engineering proceedings

MDPI

Proceeding Paper

Performance of Green Industrial Estate: A Review †

Ikse Duma Alriansyach [1], Christiono Utomo [1,*], Yani Rahmawati [2] and Aqsha Aqsha [3]

[1] Department of Civil Engineering, Institut Teknologi Sepuluh Nopember, Surabaya 60111, Indonesia; dumaalriansyach@gmail.com
[2] Department of Architecture Engineering and Planning, Universitas Gadjah Mada, Yogyakarta 55281, Indonesia; yani.rahmawati@ugm.ac.id
[3] Department of Chemical Engineering, Institut Teknologi Bandung, Bandung 40132, Indonesia; aqsha@che.itb.ac.id
* Correspondence: christiono@ce.its.ac.id
† Presented at the 2024 IEEE 4th International Conference on Electronic Communications, Internet of Things and Big Data, Taipei, Taiwan, 19–21 April 2024.

Abstract: Green industrial estates are implemented for sustainable development in the industrial sector. The industrial sector is a large consumer of energy and resources and produces pollutants. Environmentally friendly development in industrial estates is important in encouraging environmentally friendly production and ecological civilization as a strategic key to economic and social growth. This is an important basis for assessing the performance of green industrial estates. Research on green buildings in industrial estates has been conducted widely, including reviewing the performance of developing green industrial estates and using various methods. This research aims to determine research methods on the performance of green industrial estates using a literature review in reputable journals from 2014 to 2023. A mapping diagram was used to classify research types and data sources. The results showed that many researchers examined the performance of green industrial estates by reviewing environmental and economic aspects, and few researchers reviewed social aspects. Apart from these aspects, in reviewing the aspects of the performance of green industrial estate, researchers used modeling and case studies. The result of this research provides a reference for choosing the right method for assessing the performance of green industrial estates in future research.

Keywords: green; industrial estate; performance; research method

Citation: Alriansyach, I.D.; Utomo, C.; Rahmawati, Y.; Aqsha, A. Performance of Green Industrial Estate: A Review. *Eng. Proc.* **2024**, *74*, 5. https://doi.org/10.3390/engproc2024074005

Academic Editors: Shu-Han Liao, Teen-Hang Meen and Cheng-Fu Yang

Published: 27 August 2024

1. Introduction

Industrial estates are key factors of industrial production, manufacturing, and economic activity, areas with significant populations and trade associations. The number of global industrial estates is between 12,000 and 20,000, increasing construction in developed and developing countries [1]. One of the reasons for resource depletion and environmental degradation is that industrial estates are large consumers of energy and resources, and pollutant producers [2]. Industrial estates play an essential role in facilitating industrial sustainability and economic development. Green development is a model of economic transformation to improve people's welfare while preserving the environment and resources. Various problems associated with many industrial estates can occur, such as resource and energy consumption challenges and risks of high environmental impact [3]. Greening in industrial estates is related to Goal 9 of the Sustainable Development Goals (SDGs), which promotes inclusive and sustainable industrialization and encourages innovation while tackling climate change [4]. Sustainable development includes targeted infrastructure development nationally and regionally. This includes spatial planning, competition in investment incentives, the implementation of new construction projects, encouraging the regional use of buildings, and improving energy recovery processes [5]. For example, greening industrial estates in China is a way to explore sustainable development in the industrial sector. In addition, greening industrial estates creates collaborative and efficiency

gains to provide a powerful tool for regional economic growth [6]. Energy infrastructure is shared in industrial estates to have a long service life to protect industrial estates from greenhouse gas emissions. Green industrialization requires infrastructure that is resilient, efficient, and sustainable [7].

Promoting green industrial estates is essential to reduce the impacts of policies and programs in their development. In evaluating the development, the performance of green development in industrial estates is evaluated. The performance is evaluated by determining how green industrial estates promote green innovation [8]. Many researchers assessed the performance of green industrial estates using various methods including surveys and case studies.

2. Background Knowledge

2.1. Green Industrial Estate

Notions such as green building and sustainable construction have emerged from the concept of sustainable development. Green buildings are a solution for the requirements of sustainable development in the construction industry. Characteristics of green buildings include energy and water efficiency, reduced consumption of natural resources, and improved health and the environment [9]. In sustainable development, the green building concept is an innovation [10]. Green buildings can be used to reduce the impact of global climate change in achieving energy efficiency, carbon reduction, and social responsibility [11]. Green development in the construction industry is closely related to urbanization and industrialization. Its features are adapted to the region, climate adaptation, building sustainability, and the surrounding environment. Green buildings are platforms for development under current resource and environmental constraints [12].

