potential pathway for EA to contribute to sustainability outcomes.

This framework builds on the literature on Sustainability Assessment (Bond & Morrison-Saunders, 2011; Pope et

al., 2013), which calls for integrating environmental, social, and economic assessments. By mapping EA functions against sustainability pillars, the EA-SD Matrix provides a tool for both scholars and practitioners to evaluate EA's contributions and identify areas for improvement.

As illustrated in Table 1, each EA function contributes differently to environmental, social, and economic dimensions, revealing cross-linkages essential for sustainable governance. Case studies provide empirical evidence of EA's strengths and weaknesses in advancing sustainability. In Korea, the Sejong City project illustrates a failure case where socio-economic impacts were neglected despite EA, leading to significant conflicts. The Four Rivers Project revealed

Table 2. Comparative Case Studies

Project	EA Characteristics	Limitations	SDG Linkages	Key Lessons
Sejong City (Korea)	EA conducted but lacked socio-economic integration	Failed to consider community displacement and equity impacts	SDG 11, SDG 16	Need for inclusive, socially sensitive EA
Four Rivers Project (Korea)	Large-scale hydrological EA	Insufficient cumulative ecological assessment	SDG 6, SDG 15	Importance of cumulative and ecosystem-based approaches
Songdo Wetland (Korea)	International scrutiny improved SEA quality	Initial neglect of wetland biodiversity	SDG 15	External review can enhance biodiversity protection
Belo Monte Dam (Brazil)	Extensive EA process but politically contested	Failed to prevent social displacement and ecological harm	SDG 7, SDG 15, SDG 16	Political independence essential to safeguard sustainability
Heathrow Airport Expansion (UK)	Integrated EA with climate litigation	High carbon emissions not fully mitigated	SDG 13	EA increasingly tied to climate neutrality debates
Delta Program (Netherlands)	SEA embedded in climate adaptation planning	Challenges in long-term governance coordination	SDG 13	SEA effective for climate resilience
Great Barrier Reef (Australia)	SEA linked biodiversity with tourism planning	Economic pressures remain dominant	SDG 14, SDG 15	Balancing conservation with economic needs
Post-Disaster Recovery (Japan)	EA integrated in reconstruction planning	Limited participatory inclusivity	SDG 11, SDG 13	EA can guide resilient reconstruction

EAs inability to adequately address cumulative ecological impacts, though it spurred subsequent institutional reforms. Conversely, the Songdo Wetland case demonstrated how international scrutiny improved SEA practice and fostered biodiversity protection.

Internationally, the Netherlands' Delta Program illustrates SEA's role in integrating climate adaptation into water management, directly contributing to SDG 13. In Canada, EA processes involving Indigenous communities enhanced environmental justice and inclusivity, aligning with SDG 16. By contrast, Brazil's Belo Monte Dam highlighted EA's failure to prevent large-scale social and ecological harm. The Heathrow Airport expansion in the UK underscored EA's role in climate litigation, reflecting growing integration of EA with carbon neutrality debates. In Australia, SEA processes around the Great Barrier Reef demonstrated how EA can integrate biodiversity conservation (SDG 15) with tourism and economic planning. Post-disaster recovery in Japan after the 2011 earthquake and tsunami illustrated EA's evolving role in reconstruction planning.

These cases underscore that EA's effectiveness as a catalyst for SD depends on its qualitative implementation, political independence, and integration with sustainability frameworks. To strengthen comparative insights, the case studies are synthesized in Table 2 below. The table contrasts domestic and international experiences, highlights successful versus failed cases, and extracts generalized policy implications. This structured comparison moves beyond narrative description and clarifies how EA performance aligns with sustainability outcomes

V. Result: Comparative Analysis

The comparative analysis of case studies reveals several key insights. Domestic cases such as Sejong City and the Four Rivers Project illustrate the limitations of EA when socio-economic dimensions and cumulative ecological impacts are neglected. These failures demonstrate the risks of treating EA as a procedural formality rather than

a substantive governance tool. By contrast, the Songdo Wetland case highlights how international scrutiny and external accountability can elevate the quality of EA, contributing positively to biodiversity protection.

To demonstrate how these conceptual linkages manifest in practice, Table 2 presents a comparative analysis of domestic and international cases. International cases further enrich the analysis. The Belo Monte Dam in Brazil underscores the consequences of political capture, where EA processes exist but fail to prevent large-scale environmental and social harm. Conversely, the Netherlands' Delta Program exemplifies the integration of SEA into climate adaptation planning, directly contributing to resilience under SDG 13. The Heathrow expansion in the UK demonstrates how EA is becoming increasingly entangled with climate litigation and carbon neutrality debates, suggesting an expanded role of EA in climate governance.

When comparing successes and failures, a pattern emerges: successful cases tend to embed EA into broader governance frameworks, emphasize inclusivity, and link outcomes to specific SDGs. Failures, by contrast, are marked by weak participation, limited independence, or insufficient attention to cumulative and long-term impacts. This domestic versus international contrast shows that while contextual differences exist, the underlying conditions for effective EA—scientific rigor, independence, and genuine participation—remain universal.

