



Industrial Symbiosis in Eco-Industrial Parks of Developing Countries: A Review of Challenges, Barriers and Success Factors

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ABSTRACT

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Keywords:
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This study aimed to systematically review the challenges, barriers, and success factors of industrial symbiosis in eco-industrial parks of developing countries. Despite extensive research in industrialized countries, developing contexts have remained overlooked in the literature due to institutional voids, weak infrastructure, financial constraints, and specific socio-cultural norms. The study seeks to identify theoretical gaps and propose a context-based model for implementing industrial symbiosis in these countries. A systematic search was conducted in Web of Science, Scopus, Science Direct, and Google Scholar using keywords related to industrial symbiosis, eco-industrial parks, developing countries, and challenges/success factors. Inclusion criteria comprised full peer-reviewed research articles focused on developing countries and written in English or Persian. After two-stage screening (title/abstract and full text) and methodological quality assessment, 35 eligible articles were selected. Data were coded based on a four-dimensional framework (institutional, technical, economic, and socio-cultural) and synthesized using qualitative content analysis. Barriers were identified in four categories: institutional (weak laws, lack of incentive policies, ambiguous ownership), technical (poor infrastructure, data scarcity, limited awareness), economic (high investment costs, high risk, limited access to finance), and socio-cultural (distrust, resistance to change, low social capital). In contrast, four key success factors were identified: the role of facilitators and intermediary institutions, participatory design and trust-building through pilot projects, flexibility in financial models and utilization of foreign investment, and adaptation to local context through the use of indigenous waste streams and anchor industries. The proposed conceptual model rests on four pillars: gradual institutionalization, pilot-orientation, local context adaptation, and stakeholder participation. Copying developed-country experiences without considering local requirements is associated with high failure rates, and success requires stepwise, context-sensitive, and capacity-based design. The findings provide clear policy implications for governments, industrial managers, and international bodies to facilitate the transition toward sustainable eco-industrial parks.

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Introduction

Increasing resource depletion, climate change, and the accumulation of industrial waste have intensified the need to move beyond linear models of production and consumption toward circular and resource-efficient industrial systems. Industrial symbiosis (IS), which involves the exchange of materials, energy, water, infrastructure, and knowledge among industrial actors, provides an important mechanism for implementing circular economy principles at the industrial ecosystem level. When these interactions are organized within a geographically defined industrial area, they can contribute to the development of eco-industrial parks (EIPs), in which firms and other stakeholders pursue environmental, economic, and social benefits through coordinated resource sharing and collective action. Despite the growing international attention to industrial symbiosis and eco-industrial parks, their implementation in developing countries cannot be considered a simple transfer of models developed in industrialized contexts. Many developing countries are characterized by institutional fragmentation, weak regulatory enforcement, inadequate infrastructure, limited access to finance and technology, informal economic activities, market instability, and context-specific social and cultural conditions. These characteristics influence the formation, coordination, and sustainability of symbiotic relationships and may substantially alter the conditions required for successful EIP development.

Existing literature provides valuable insights into industrial symbiosis; however, evidence concerning the specific barriers and enabling conditions in developing countries remains fragmented across different geographical, industrial, and institutional contexts. This fragmentation limits the development of context-sensitive implementation strategies and may encourage the adoption of standardized approaches that do not adequately reflect local conditions. Therefore, this study systematically reviews the literature on industrial symbiosis and eco-industrial parks in developing countries, focusing on the major barriers, enabling conditions, and implementation mechanisms. The review aims to develop an integrated understanding of institutional, technical, economic, and socio-cultural conditions and to synthesize these findings into a context-sensitive conceptual framework for EIP development.

Method

A systematic literature review was conducted to identify, assess, and synthesize research addressing industrial symbiosis and eco-industrial parks in developing-country contexts. Literature searches were performed in Web of Science, Scopus, ScienceDirect, Google Scholar, and selected Persian-language databases. The search strategy combined terms related to industrial symbiosis, eco-industrial parks, developing countries, barriers, challenges, enabling conditions, and success factors. Publications from 2000 to 2026 were considered, with greater attention given to recent studies in order to incorporate current developments in the field. Studies were included when they were peer-reviewed research articles that explicitly addressed industrial symbiosis or eco-industrial parks in developing or low- and middle-income countries and examined at least one relevant barrier, enabling condition, success factor, implementation mechanism, or lesson learned. Studies focusing exclusively on general sustainability or circular economy issues without a specific connection to industrial symbiosis, studies conducted solely in developed-country contexts without relevant comparison, and publications lacking sufficient methodological or empirical information were excluded.

The screening process consisted of title and abstract screening followed by full-text assessment. Duplicate and irrelevant records were removed, and the remaining studies were evaluated according to the inclusion criteria and methodological quality. The quality assessment considered the clarity of research objectives, appropriateness of methodology, transparency of reporting, and consistency between evidence and conclusions. Ultimately, 35 studies were selected for qualitative synthesis. Data were extracted using a structured coding framework covering study characteristics, geographical and industrial context, identified barriers, success factors, implementation mechanisms, and reported outcomes. The findings were analyzed through qualitative content analysis and organized into four dimensions: institutional and governance, technical and infrastructural, economic and financial, and socio-cultural factors.