The green industrial zone is related to a shared philosophy of the people about how to enhance well-being, create employment and decent work opportunities, and maintain healthier global ecosystems. Green and environmentally friendly buildings slow global warming by changing the microclimate [13]. The green industrial estate promotes development in spatial planning, industrial development, energy utilization, resource utilization, infrastructure, ecological environment, operations, and management [6]. Industrial estates have played a key role in facilitating industrial sustainability and economic development in recent years. Green development in industrial estates is an important starting point in promoting green production and ecological civilization and a key strategic shaper for economic and social growth [3]. Industrial estates continue to grow rapidly being equipped with shared infrastructure with a long service life and limited greenhouse gas emissions. Greening industrialization requires efficient, tough, and sustainable infrastructure [7]. Local communities need to reduce waste and pollution, increase resource efficiency, and strive for sustainable development to increase economic benefits and the environmental quality of environmentally friendly industrial estates [14].

2.2. Performance of Green Industrial Estate

Several criteria are used in assessing the success and effectiveness of green industrial estates [6]. Green development efficiency is a criterion used to evaluate green development performance in industrial estates. When the environmental impact of a product from an industrial estate reduces, its economic value is increased. This shows how green efficiency is realized. Apart from factors that reduce environmental impacts and increase economic value, social impacts are difficult to measure though those are related to the performance of green development in industrial estates [15]. In evaluating the performance of green development in industrial estates, various points of view such as social justice, economic development, environmental risks, and resource efficiency are needed [16]. In Ref. [16], green industrial estates were evaluated from three perspectives: gross domestic product (GDP), environmental pollution, and resource consumption. Figure 1 shows the three aspects that represent the performance of industrial estates. It is important to evaluate the use of resources and environmental pressures from eco-industrial development in

industrial estates. However, the complexity and difficulty of measuring resource flows make the evaluation difficult because environmentally friendly industrial estates change the resource flow [2].

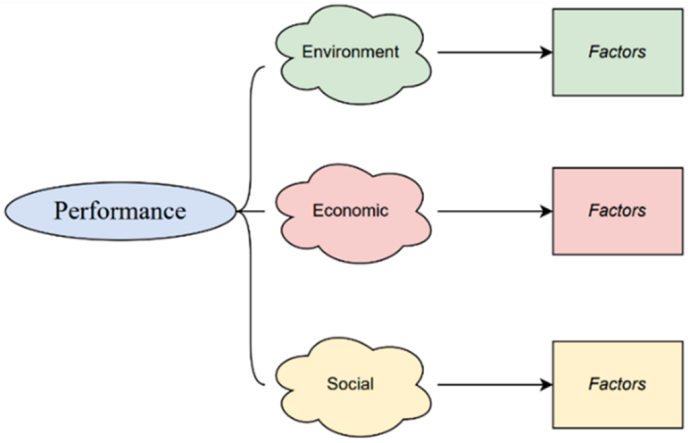

Figure 1. Aspects and factors of performance of green industrial estate.

2.2.1. Environment

Environmental pressure and increasing carbon emissions are challenges in an industrial estate. Reducing the resulting environmental impact can increase costs and encourage green efficiency. To achieve the goal of a green industrial estate preserving the environment, the following factors are used in the evaluation of the green industrial estate: economic growth, environmental preservation, climate change, and green development [6]. In worsening global environmental problems, green innovation helps reduce environmental pollution. Environmentally friendly industrial estates increase the economic benefits of a company while minimizing the environmental impact it produces [8].

2.2.2. Economy

In assessing the sustainability of the development of green industrial estates, various indicators are used. The application of industrial symbiosis is linked to economic aspects [15]. The benefits of green industrial estates include reduced waste disposal costs and reduced purchases of raw materials. The economic benefits are easy to measure [16]. Green industrial estates promote economic development [17]. The economic performance of an industrial estate is affected by economic fluctuation. Investments in research and continuous development in industrial estates increase economic resilience.

2.2.3. Society

In assessing sustainability, social aspects have been little discussed. An environmentally friendly industrial estate improves environmental, economic, and social performance in managing environmental and resource problems collaboratively. Social impacts from the development of green industrial estates are related to lifestyle and health in the vicinity of green industrial estates. However, assessing the performance of this social aspect requires appropriate evaluation because it is difficult to measure and assess its application [15].

