Електронний журнал «Ефективна економіка» включено до переліку наукових фахових видань України з питань економіки (Категорія «Б», Наказ Міністерства освіти і науки України № 975 від 11.07.2019). Спеціальності – 051, 071, 072, 073, 075, 076, 292. Ефективна економіка. 2024. № 9.

DOI: http://doi.org/10.32702/2307-2105.2024.9.30
УДК 338.246.88

A. Kleshchov,
PhD in Technical Sciences, Doctoral candidate of the Department of Smart Economics, Kyiv National University of Technology and Design
National Project Coordinator,
United Nations Industrial Development Organisation
ORCID ID: https://orcid.org/0000-0002-9412-4156

EXPRESS ANALYTIC HIERARCHY PROCESS METHOD AS A TOOL FOR IDENTIFICATION OF SUCCESS FACTORS FOR ECO-INDUSTRIAL PARKS IMPLEMENTATION

А. Й. Клещов,
к. т. н, докторант кафедри смарт-економіки,
Київський національний університет технологій та дизайну;
Національний координатор проєкту,
Організація Об'єднаних Націй з промислового розвитку

ЕКСПРЕС МЕТОД АНАЛІТИЧНОЇ ІЄРАРХІЇ ЯК ІНСТРУМЕНТ ІДЕНТИФІКАЦІЇ ФАКТОРІВ КРИТИЧНИХ ДЛЯ ВПРОВАДЖЕННЯ МОДЕЛІ ЕКОІНДУСТРІАЛЬНИХ ПАРКІВ

This paper delves into the intricate institutional frameworks that are crucial for the successful implementation of Eco-Industrial Parks (EIPs) on a global scale. The study is grounded in the analysis of various case studies and leverages the Analytic Hierarchy Process method to assess the relative importance of several factors that contribute to the effectiveness of EIPs. The research highlights that without a flexible and supportive regulatory

environment, the full potential of EIPs cannot be realized. Moreover, the paper emphasizes the importance of stakeholder engagement, which is essential for fostering collaboration between government entities, industry participants, and local communities. The study finds that stakeholder engagement, when coupled with strong government policy, creates a synergistic effect that significantly enhances the likelihood of successful EIP implementation. Technological innovation is another key factor explored in this paper. The integration of advanced technologies is identified as a critical component for improving resource efficiency, reducing waste, and minimizing environmental impact within EIPs. The study suggests that continuous technological advancements are necessary to maintain the competitive edge of EIPs and to ensure that they remain relevant in the face of evolving environmental and economic challenges. The paper also presents a stakeholder network graph that visually represents the complex interactions between various entities involved in the implementation of EIPs. By mapping out these interactions, the research provides valuable insights into the institutional landscape required for successful EIP implementation. In addition, the study explores the challenges and barriers that have hindered the widespread adoption of EIPs, particularly in regions where institutional support is lacking. It argues that overcoming these barriers requires a comprehensive approach that includes not only policy reform but also capacity building, financial incentives, and public awareness campaigns. The paper concludes by asserting that while the path to successful EIP implementation is fraught with challenges, the potential benefits are significant. EIPs offer a viable solution to the pressing issues of environmental degradation and resource depletion, and their successful implementation can lead to a more sustainable and resilient industrial sector. The research calls for a concerted effort from all stakeholders to address the institutional barriers that currently impede the progress of EIPs and to work towards creating an enabling environment that fosters innovation, collaboration, and sustainable development.

Ця стаття досліджує складні інституційні рамки, які є критично важливими для успішного впровадження еко-промислових парків (ЕІП) у глобальному масштабі. Дослідження базується на аналізі різних тематичних досліджень та використовує метод аналітичного

