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Integrating Environmental Resilience-Based Spatial Utilization for Eco-Industrial Park: Sustainable Industrial Development

Agus Salim[1], Nasrullah[2], Murssyid Mustafa[3], Abdul Karim[4]

Abstract

This research aims to identify the factors influencing Sustainable Industrial Development in developing the Eco-Industrial Park (EIP) Model in Industrial Areas. This research will produce a deeper understanding of the complex dynamics between these factors and how they influence each other in creating a sustainable industrial environment. The research was conducted in the Selayar industrial area in the Selayar Islands Regency of South Sulawesi Province, focusing on various aspects, including activity systems, spatial resource allocation, land use change, environmental resilience, and sustainable industrial development. Data collection involved distributing questionnaires to 352 respondents, with 214 questionnaires meeting the criteria for analysis. The demographic profile of the participants exhibited diversity in terms of gender, age, education level, and income level, contributing to a comprehensive cross-section of individuals. The variables were measured using multiple-item scales on a five-point Likert scale, ranging from 'strongly disagree' to 'strongly agree.' Structural Equation Modeling (SEM) with AMOS software was employed for data analysis, encompassing parameter estimation, model testing, and interpretation of findings. Integrating green technology into sustainable industrial practices strengthens its positive impact on environmental resilience. These findings depict the intricate interplay between environmental resilience, various factors, and sustainability goals, serving as a solid foundation for focused strategic planning aligned with sustainability objectives. To sharpen this strategy, greater attention to eco-friendly technology innovation, cross-sector collaboration, more detailed performance measurement, and active stakeholder engagement can enhance the positive contribution to environmental resilience and establish a robust foundation for a sustainable future.

Keywords: *Green Industry; Industrial Ecology; Environmental Resilience; Environmental Concerns; Sustainable Development.*

1. INTRODUCTION

Modeling an industrial system to address environmental concerns involves emulating the structure of a natural ecological system. Solar-powered natural ecological systems bear a resemblance to industrial ecology. Within these ecosystems, diverse organisms engage in interactions, establishing interdependent relationships. This intricate network of connections facilitates the exchange of materials in a lengthy cycle [1], [2]. Consequently,

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[1] Department of Regional Planning, Faculty of Engineering, University Bosowa, Makassar 90231, Indonesia, agus.salim@universitasbosowa.ac.id

[2] Department of Architectural, Faculty of Engineering, University Bosowa, Makassar 90231, Indonesia, nasrullah.nasrullah@universitasbosowa.ac.id

[3] Department of Architecture, Faculty of Engineering, University Muhammadiyah, Makassar 90231, Indonesia, it@unismuh.ac.id

[4] Department of Management, Faculty of Economic and Business, University Bosowa, Makassar, South Sulawesi, Indonesia, abdul.karim@universitasbosowa.ac.id

industrial ecology employs the principles of natural ecology to effectively regulate the dynamics of energy or matter, striving for optimal efficiency and minimal environmental contamination [3]. Industrial ecology functions as a method of ecological governance. It views industrial frameworks as integral and interconnected components of their broader context. The optimization of material flow from raw materials to finished goods becomes the central objective [4]. The overarching goal of industrial ecology is establishing a systematic framework for the industrial system, encompassing all human endeavors. This pursuit aims to achieve a development paradigm that is both environmentally conscious and sustainable [5].

The industrial sector holds a crucial and significant role in attaining development goals. However, it encounters challenges from conflicts between industrial activities and their environmental impacts and sustainable development. Ecological degradation surrounds industrial areas, disputes and tensions arising between the industry and the community regarding disparities in welfare, the potential for various forms of environmental pollution (liquid, gas/air, solids), and the emergence of technical issues [6]–[8]. These issues encompass constrained access to raw process water, limited energy sources for generation, and management of industrial waste, all of which influence industrial sustainability.