3. Methodology

Previous Data

We reviewed the methods of previous research in analyzing green buildings in industrial estates. We analyzed articles from various quality journals on the performance of green in industrial estates. Related articles published from 2014 to 2023 were collected. Table 1 shows the list of journals and the SCImago Journal Rank (SJR) of articles from each journal.

Table 1. Selected journals in this study.

Journal Publications	SJR	Quartiles Category
Structural Change and Economic Dynamics	1.32	Q1 in Economics and Econometrics
Energy Strategy Reviews	2.06	Q1 in Energy
Nature Communications	5.11	Q1 in Biochemistry, Genetics, and Molecular Biology
Journal of Cleaner Production	1.98	Q1 in Renewable Energy, Sustainability, and the Environment
Journal of Environmental Management	1.67	Q1 in Environmental Engineering
Waste Management	1.74	Q1 in Waste Management and Disposal
Environmental Science and Pollution Research	0.94	Q1 in Environmental Chemistry
City and Environment Interactions	0.80	Q1 in Environmental Science
Sustainability	0.66	Q1 in Renewable Energy, Sustainability, and the Environment
Cleaner Engineering and Technology	0.77	Q1 in Environmental Engineering
Heliyon	0.60	Q1 in Multidisciplinary
Technological Forecasting and Social Change	2.64	Q1 in Management of Technology and Innovation
World Development	2.50	Q1 in Economics and Econometrics

4. Results and Discussion

The selected articles were used for performance analysis in green industrial estates. Table 2 shows the environmental factors of performance in the green industrial estate. Table 3 presents the economic factors, while Table 4 shows the social factors of the performance of green industrial estates in previous research.

Table 2. Environmental factors of performance.

No	Factors	Source
1	Investment in clean production	[2,6,14,16,18]
2	Developing the use of environmentally friendly energy	[2,3,6]
3	Reducing the rate of untreated industrial solid waste	[2,6,18,19]
4	Reducing carbon emissions	[1,6,7,15,20,21]
5	Increasing the exchange of products or materials	[2,22–24]
6	Comprehensive resource energy utilization	[2,3,20,21,24–28]
7	Technological innovation	[8,20,21]

Table 3. Economic factors of performance.

No	Factors	Source
1	Optimization of material and energy utilization at the lowest cost	[2,6]
2	Optimizing the use of public facilities	[2]
3	Value added per capita	[6,15,18]
4	Investment	[15]
5	Economic growth	[6,18]
6	Clean production audit	[2]
7	Utilization of waste resources	[1,2,19]
8	Comprehensive resource and energy utilization	[25]
9	Determining strategic locations to unite industry	[26]
10	Optimizing the flow of materials and waste	[22,24]
11	Industrial structure	[8,14,17]
12	Technological innovation	[17]
13	Planning and governance	[17]
14	Reducing the rate of untreated industrial solid waste	[19]

Table 4. Social factors of performance.

No	Factors	Source
1	Optimization of material and energy utilization at the lowest cost	[2,6]
2	Optimizing the use of public facilities	[2]
3	Satisfaction of residents	[15]
4	Contribution of the company's workforce	[15]
5	Environmental reporting	[15]

The factors related to the performance of green industrial estates were connected to the research methods. The type of research was divided into qualitative and quantitative and mixed quantitative–qualitative research. The quantitative method included modeling, surveys, questionnaires, interviews, and descriptive statistics. In contrast, the qualitative method included case studies and literature reviews.

To measure the performance of green industrial estates from the environmental aspect, modeling and case studies were used. Literature reviews, questionnaires, descriptive statistics, interviews, and surveys were also used. From the economic aspect, modeling and case study methods were widely used with literature reviews and descriptive statistics. From the social aspects, modeling, case studies, and literature reviews were employed (Figure 2).