ієрархічного процесу для оцінки відносної важливості кількох факторів, що сприяють ефективності ЕІП. У дослідженні підкреслюється, що без гнучкого та підтримуючого регуляторного середовища повний потенціал ЕІП не може бути реалізований. Крім того, стаття акцентує увагу на важливості залучення стейкголдерів, що є необхідним для сприяння співпраці між державними установами, учасниками промисловості та місцевими громадами. Дослідження виявляє, що залучення стейкголдерів у поєднанні з сильною державною політикою створює синергетичний ефект, який значно підвищує ймовірність успішного впровадження ЕІП. Технологічні інновації є ще одним ключовим фактором, дослідженим у цій статті. Інтеграція передових технологій визначається як критичний компонент для підвищення ефективності використання ресурсів, зменшення відходів та мінімізації впливу на навколишнє середовище в межах ЕІП. У дослідженні зазначається, що постійний розвиток технологій є необхідним для підтримки конкурентних переваг ЕІП і забезпечення їх актуальності в умовах постійно змінюваних екологічних та економічних викликів. У статті також представлено графік мережі стейкголдерів, який наочно відображає складні взаємодії між різними суб'єктами, залученими до впровадження ЕІП. Графік взаємодій визначає інституційний ландшафт, необхідний для успішного впровадження ЕІП. Крім того, дослідження аналізує виклики та бар'єри, які перешкоджають широкому впровадженню ЕІП, особливо в регіонах, де відсутня інституційна підтримка. Результати цього дослідження мають слугувати керівництвом для політиків, лідерів промисловості та інших зацікавлених сторін, які прагнуть просувати сталі промислові практики через розвиток ЕІП. В підсумку, визначено, що хоча шлях до успішного впровадження ЕІП є складним, потенційні переваги значні. ЕІП пропонують життєздатне рішення для нагальних проблем деградації довкілля та виснаження ресурсів, і їх успішне впровадження може призвести до більш стійкого та резильєнтного промислового сектора. Дослідження закликає до скоординованих зусиль усіх зацікавлених сторін для подолання інституційних бар'єрів, які наразі перешкоджають прогресу ЕІП, та створення сприятливого середовища, яке сприяє інноваціям, співпраці та сталому розвитку.

Keywords: *eco-industrial parks, institutional changes, express analytic hierarchy process method, criteria, normalised matrix.*

Ключові слова: *екоіндустріальні парки, інституційні зміни, експрес метод аналітичного ієрархічного процесу, критерії, нормалізована матриця.*

Problem Statement. The primary challenge in implementing EIPs globally lies in overcoming institutional barriers such as inflexible regulatory frameworks, insufficient financial incentives, and fragmented stakeholder engagement. Addressing these challenges is crucial for realizing the full potential of EIPs as sustainable industrial solutions. Without the necessary institutional support, EIPs struggle to achieve their goals of environmental sustainability and economic efficiency.

Literature Review. This study combines qualitative analysis with quantitative assessment using the Express Analytic Hierarchy Process (EAHP). The qualitative analysis shall be done through literature review in order to identify key factors that influence the success of EIP, while by the use of the EAHP method, a comparative assessment of their relative importance and ranking in order of the most critical institutional changes will be performed. The results integrated into a stakeholder network graph contribute to a better understanding of complex relationships among key stakeholders involved in the implementation of EIP. The literature review identifies three primary criteria crucial for the success of EIPs:

1. Government Policy Adaptation. Success in EIPs requires adaptive policies to support the principles of a circular economy, provide financial incentives, and set clear regulatory frameworks. For example, policies promoting industrial symbiosis and resource efficiency are major drivers for EIP success (Geng et al., 2009) [1].

2. Stakeholder Engagement. Stakeholder engagement could lead toward collaboration among the government, industry, and local communities for the successful outcome of EIPs, leading to shared goals and mutual efforts toward attaining sustainability (Chertow, 2007) [2].

3. Technological Innovation. A core component of EIP sustainability is the integration of advanced technologies. Technologies that enhance resource efficiency and waste reduction are critical for attaining both the environmental and economic benefits attributed to EIPs (Mathews & Tan, 2011) [3].

The identified institutional challenges to EIP implementation at the global level originate from institutional barriers—like rigid regulatory frameworks, inadequate financial incentives, and poor stakeholder engagement. The challenge posed by these issues is one of unlocking the full potential of EIPs as a sustainable industrial solution. EIPs have their goals or ambitions regarding environmental sustainability and economic efficiency constrained by institutional barriers.

Tasks of the study. Therefore, the main tasks of the study are the following:

– Conduct Institutional Analysis of institutional changes in government policy, stakeholder engagement, and technological innovation.

– Identify Critical Factors of EIP implementation to be used in the Express AHP method.

– Create a stakeholder network graph to clarify the institutional landscape for EIP success.

Results of the study.