The capacity of the environment to sustain itself is diminished due to pollution and other repercussions arising from this industry [9]. To curtail the industry's environmental footprint, all stakeholders must pledge their commitment to environmental sustainability. This collective commitment aims to prevent the transmission of environmental damage caused by ongoing human activities, including industrial development, to future generations [10], [11]. Simultaneously, it seeks to ensure that the industry's endeavors to enhance the socio-economic status of society do not give rise to predicaments. In pursuing sustainable development, the industrial realm must contribute to fostering a harmonious and mutually advantageous interplay between industrial operations and the ecosystems that support them. The industrial sector has embraced the "environmentally sound industry" or "green industry" in response to global environmental shifts.

Industrial development in Indonesia finds its justification in the multifaceted consequences it exerts on activity systems, spatial allocation, and alterations in land use patterns. These cumulative impacts can, in turn, precipitate pollution and environmental degradation, resulting in a diminishment of overall environmental resilience [12]–[14]. The escalation of industrial activities and the concurrent evolution of activity systems exhibit a discernible correlation with the dynamics of spatial allocation and changes in land utilization, along with their repercussions on the environmental milieu within industrial regions [15]. Consequently, the strategic allocation of space within industrial locales has a tangible influence on creating an industrial ambiance, orchestrating spatial arrangements, and deterring potential environmental pollution [16], [17]. Moreover, the developmental impetus behind industrial zones is guided by the aim of fostering a more directed and harmoniously integrated expansion of the industrial sector. This approach seeks to optimize the benefits derived from industrial zones for the regions in which they are situated, thereby contributing to the trajectory of sustainable industrial area development [18]. In essence, the overarching purpose of industrial area development resides in propelling economic growth and erecting a robust foundation for a sustainable industrial ecosystem [19].

Research into the development of industrial areas and their effects on the environment and sustainability has generated valuable insights. Numerous related studies have offered profound perspectives on the interplay between economic growth and environmental preservation. For instance, in the investigation by [20], industrial agglomeration emerged as a primary catalyst in the urban establishment. They emphasized the need to enhance the efficiency of urban green space utilization to achieve sustainable development. A comparable strategy was put forth by [21], who introduced innovative solutions to address land scarcity concerns during spatial expansion. By converting inefficient industrial land into new industries, they highlighted the importance of optimal and sustainable land utilization. The impact of industrial expansion on urban sprawl and ecological sustainability also attracted attention in the research [22], [23]. They stressed the imperative of sustainable land management and endeavored to curtail urban sprawl to uphold environmental quality and local sustainability. In further advancement, [24] emphasized the wide-ranging consequences of industrial area development, encompassing industrial climate, land use regulation, heightened economic productivity, and environmental preservation. These perspectives underscore the vital role of careful and sustainable planning in industrial area development, aiming to mitigate adverse environmental repercussions.

The research provides a comprehensive evaluation of its long-term benefits. Firstly, it stimulates industrial growth in regions abundant in resources. Secondly, it facilitates strategic spatial allocation, promoting the development of industrial zones while enhancing environmental resilience. Lastly, it instills environmentally conscious governance in industrial advancement, leading to a reduction in environmental pollution. These three benefits synergistically contribute to nurturing sustainable environmental resilience through cohesive activity systems, spatial organization, and land utilization [25]. The development of industrial areas yields a plethora of substantial benefits. These benefits include enhancing convenience for the business world, providing protection against disruptions, offering accessible supporting facilities, resolving spatial issues, and mitigating environmental impacts. This comprehensive approach aligns with the concept presented by [26], who emphasize the importance of cultivating industrial areas that are both sustainable and exert a positive influence on various aspects of society and the environment.

Industrial area development aims to promote focused and integrated expansion within the industrial sector, resulting in optimal outcomes for the regions that accommodate these industrial zones. From a spatial perspective, the presence of industrial zones helps alleviate conflicts stemming from land use. Similarly, directing industrial activities into designated zones enhances the feasibility of management and planning, particularly in the surrounding areas. From an environmental perspective, the concentration of industrial activities in controlled locations improves the efficiency of waste treatment facilities and waste disposal management. As a result, the focal point of this research centers on exploring the model of land use change, spatial allocation, activity systems, and their combined impact on environmental resilience and the sustainability of regional development.