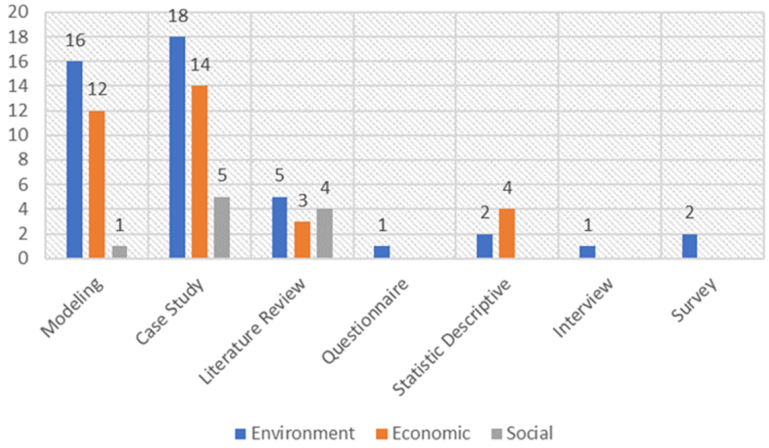

Figure 2. Method of factors of performance of green industrial estate.

5. Conclusions

We conducted a literature review on green industrial estate performance. The performance of green industrial estates was evaluated from the environmental, economic, and social aspects. For each aspect, criteria or factors were determined. Many researchers have reviewed environmental and economic aspects using modeling and case studies, whereas few researchers have reviewed the social aspects. In future research, appropriate methods should be used to evaluate the performance of green industrial estates.

Author Contributions: Conceptualization, I.D.A. and C.U.; methodology, I.D.A.; formal analysis, I.D.A.; investigation, Y.R.; resources, C.U.; writing—original draft preparation, I.D.A.; writing—review and editing, I.D.A., Y.R., A.A. and C.U.; supervision, C.U., Y.R. and A.A.; project administration, I.D.A.; funding acquisition, C.U., Y.R. and A.A. All authors have read and agreed to the published version of the manuscript.

Funding: The research have been funded by Program Riset Kolaborasi Indonesia (Skema A) 2023. Contract Number: 1660/PKS/ITS/2023.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data supporting the conclusions of this article will be made available by the authors on request.