The EAHP method, described in [7], is a simplified version of the traditional Analytic Hierarchy Process, specifically designed to face the problems related to time-consuming pairwise comparisons in decision-making. Traditional AHP, proposed by Thomas Saaty, is an extremely popular tool for multi-criteria decision-making; however, it often requires a large number of comparisons, which makes it less feasible in business contexts where time availability of decision-makers could be scarce, especially for senior executives. The simplified method measures the priority vector by means of a formula which sets the relative importance between one key alternative and others. Indeed, this formula is derived so that the priority vector will correspond to the eigenvector of the largest eigenvalue in classical AHP if the evaluations are consistent. In particular, EAHP is suitable for business applications wherein speed and consistency of decisions are

extremely important. It is designed to ensure a high degree of consistency in the evaluations, which is vital in making reliable decisions without the time-consuming procedure required by traditional AHP. EAHP constitutes an effective solution opposite traditional AHP because it makes possible many more applications of this method by shortening the procedure for making a decision. It is especially useful in business, where decisions often have to be made quickly but consistently. This efficiency, however, is at the cost of potential precision and may limit its applicability in more complex scenarios. The express EAHP thus imposes on a decision-maker an added layer of trade-off between efficiency and effectiveness while opting for it over the traditional AHP, depending on their decision-making context.

Application of the Express AHP Method.

1. The objective of the EAHP analysis in this study is to identify which among the numerous institutional changes can best ensure the effective implementation of EIPs.

2. Based on the [1-3], the following criteria were selected:

- Government Policy Adaptation [1]
- Stakeholder Engagement [2]
- Technological Innovation [3]

3. The EAHP process involves the development of a pairwise comparison matrix in which each criterion, vis-à-vis others, is compared for its relative importance. This matrix shall be based on expert judgment and literature insights:

- Government Policy vs. Stakeholder Engagement: 1 (equally important)
- Government Policy vs. Technological Innovation: 3 (moderately more important)
- Stakeholder Engagement vs. Technological Innovation: 1/2 (moderately less important).

The resulting matrix is presented in the Table 1.

Table 1. EAHP method resulting matrix

Criteria	Government Policy	Stakeholder Engagement	Technological Innovation
Government Policy	1	1	3
Stakeholder Engagement	1	1	1/2
Technological Innovation	1/3	2	1

Source: Systematized, summarized and grouped according to data [7].

4. Each value in the matrix is divided by the sum of its column to normalize the values:

- Column Sum (Government Policy): $1 + 1 + 1/3 \approx 2.33$
- Column Sum (Stakeholder Engagement): $1 + 1 + 2 \approx 4$
- Column Sum (Technological Innovation): $3 + 1/2 + 1 \approx 4.5$

The normalised matrix is in the Table 2.

Table 2. EAHP method normalised matrix

Criteria	Government Policy	Stakeholder Engagement	Technological Innovation
Government Policy	$1/2.33 \approx 0.43$	$1/4 = 0.25$	$3/4.5 \approx 0.67$
Stakeholder Engagement	$1/2.33 \approx 0.43$	$1/4 = 0.25$	$1/2 \approx 0.22$
Technological Innovation	$1/3/2.33 \approx 0.14$	$2/4 = 0.50$	$1/4.5 \approx 0.22$

Source: Systematized, summarized and grouped according to data [7].

5. The weight of the priority for each of the criteria is then computed by taking the average of the values in its row in the normalised matrix:

- Government Policy: $(0.43 + 0.25 + 0.67) / 3 \approx 0.45$
- Stakeholder Engagement: $(0.43 + 0.25 + 0.22) / 3 \approx 0.30$
- Technological Innovation: $(0.14 + 0.50 + 0.22) / 3 \approx 0.29$

These weights represent the relative importance of each criterion:

- Government Policy: 0.45
- Stakeholder Engagement: 0.30
- Technological Innovation: 0.29

6. The Consistency Ratio (CR) is calculated to check whether the matrix has an acceptable level of consistency ($CR<0.1$) [7]. The CR for this matrix was

within the tolerable range, showing that the pairwise comparisons were made consistently and dependably.

7. EAHP analysis shows that government policy adaptation is the most important factor behind the success of EIPs, while stakeholder engagement and technological innovation come second.

8. Expanded Network of Stakeholders in EIP Implementation.

The implementation of EIPs in Ukraine is reliant on a multifaceted network of stakeholders. This is depicted below in a network graph (Figure 1) that shows how various stakeholders relate; each stakeholder is denoted by a number corresponding to an individual involved in the process.

As per this graph, the key players and their connections are viewed in a way that focus on how influential they are and how they work with each other for EIP to be established well and further run effectively.