2. THEORIES AND RESEARCH HYPOTHESES

Developing an eco-industrial park (EIP) is intrinsically linked to efforts to integrate this EIP with the surrounding community. However, the community will directly experience the impacts of an industrial zone. Additionally, establishing such an area should be a consideration for regional development, primarily focused on enhancing the local population's well-being. Consequently, implementing an eco-industrial park cannot be isolated from endeavors to establish a sustainable community. The term "sustainable community" varies and possesses unique characteristics in each region, in line with the needs and cultural aspects of the local populace.

The definition of a sustainable community revolves around an integrated, long-term systemic approach that encompasses issues related to economics, environment, and society. This concept perceives economic, environmental, and social concerns as interconnected and interdependent. Economic matters within a sustainable community emphasize generating meaningful employment opportunities, ensuring equitable wages, maintaining stable businesses, appropriately implementing and advancing technology, fostering business development, and more. Without a robust economic foundation, achieving sustainability remains a distant aspiration. Sustainable development entails a dynamic equilibrium between preservation (sustainability) and evolution (development) to fulfill livelihood needs [27], [28].

Lowe's delineation of the Eco-Industrial Park (EIP) concept in 1997 established a framework for an industrial community encompassing multiple manufacturing and business service entities. Their collaborative endeavors aim to enhance environmental and economic performance through cooperative management of environmental and resource-related concerns, including energy, water, and materials. The fundamental objective of the EIP is to mitigate detrimental environmental impacts while simultaneously fostering new avenues for sustainable economic growth [29]. Within the confines of an Eco-Industrial Park, the operating companies jointly engage in resource-sharing and production processes. This framework actively stimulates the creation of an enhanced cycle of resource utilization. As a result, waste generated by one company serves as a viable input for other entities, leading to waste reduction and the promotion of optimal resource utilization. Beyond its environmental advantages, the EIP also confers noteworthy economic benefits. The synergy and collaboration fostered among entities spanning diverse sectors yield heightened operational efficiency, amplified productivity, and substantial cost savings.

Moreover, cultivating a favorable reputation centered around sustainability and social responsibility can confer a competitive edge in a market that is progressively attuned to environmental concerns [30]. The workshop, organized by the United States President's Council on Sustainable Development, has yielded two pivotal definitions of an Eco-Industrial Park (EIP). One definition identifies it as the Enterprise Integration Platform, fostering collaboration within the business community and extending to the broader community for optimizing resource utilization. The other portrays it as an industrial system coordinating the exchange of raw materials, emphasizing minimal energy and resource consumption and waste generation. All these factors operate within a sustainable economic, ecological, and social framework [31].

Developing industrial zones serves as a means to foster environmentally conscious industrial activities while providing ease of investment and attractiveness through an approach focused on efficiency, spatial planning, and the environment [32], [33]. Developing industrial zones also leads to physical, social, and economic changes in the surrounding environment [34]. Consequently, industrial growth will have implications for activity systems, spatial utilization allocation, and land use changes, resulting in a decline in environmental quality. Furthermore, the sustainable development of industrial zones will impact the growth of the industrial climate, land use management, and prevention of environmental contamination [35], [36].

Activity System

The development of industrial activities has become a catalyst for the formation of activity systems, both in regional and local contexts, which contribute to the creation of an industrial climate [37], [38]. An activity system organizes land utilization for trade, industry, settlement, and education. It requires optimal ecological spatial arrangement and orderly spatial planning [39]. The connectivity of transportation infrastructure systems has an impact on enhancing mobility and the flow of goods, including raw materials for industries and processed industrial products [40]. Developing integrated industrial zones equipped with various supporting infrastructures that align with environmental preservation, including the harmony and balance between social and economic activities, will drive the realization of sustainable industries [41]. Industrial areas within urban settings can provide added value as reinforcements for spatial industry linkages [42]. In implementing industrial zone planning, the synergy among activity systems aims to control spatial utilization, enhance environmentally conscious industrial development efforts, provide location certainty assurance in planning, and develop coordinated infrastructure across industry-related sectors [43].