Acknowledgments: The authors gratefully acknowledge financial support from the Institut Teknologi Sepuluh Nopember for this work, under the Capacity Development Program of Higher Education for Technology and Innovation Project Asian Development Bank Loan No 4110-INO.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Yan, X.; Wang, L.; Fang, M.; Hu, J. How can industrial parks achieve carbon neutrality? Literature review and research prospect based on the citespace knowledge map. *Sustainability* **2023**, *15*, 372. [CrossRef]
2. Fan, Y.; Fang, C. Assessing environmental performance of eco-industrial development in industrial parks. *Waste Manag.* **2020**, *15*, 219–226. [CrossRef] [PubMed]
3. Lyu, Y.; Liu, Y.; Guo, Y.; Sang, J.; Tian, J.; Chen, L. Review of green development of Chinese industrial parks. *Energy Strategy Rev.* **2022**, *42*, 100867. [CrossRef]
4. United Nations. Sustainable Development. Available online: https://sdgs.un.org/goals (accessed on 11 July 2023).
5. Komarovska, A.; Ustinovichius, L.; Shevchenko, G.; Nazarko, L. Multicriteria evaluation of commercial industrial zone development. *Int. J. Strateg. Prop. Manag.* **2015**, *19*, 84–95. [CrossRef]
6. Yu, X. An assessment of the green development efficiency of industrial parks in China: Based on non-desired output and non-radial DEA model. *Struct. Chang. Econ. Dyn.* **2023**, *66*, 81–88. [CrossRef]
7. Guo, Y.; Tian, J.; Chen, L. Managing energy infrastructure to decarbonize industrial parks in China. *Nat. Commun.* **2020**, *11*, 1–9. [CrossRef] [PubMed]
8. Wu, Y.; Gao, X. Can the establishment of eco-industrial parks promote urban green innovation? Evidence from China. *J. Clean. Prod.* **2022**, *341*, 130855. [CrossRef]
9. Dwaikat, L.N.; Ali, K.N. The economic benefits of a green building—Evidence from Malaysia. *J. Build. Eng.* **2018**, *18*, 448–453. [CrossRef]
10. Meena, C.S.; Kumar, A.; Jain, S.; Ateeq, U.R.; Sachin, M.; Naveen, K.S.; Mohit, B.; Muhammad, S.; Elsayed, T. Eldin. Innovation in green building sector for sustainable future. *Energies* **2022**, *15*, 6631. [CrossRef]
11. Onuoha, I.J.; Aliagha, G.U.; Rahman, M.S.A. Modelling the effects of green building incentives and green building skills on supply factors affecting green commercial property investment. *Renew. Sustain. Energy Rev.* **2018**, *90*, 814–823. [CrossRef]
12. Zhu, J.; Cao, Y.; Zhai, J.; Zhao, X.; Zhao, Y.; Kang, S. Analysis on synergies and trade-offs in green building development: From the perspective of SDG 11. *Chin. J. Popul. Resour. Environ.* **2019**, *17*, 341–351. [CrossRef]
13. Utomo, C.; Astarini, S.D.; Rahmawati, F.; Setijanti, P.; Nurchayo, C.B. The influence of green building application on high-rise building life cycle cost and valuation in Indonesia. *Buildings* **2022**, *12*, 2180. [CrossRef]
14. Xu, F.; Xiang, N.; Tian, J.; Chen, L. 3Es-based optimization simulation approach to support the development of an eco-industrial park with planning towards sustainability: A case study in Wuhu, China. *J. Clean. Prod.* **2011**, *164*, 476–484. [CrossRef]
15. Valenzuela-venegas, G.; Salgado, J.C.; Diaz-Alvarado, F.A. Sustainability indicators for the assessment of eco-industrial parks: Classification and criteria for selection. *J. Clean. Prod.* **2016**, *133*, 99–116. [CrossRef]
16. Hou, D.; Li, G.; Chen, D.; Zhu, B.; Hu, S. Evaluation and analysis on the green development of China's industrial parks using the long-tail effect model. *J. Environ. Manag.* **2019**, *248*, 109288. [CrossRef]
17. Pan, S.C.; Hu, T.S.; You, X.; Chang, S.L. Characteristics and influencing factors of economic resilience in industrial parks. *Heliyon* **2023**, *9*, e14812. [CrossRef]
18. Tian, J.; Liu, W.; Lai, B.; Li, X.; Chen, L. Study of the performance of eco-industrial park development in China. *J. Clean. Prod.* **2014**, *64*, 486–494. [CrossRef]
19. Abu-Qdais, H.A.; Kurbatova, A.I. The role of eco-industrial parks in promoting circular economy in Rusia: A life cycle approach. *Sustainability* **2022**, *14*, 3893. [CrossRef]
20. Wang, Y.; Ren, H.; Dong, L.; Park, S.; Zhang, Y.; Xu, Y. Smart solutions shape for sustainable low-carbon future: A review on smart cities and industrial parks in China. *Technol. Forecast. Soc. Chang.* **2019**, *144*, 103–117. [CrossRef]
21. Zeng, D.Z.; Cheng, L.; Shi, L.; Luetkenhorst, W. China's green transformation through eco-industrial parks. *World Dev.* **2021**, *140*, 105249. [CrossRef]
22. Genc, O.; Kurt, A.; Yazan, D.M.; Erdis, E. Circular eco-industrial park design inspired by nature: An integrated non-linear optimization, location, and food web analysis. *J. Environ. Manag.* **2020**, *270*, 110866. [CrossRef]
23. Perrucci, D.V.; Aktas, C.B.; Sorentino, J.; Akanbi, H.; Curabba, J. A review of international eco-industrial parks for implementation success in the United States. *City Environ. Interact.* **2022**, *16*, 100086. [CrossRef]
24. Shah, I.H.; Dong, L.; Park, H.S. Tracking urban sustainability transition: An eco-efficiency analysis on eco-industrial development in Ulsan, Korea. *J. Clean. Prod.* **2020**, *262*, 121286. [CrossRef]
25. Gao, G.; Wang, S.; Xue, R.; Liu, D.; Huang, B.; Zhang, R. Eco-efficiency assessment of industrial parks in Central China: A slack-based data envelopment analysis. *Environ. Sci. Pollut. Res.* **2022**, *29*, 30410–30426. [CrossRef]

26. Nuhu, S.K.; Manan, Z.A.; Wan, A.S.R.; Reba, M.N. Integrated modelling approach for an eco-industrial park site selection. *J. Clean. Prod.* **2022**, *368*, 133141. [CrossRef]
27. Uusikartano, J.; Vayrynen, H.; Aarika-Stenroos, L. Public actors and their diverse roles in eco-industrial parks: A multiple-case study. *J. Clean. Prod.* **2021**, *296*, 126463. [CrossRef]
28. Kreiner, I.; Bressers, H.T.A.; Franco-Garcia, M.L. Challenges to implementing a sustainable strategic evaluation framework of industrial parks: Mexican case. *Clean. Eng. Technol.* **2023**, *13*, 100612. [CrossRef]