According to the outcomes of the EAHP analysis, these results greatly helped in the development of the stakeholder network graph (Figure 1). The EAHP method revealed that Government Policy Adaptation was the most significant factor for effectively running eco-industrial parks (EIPs), followed by Stakeholder Engagement and Technological Innovation. The choice and priority of stakeholders in the network were thus guided by these findings so that the most powerful entities would be highlighted in this graph. The Verkhovna Rada of Ukraine, Cabinet of Ministers and different ministries are paramount to the network. Their position in the graph represents how government policy adaptation is important by virtue of their EAHP results. These bodies have an obligation to develop regulatory structures and economic incentives that facilitate EIP creation. The strong links between these agencies suggest that coordinated policy initiatives among various levels of government are required for enabling due process for EIPs. In EAHP analysis, Stakeholder Engagement emerged as second only to Government Policy Adaptation. In the network, this clear indicator includes Oblast State Administrations and Local Councils whose roles are essential.

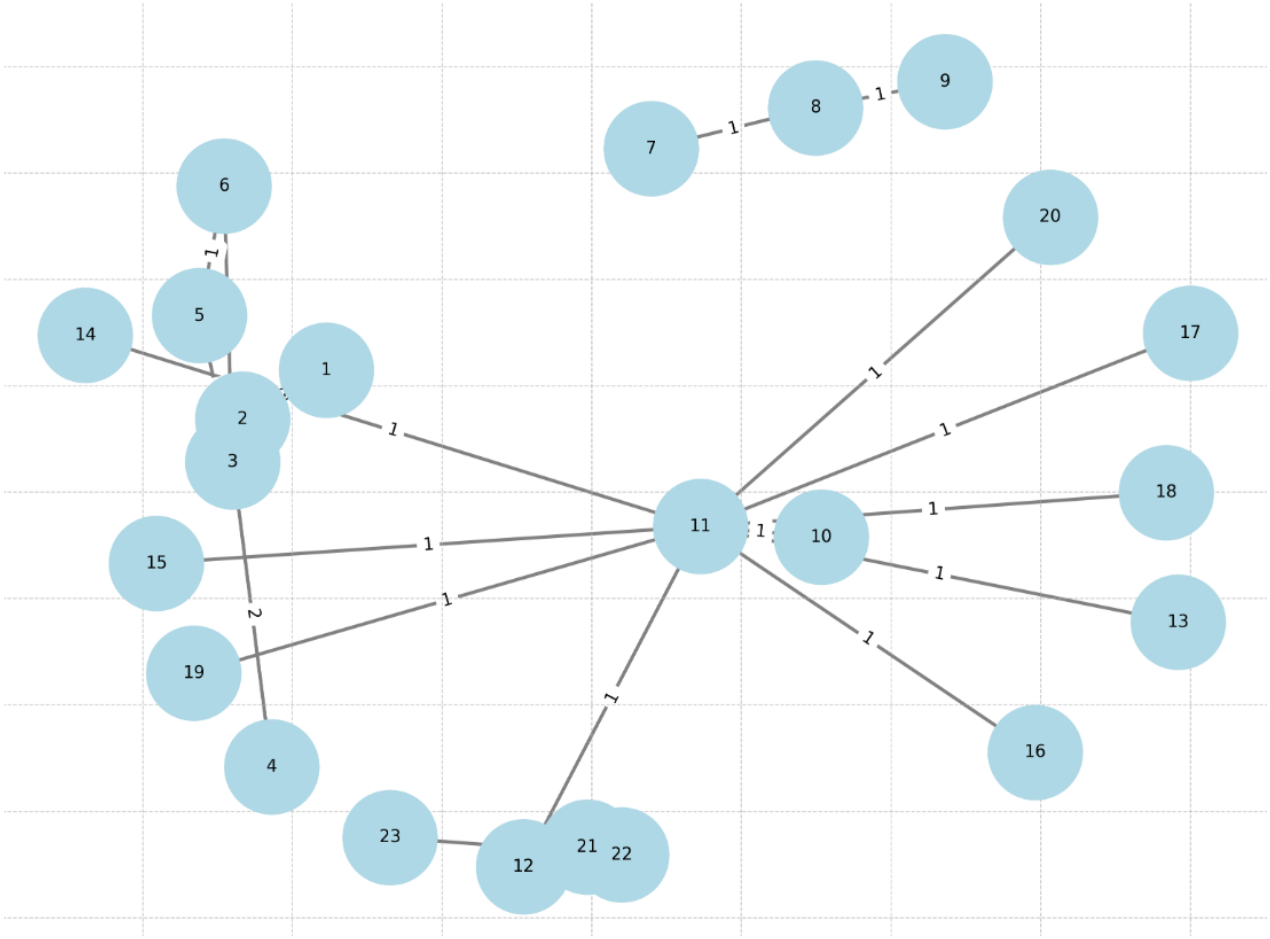

Figure 1: Expanded Network Graph of Stakeholders in EIP Implementation, where 1. Verkhovna Rada of Ukraine (Committees); 2. Cabinet of Ministers of Ukraine; 3. Ministry of Economy of Ukraine; 4. Ministry of Strategic Industries; 5. Ministry of Environment and Natural Resources; 6. Ministry of Infrastructure; 7. Oblast State Administrations; 8. Local Councils; 8. Local Executive Bodies; 9. Initiators and Managing Companies of Industrial Parks; 10. Industrial Parks' residents; 11. SECO; 12. World Bank; 13. GIZ; 14. USAID; 15. NEFCO; 16. GEF; 17. EBRD; 18. EIB; 19. IFC; 20. Educational Institutions; 21. Research Institutes; 22. NGOs and Civil Society Organizations

Source: Systematized, summarized and grouped according to data [6].

The integration of EAHP results into the stakeholder network graph (Figure 1) provides a visual representation of the institutional landscape required for successful EIP implementation. By mapping out the interactions between key stakeholders, the network offers several additional insights:

Holistic Understanding of Interactions. The network graph highlights the interconnectedness of various stakeholders and shows how their interactions contribute to the overall success of EIPs. This holistic view underscores the importance of aligning government policies, engaging stakeholders, and fostering innovation simultaneously.

Identification of Key Relationships. The graph helps identify critical relationships that may require further strengthening. For example, strong links between government bodies and financial institutions, such as the EBRD, EIB, and IFC, are crucial for securing the funding needed to develop infrastructure and support industrial participants in EIPs.