Results

The findings indicate that barriers to industrial symbiosis in developing countries are interconnected across four dimensions. Institutional and governance barriers include weak or poorly enforced

regulations, fragmented responsibilities, limited institutional capacity, insufficient incentives, and uncertainty regarding ownership and benefit sharing. Technical and infrastructural barriers involve inadequate waste treatment and segregation, limited information on resource flows, technological constraints, inconsistent quality of secondary resources, and spatial separation between potential partners. Industrial symbiosis extends beyond material exchange to include water reuse, energy integration, and shared value-chain activities such as logistics, procurement, knowledge exchange, and workforce development. Economic and financial barriers include limited access to capital, high financing costs, investment uncertainty, and difficulties in funding shared infrastructure. Diversified financing, public-private partnerships, green finance, and risk-sharing mechanisms can help address these constraints, provided that appropriate institutional and regulatory frameworks are in place. Socio-cultural barriers include limited awareness, lack of trust, reluctance to share information, weak collaboration, and insufficient stakeholder participation, highlighting the importance of communication and trust-building.

Four major groups of success factors were identified. First, intermediary and facilitator institutions can improve coordination, information exchange, trust, and identification of symbiotic opportunities. Second, participatory implementation and pilot projects can reduce uncertainty, support institutional learning, demonstrate benefits, and build stakeholder confidence. Third, financial flexibility and risk-sharing mechanisms can facilitate investment by diversifying financing sources and reducing financial risks. Fourth, adaptation to local conditions is essential; symbiotic networks should reflect local resources, industries, infrastructure, markets, institutional capacities, and regional priorities rather than replicate standardized EIP models. In less mature industrial networks, anchor industries can also provide a foundation for developing broader symbiotic relationships.

Conclusions

The synthesis indicates that industrial symbiosis in developing countries involves two simultaneous processes: establishing the institutional, technical, financial, and social foundations required for collaboration and generating tangible environmental and economic benefits through that collaboration. Consequently, successful EIP development requires more than technological solutions or waste-exchange opportunities. It requires an integrated process of institutional development, stakeholder coordination, financial mobilization, capacity building, and adaptation to local conditions.

Based on the synthesized evidence, a four-pillar conceptual framework is proposed. The first pillar is gradual institutionalization and effective governance, emphasizing clear responsibilities, supportive policies, regulatory capacity, and appropriate incentive mechanisms. The second is intermediary facilitation and stakeholder participation, focusing on trust building, information exchange, coordination, and inclusive decision-making. The third is pilot-oriented and financially flexible implementation, emphasizing incremental development, institutional learning, risk reduction, and diversified financing. The fourth is local-context adaptation, which aligns symbiotic networks with regional resources, industries, infrastructure, market conditions, and socio-economic characteristics.

The findings suggest that industrial symbiosis in developing countries should be approached as an evolutionary and context-dependent process rather than as the direct replication of standardized models. Effective implementation requires simultaneous attention to institutional capacity, technical infrastructure, economic feasibility, and socio-cultural conditions. Policies and programs should therefore combine regulatory and financial support with participatory planning, local facilitation, capacity building, and experimentally oriented implementation.

Several limitations should be considered. The reviewed literature is heterogeneous in terms of definitions, analytical approaches, geographical coverage, and methodological quality. The number of longitudinal studies remains limited, and evidence is concentrated in particular regions. In addition, the review was restricted to English- and Persian-language literature. Future research should strengthen longitudinal and comparative analyses, employ quantitative and econometric approaches where appropriate, investigate the role of digital technologies and informal economic activities, and develop empirical models for assessing the long-term performance of EIPs in different developing-country contexts. Further research can also contribute to developing context-specific implementation frameworks for industrial symbiosis and eco-industrial parks in countries undergoing industrial and circular-economy transitions.

منحصربه‌فردی مواجه می‌سازد. یافته‌ها دلالت‌های سیاستی روشنی برای دولت‌ها، صنعتگران و نهادهای بین‌المللی دارد و نشان می‌دهد که موفقیت نیازمند طراحی بافت‌مند، گام‌به‌گام و مبتنی بر ظرفیت‌های محلی است.

نتیجه‌گیری

این پژوهش با مرور نظام‌مند ۳۵ مقاله، نشان داد که موانع همزیستی صنعتی در کشورهای در حال توسعه در چهار دسته نهادی، فنی، اقتصادی و اجتماعی-فرهنگی قرار دارند و عوامل موفقیت شامل نقش تسهیل‌گر، طراحی مشارکتی، انعطاف‌پذیری مالی و انطباق با بافت محلی هستند. تفاوت بنیادین با کشورهای توسعه‌یافته در این است که در بسترهای در حال توسعه، عوامل موفقیت باید همزمان به «ایجاد بستر» و «بهره‌مندی از بستر» بپردازند (Castillo-Vergara et al., 2022; Nylén et al., 2025). مدل مفهومی چهاررکنی پیشنهادی بر نهادسازی تدریجی، پایلوت‌محوری، انطباق با بافت محلی و مشارکت ذی‌نفعان تأکید دارد.

محدودیت‌های پژوهش شامل اتکا به مقالات انگلیسی و فارسی، تنوع تعاریف همزیستی، کمبود مطالعات طولی، تمرکز جغرافیایی بر آسیا و آفریقا و استفاده از منابع فاقد تاریخ انتشار دقیق (مانند بانک جهانی، بی‌تاریخ) است. پیشنهاد برای پژوهش‌های آتی: انجام مطالعات تطبیقی طولی، روش‌های اقتصادسنجی، پژوهش‌های اقدام‌محور، بررسی نقش فناوری‌های دیجیتال و بخش غیررسمی اقتصاد، و مطالعات میان‌منطقه‌ای پیشنهاد می‌شود. همچنین پژوهشی با عنوان «ارائه مدل بومی پیاده‌سازی همزیستی صنعتی در پارک‌های اکولوژیک ایران با رویکرد اقتصاد چرخشی و با تأکید بر منطقه ویژه اقتصادی پتروشیمی» می‌تواند با روش‌های ترکیبی و مشارکت ذی‌نفعان کلیدی، چارچوبی عملیاتی برای گذار از پارک‌های صنعتی سنتی به اکولوژیک در ایران ارائه دهد.

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