From a policy perspective, the comparative findings highlight the necessity of strengthening institutional independence, enhancing cumulative impact assessment, and aligning EA explicitly with SDGs. These lessons generalize beyond individual projects, offering guidance for reforming EA as a catalyst for sustainable development

VI. Policy Implications: Toward Quality EA

Drawing from critiques, frameworks, and case studies,

several policy implications emerge. First, participation must be deepened beyond compliance, adopting deliberative processes such as citizens' assemblies and leveraging digital platforms for inclusivity. Second, scientific rigor should be enhanced through cumulative impact assessment, climate modeling, and integration of ecosystem services. Third, institutional independence is essential to insulate EA from political interference and ensure transparency. Fourth, EA must align with international sustainability frameworks, particularly SDGs 13, 15, and 16. Finally, EA should evolve into Sustainability Assessment (SA), encompassing environmental, social, and economic appraisals within a unified framework. Future-oriented approaches could incorporate artificial intelligence for scenario modeling and blockchain for transparent public engagement. These reforms would enable EA to transition from a procedural safeguard to a transformative institution of governance and sustainability.

This study contributes to academic theory by introducing the EA-SD Matrix as a novel analytical framework. Unlike prior research that mainly critiqued EA's procedural shortcomings, the EA-SD Matrix systematically links EA functions with the three pillars of sustainability, offering a structured and reproducible tool for scholarly analysis. This theoretical advancement reframes EA as a governance-based institution, demonstrating how impact assessment

can evolve into a catalyst for sustainable development. It enriches academic debates in sustainability assessment, environmental governance, and policy analysis by providing a framework that future researchers can adapt and refine in diverse contexts.

Beyond theory, this research makes a practical contribution to policy and governance. By aligning EA explicitly with SDGs 13, 15, and 16, the EA-SD Matrix provides policymakers and practitioners with a concrete tool to evaluate the effectiveness of EA in practice. The comparative case study analysis further illustrates how institutional independence, cumulative impact assessment, and inclusive participation are critical for improving sustainability outcomes. These insights directly inform reforms in EA legislation, international development cooperation, and digital participation platforms, thereby enhancing the practical utility of EA as a governance instrument for sustainable development.

Despite these contributions, this study has several limitations. First, the research relies primarily on qualitative synthesis through literature review and comparative case analysis, which may limit empirical generalization. Second, the dataset was constrained to publications between 2015 and 2024 drawn from selected databases (Scopus, Web of Science, and KCI), potentially omitting relevant regional or unpublished studies. Third, the EA-SD Matrix, while

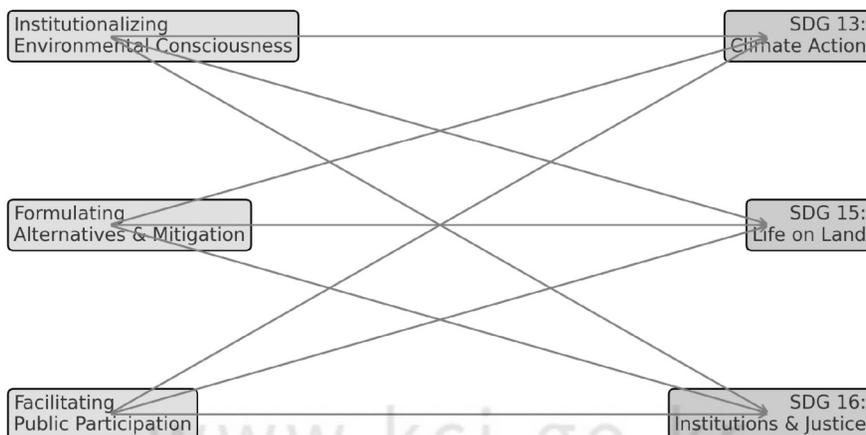


Figure 1. EA-SDGs Linkage Diagram

conceptually robust, requires further empirical testing to validate its applicability in diverse governance contexts. Future studies should therefore employ mixed-method approaches, including quantitative evaluation and longitudinal case tracking, to strengthen evidence-based insights.

VII. Conclusion and Future Research

This paper reviewed EA's institutional development, critiques, and potential as a catalyst for sustainable development. By proposing the EA-SD Matrix and analyzing domestic and international case studies, it highlighted both opportunities and challenges. The analysis shows that EA's contribution to sustainability depends not on its existence as a legal requirement but on its qualitative integrity: rigorous science, genuine participation, institutional independence, and adaptability to global challenges. EA must evolve into a governance-based learning institution, capable of addressing climate change, biodiversity loss, and social justice.

Future research directions can be advanced by articulating specific research questions (RQs). For example:

- RQ1: How can AI-driven modeling improve cumulative impact assessment in EA?
- RQ2: What institutional reforms are most effective in ensuring EA's independence from political capture?
- RQ3: How can digital governance platforms and blockchain technologies enhance transparency and public trust in EA?
- RQ4: In what ways can EA contribute to post-SDG global sustainability frameworks beyond 2030?

These questions highlight the importance of interdisciplinary collaboration across urban planning, public policy, environmental law, and data science. Addressing them will require cross-disciplinary approaches

and comparative research across governance contexts. Ultimately, EA's transformative potential lies in its ability to integrate scientific innovation with participatory governance, ensuring that environmental assessment evolves into.

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