Emphasis on Coordination and Collaboration. The network underscores the need for coordination across multiple levels of government and between public and private sectors. This insight reinforces the EAHP findings, suggesting that policy adaptation alone is insufficient without effective stakeholder engagement and support for innovation.

Guidance for Policymakers and Industry Leaders. The combined use of EAHP results and the network graph provides actionable guidance for policymakers and industry leaders. By focusing on the most influential stakeholders and relationships, they can prioritize efforts that will have the greatest impact on the development and sustainability of EIPs.

Eco-Industrial Parks development in Ukraine encompass a conglomerate of stakeholders within the economic, environmental, industrial, fiscal, territorial, and strategic planning domains. Successful implementation of the EIP policy will be determined by the profound understanding of stakeholders, their relations, levels of interest, and influence.

Key Stakeholders and Their Roles.

Ministry of Economic Development and Trade of Ukraine: This ministry should be the leader in formulating and positioning EIP policies, driving legislative development, and ensuring the integration of EIP-related concepts within the

national strategies. It will have very high influence as it is responsible for the overall economic policy direction.

The committees of the Verkhovna Rada on Economic Development and Finance, Tax, and Customs Policy play a significant role in the development of the legislative framework that is likely to govern the operation of EIPs. They are powerful bodies since they control the institutions of economic incentives and regulatory frameworks.

Ministry of Environmental Protection and Natural Resources: This ministry would need to have active participation to align the EIP policies with environmental norms and sustainability objectives. Without their participation, the ecological balance of EIPs will be severely compromised.

Regional and Local Governments: Regional State Administrations and local councils are very necessary to drive these EIP policies down to the grass-root level; these approvals are concerned with local budget supports and the tax incentives which become absolutely critical to give a genuine shape to the EIPs at a practical level.

UNIDO represents a leading donor to EIP-related activities in Ukraine and offers the necessary expertise, tools, and frameworks for policy development. Its engagement would, therefore, be instrumental in safeguarding that EIP policies are consistent with international best practices.

World Bank, GIZ, USAID, NEFCO: These are the institutions who provide financial and technical support to EIP projects; hence, they are important stakeholders and interested parties in the successful implementation of EIP. Their influence, however, mainly is through the provision of resources and not in direct policy-making.

Management Companies for an Industrial Park: These companies are the real movers and shakers in the development of EIPs, with very high levels of interest due to the operational and economic benefits that can be derived. These are high because they would then be managing and responsible for the daily success of the EIP.