H1: Activity System has a significant effect on Environmental Resilience.

Spatial Resource Allocation

Diverse spatial resource allocations contribute to interconnections among various aspects: natural resources, artificial resources, social, cultural, economic, technological, informational, administrative, and defense security. When integrated comprehensively and harmoniously, these components form a high-quality spatial structure and enforce stringent rules for resource utilization and environmental protection [44]. The allocation of urban industrial land is significantly influenced by economic growth, with the impact of industrial structure and technological innovation experiencing a rapid escalation. A disparity in quantity exists between industrial land consumption and manufacturing growth within urban areas. The incongruity above can be resolved by implementing spatial planning and land use strategies. Establishing zoning management and governance systems to allocate urban industrial land resources optimally is suggested by implementing standard land commitment systems and industrial land protection pathways [45]. Population mobility, increased transportation needs, and complex land use have reduced environmental quality and air pollution—each type of spatial resource allocation results in varying environmental impacts [46]. Achieving sustainable economic growth necessitates utilizing contemporary and efficient production techniques, employing environmentally friendly industrial inputs, and enhancing public and private awareness. There is a suggestion to promote the adoption of cutting-edge, ecologically sustainable, and efficient processing techniques within the public and commercial sectors [47].

H2: Spatial Resource Allocation has a significant effect on Environmental Resilience.

Land Use Change

Land use change is influenced by environmental and socio-economic factors, with natural and social-economic factors dominating the initial stages and location and policy factors exerting significant impacts in later stages. This involves adopting zoning methods for management and control, establishing varying control intensity levels, and developing different land use control strategies. Other factors influencing land use change include community income, vacant land availability, government policies, land prices, accessibility, family systems, and historical values [48], [49]. Rapid changes in land use due to industrial growth occur quickly, driven by evolving government regulations that accelerate these shifts. Communities transform residential zones into industrial activities, leading to informal land use and circulation patterns [50]. Industrial agglomeration has become crucial for enhancing urban land use efficiency. The intricate interplay between externalities arising from industrial agglomeration and the efficiency of urban land use entails dynamic and uncertain effects on urban land utilization. Coexistence, substitution, and aging mechanisms of agglomeration externalities are observed [51]. Gaining insight into the correlation between alterations in urban industrial land and economic growth is important in resource management within spatial planning. The transformation of industrial land and the corresponding increase in value-added growth have created a need for urban industrial land management that prioritizes sustainable and high-quality development. The management and governance of zoning for urban industrial land classification encompass policies focused on reducing transformation, implementing high-quality incremental development zoning, synchronizing incremental growth zoning, and reducing and enhancing development zoning [52].

H3: Land Use Change has a significant effect on Environmental Resilience.

Environmental Resilience

In the face of global economic uncertainties, companies must adopt automation and digital transformation to bolster competitiveness. Economic resilience and adaptation to environmental shifts necessitate adaptive adjustments in industrial areas, promoting innovation and enhancing structures. The goal is to guide regional economies toward stable, sustainable trajectories [53]. Rapid population growth poses a grave environmental threat, driving agricultural expansion, unchecked urbanization, and habitat destruction. This reduces essential resources like agricultural land, forests, and water. The ensuing pressure leads to land degradation, soil erosion, and concerning environmental impacts such as pollution and global warming, fueled by rising consumption [54]. Environmental resilience challenges involve diminishing forests due to expanding agriculture, mining, and urban growth. Environmental preservation directly contributes to maintaining resilience and fostering sustainable cities with ample opportunities [55]. However, unchecked industrial development, coupled with inadequate environmental conservation, accelerates degradation and reduces the environmental carrying capacity [56], [57]. Around industrial areas, pollution and degradation trigger conflicts with the community, affecting well-being and industrial sustainability. Stakeholder commitment is crucial to mitigating environmental impact, ensuring a sustainable future for upcoming generations [58], and making environmental knowledge pivotal in fostering responsible behavior [59].