TPPU (Ukrainian Chamber of Commerce and Industry): Represents the interest of businesses and can articulate the aggregated views and expectations of those entities to the key stakeholders. They have a high interest in the EIP policies, which directly affect their members.

Civil Society Organizations: These organizations have an interest in seeing that EIPs are developed in a community-friendly and environment-friendly manner. Although their influence is relatively low in respect to government bodies, their advocacy can shape public opinion and hence indirectly affect policy decisions.

Academic and Research Institutions: These organizations are intermediaries in the setting of EIP standards and in conducting the research that makes up the applicable evidence base in policy decisions. Their power is moderate, but their interest registered as high, especially in contributing new knowledge and technologies.

Stakeholder Influence and Interest Analysis

The different stakeholders outlined in this analysis have different power and interest, as shown in the stakeholder matrix below:. Key stakeholders are the most powerful bodies in terms of driving the EIP agenda, such as the Ministry of Economic Development and the Verkhovna Rada Committees, since their decisions depend directly on policy elaboration and implementation. However, interests of such key stakeholders not always coincide with these of other stakeholders, such as local governments or civil society, which makes up an issue area.

Major stakeholders such as international organizations and industrial park management companies wield significant power but may exhibit interests that do not coincide with those of others. Enterprises based in industrial parks and industrial zones, for instance, pay more attention to economic outcomes than UNIDO, which is hinged on sustainable development and international standards. This creates an inconsistency in the policy set up.

Others could be secondary stakeholders, like civil society organizations and academia, who have less direct influence on the decision-making process. They are

essential in making the said policies comprehensive and duly considering other wider societal and environmental impacts. Their participation is vital for the long-term success of the EIP for keeping the balance between economic growth and sustainability.

Potential Challenges in Stakeholder Engagement.

Diverging interests: One of the most important challenges shall be the potential divergence in interests among the stakeholders. The government body would focus on economic growth and industrial development, whereas civil society organizations would look towards the protection of the environment and issues with social equity. This may lead to conflicts in objectives and hamper policy execution of EIPs.

Stakeholder Coordination.

Since EIP policies have a general interdisciplinary character, this seriously requires coordination with stakeholders, most of whom are government ministries, international organizations, and local governments, among others. On the other hand, without a coordinating body to integrate all these efforts, there is always the risk of fragmented efforts and inefficiencies.

Typically, local governments and civil society organizations, which play a pivotal role in on-the-ground implementation and community acceptance of EIPs, usually have very little influence in the making of national policy. This would result in a disjunction between policy goals and the local situation and, by consequence, affect the successful rollout of EIPs.

Most of the essential resources for the development and growth of EIP are provided by international organizations and financial institutions; however, heavy dependence on external financing also means that at some point, its future is put in doubt, as external funding eventually dries up for a project being implemented in over a decade. As such, long-term financial sustainability is a significant issue.

A policy and regulatory challenge may be the legislative and regulatory hurdles in developing EIPs. Regulations within the various sectors are sometimes conflicting, hence making it difficult for stakeholders, especially business and local

governments who are trying to implement the EIP projects, to have the capacity to comply with these regulations.

Case Studies.

To validate the findings from the EAHP analysis, the study examines three case studies from different regions:

Government policies in China have been instrumental in the success of EIPs, particularly through the promotion of industrial symbiosis and circular economy practices (Geng et al., 2009) [1].

The development of EIPs in Vietnam has been challenged by a lack of financial incentives and insufficient government support. However, recent efforts to engage local communities and international partners have shown promise (Nguyen & Le, 2017) [4].

The Ulsan Eco-Industrial Park in South Korea is a successful example where strong government support and stakeholder collaboration have led to significant environmental and economic benefits (Park et al., 2008) [5].

Conclusions. This study concludes that effective institutional changes, particularly in the areas of government policy adaptation, stakeholder engagement, and technological innovation, are essential for the successful implementation of EIPs. The EAHP analysis has identified these as the most critical factors, and their integration into a stakeholder network graph has provided a clear visualization of the institutional landscape necessary for EIP success. Policymakers should prioritize the development of flexible policies that encourage innovation and foster stakeholder collaboration. This will ensure that EIPs can achieve their full potential as models of sustainable industrial development. The insights provided by this research offer a strategic guide for enhancing collaboration among government bodies, industry participants, financial institutions, and research organizations, ultimately leading to more effective and sustainable outcomes in the development of EIPs globally.

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Стаття надійшла до редакції 17.08.2024 р.