H4: Environmental Resilience has a significant effect on Sustainable Industrial Development.

3. RESEARCH METHODS

Location Study

The researchers conducted this study in the Selayar industrial area in the Selayar Islands Regency of South Sulawesi Province. The Selayar industrial area is positioned in the northern part of Selayar Island, as indicated in the spatial pattern direction policy for the Selayar Islands Regency. The selection of the research location was underpinned by a nuanced interplay of reasons for the area’s integration into a national program, the potential socio-economic ramifications, the influence of land use changes, the strategic resource reliance on the foreland region, and the necessity of sustainable coastal development. This comprehensive approach aimed to provide a holistic understanding of the multifaceted factors shaping the Selayar industrial area.

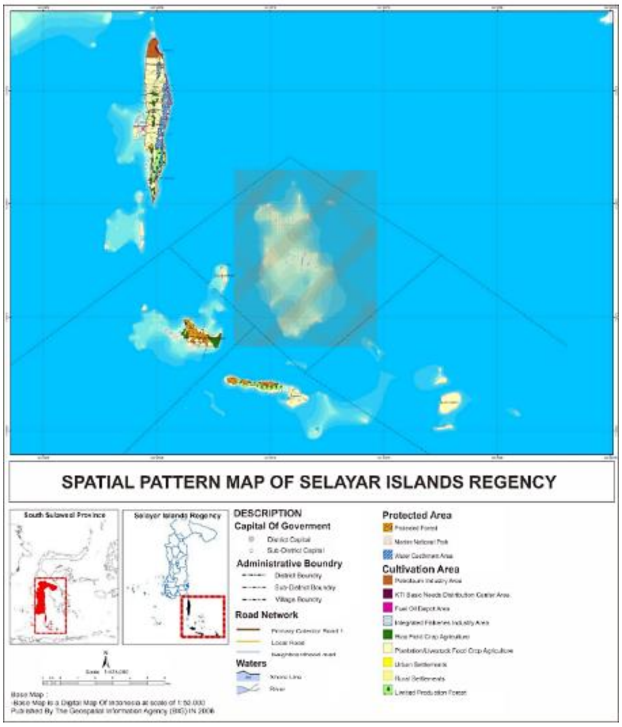

Figure 1. Map of Selayar Islands Regency

Data and Sample Collection

We employed various techniques to gather the necessary information in the data and sample collection context. We utilized the Google Form method and manual questionnaires, distributing them among individuals residing in Industrial Estates. This data collection survey transpired during the period from April to July 2022. The data collection process unfolds across distinct, structured stages. In its initial phase, we distributed 352 questionnaires to respondents who constituted the targeted population for our research. After the return of the questionnaires, the ensuing step involved the review of each received questionnaire. This review aimed to verify that the questionnaires had been accurately and comprehensively completed, aligning seamlessly with the research objectives. Following the initial distribution of 352 questionnaires among respondents, after undergoing a review process, 214 questionnaires adhered to the stipulated criteria and thus proved suitable for utilization as data in this study. This equates to a response rate of 60.80% (214 out of 352).

The demographic profile is an essential backdrop, allowing us to interpret and contextualize the study's findings within the expansive social landscape. By examining factors encompassing gender, age, education level, and income level, we acquire invaluable insights into the array of perspectives and experiences that mold the responses and outcomes of the research.

Table 1. Demographic Profile of Respondents

Respondents Characteristics	Items	Freq. (n=241)	Percentage (%)
Gender	Male	156.00	64.73%
	Female	85.00	35.27%
Age	Under 20	24.00	9.96%
	21 to 30	35.00	14.52%
	31 to 40	48.00	19.92%

	41 to 50	78.00	32.37%
	51 to 60	38.00	15.77%
	Over 60	18.00	7.47%
Education Level	Elementary school	25.00	10.37%
	Junior high school	35.00	14.52%
	Senior High School	83.00	34.44%
	College	98.00	40.66%
Income Level (IDR per month)	Under 1.5 million	21.00	8.71%
	1.5 to 2 million	43.00	17.84%
	2 to 2.5 million	75.00	31.12%
	2.5 to 3 million	68.00	28.22%
	Over 3 million	34.00	14.11%

This study encompassed a total of 241 participants, thereby providing a comprehensive cross-section of individuals. The gender distribution revealed that 156 participants identified as male (64.73%), while 85 identified as female (35.27%). This gender distribution is indicative of a diverse representation within our sample. In our exploration of the age composition of our respondents, a spectrum of age groups emerged. Among these, 24 participants (9.96%) were under 20 years old, 35 (14.52%) fell within the 21 to 30 age bracket, 48 (19.92%) were aged 31 to 40, 78 (32.37%) were between 41 and 50, 38 (15.77%) were in the 51 to 60 range, and 18 (7.47%) were over 60 years old. This diverse age distribution signifies a wide array of life experiences and perspectives within our study.

Educational backgrounds exhibited equal diversity among the respondents. We discovered that 25 participants (10.37%) had completed elementary school, 35 (14.52%) had completed junior high school, 83 (34.44%) held senior high school diplomas, and 98 (40.66%) had pursued higher education at the college level. This range of educational attainments contributes to the richness of perspectives within our study. Shifting our focus to income levels (measured in Indonesian Rupiah per month), the data unveiled varying degrees of financial well-being. Twenty-one participants (8.71%) reported an income of under 1.5 million IDR, 43 (17.84%) fell within the 1.5 to 2 million IDR bracket, 75 (31.12%) reported incomes ranging from 2 to 2.5 million IDR, 68 (28.22%) earned between 2.5 to 3 million IDR, and 34 (14.11%) enjoyed an income exceeding 3 million IDR per month. This diverse range of incomes underscores the socio-economic diversity within our participant group.

Research Model Measurement

All the variables in this research are latent and were measured using multiple-item scales. All the items were adapted from previous literature and slightly modified to align with the current research context. Each item was assessed on a five-point Likert scale, ranging from 1 (‘strongly disagree’) to 5 (‘strongly agree’).

The conducted research primarily focused on latent variables, which are not directly observable but underlie the phenomena of interest. These latent variables were evaluated using scales consisting of multiple items. These items were derived from prior literature and carefully adapted to suit the study's specific context.

To capture participants' viewpoints, each item in the scales was formulated to be evaluated on a five-point Likert scale. This scale provided a structured framework for participants to convey their opinions and attitudes toward the examined latent variables. The Likert scale ranged from 1 to 5, where one denoted 'strongly disagree' and five indicated 'strongly agree.' This spectrum of choices allowed participants to express the degree to which they concurred or disagreed with each statement.

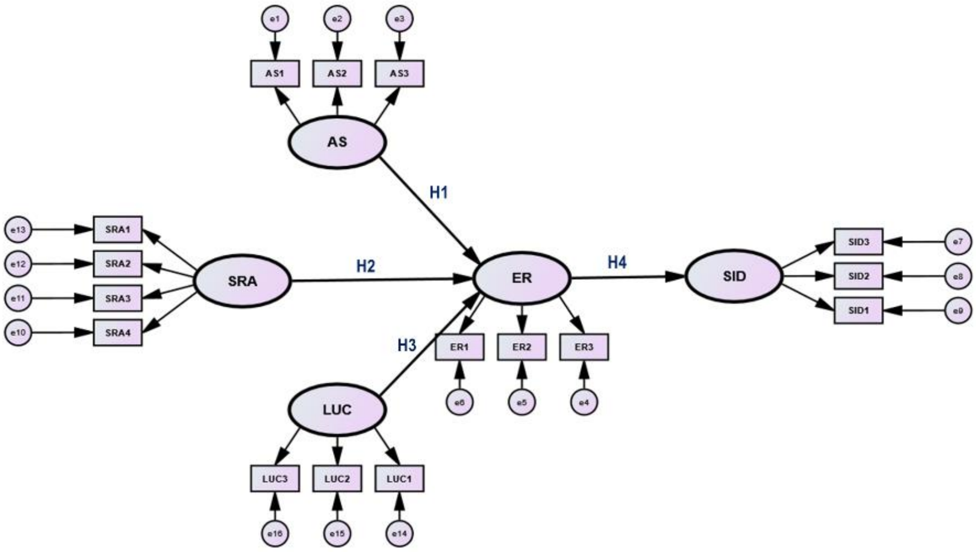

Figure 1. Research Model

Activity System: These variables are measured through indicators such as trade activity, industry, settlement, and education. These indicators provide insights into various dimensions of activity within the studied area.

Spatial Resource Allocation: This category includes sub-indicators such as settlements, trade, public facilities, social facilities, and infrastructure. These sub-indicators shed light on how resources are spatially distributed and allocated.

Land Use Change: The indicators in this category involve changes in the area, land cover alterations, and green open spaces. These indicators help capture the dynamics of land use over time.

Environmental Resistance: Air, water, and soil pollution indicators assess this variable. It serves as a mediating factor in understanding the impact of environmental stressors on the overall system.

Sustainable Industrial Development: This construct encompasses economic, environmental, and social sustainability as sub-indicators. It offers a comprehensive view of the multifaceted dimensions of industrial growth.

The research aimed to capture intricate insights into participants' perceptions and beliefs regarding the latent variables. Incorporating multiple-item scales and the Likert scale response format introduced a layer of depth to the data collection process, enabling a more comprehensive comprehension of the interconnections between latent variables and participants' responses. This meticulous approach to measurement bolstered the validity and reliability of the findings, thereby augmenting the overall caliber of the research outcomes.

Data Analysis

This study used the Structural Equation Modeling (SEM) method with the AMOS software for data analysis. SEM, a statistical technique, facilitates the testing and modeling of relationships among variables within a theoretical framework. Before embarking on SEM analysis, it is essential to preprocess the acquired data to ensure its quality and suitability. The preprocessing stage involves handling missing values, normalizing data, and testing fundamental assumptions like normality and variance homogeneity. Parameter estimation is accomplished using the Maximum Likelihood Estimation (MLE) technique. This technique aims to identify parameter values that are most likely to emerge based on the observed data. Following the estimation process, model testing assesses the degree of alignment between the formulated model and the observed data. This testing encompasses evaluating parameter significance, assessing goodness-of-fit, and executing hypothesis tests concerning variable relationships. The findings derived from the SEM analysis will be interpreted to conclude the relationships among the variables under investigation. These conclusions will encompass parameter significance, goodness-of-fit values, and relevant parameter interpretations.

4. RESULT AND DISCUSSION

4.1. Measurement and Structural Model Analysis

4.1.1 Model of Fit Test

The Goodness of Fit (GOF) test aims to establish the alignment between the observed distribution of sample data and a predetermined theoretical distribution within a theoretical framework. Subsequently, several experts have contributed their insights regarding the essential criteria for reporting the adequacy of model fit. Garson recommends incorporating one measure of baseline fit (such as TLI, RFI, IFI, CFI, or NFI) and one measure of parsimony fit (such as PNFI or PCFI) in the results presentation [60]. In contrast, Gefen and colleagues exclusively advocate for employing TLI, RMSEA, GFI, CFI, SRMR, AGFI, RNI and Chi-square parameters [61]. Schumacher and Lomax proposed employing three fit indices: GFI, CFI, and RMSEA [62]. The outcomes of the goodness-of-fit tests are showcased in Table III as follows.

Table 2. The Goodness of Fit Results

Criteria	Value	Cut-Off	Sources
Chi-Square (X^2)	0.994	≥ 0.050	[63]–[65]
CMIN/DF	0.698	≤ 2.000	[62], [66], [67]
GFI	0.959	≥ 0.900	[62], [63], [68]
RMSEA	0.000	≤ 0.080	[62], [69]–[73]
TLI	1.166	≥ 0.900	[62], [74], [75]
CFI	1.000	≥ 0.900	[73], [76], [77]
IFI	1.106	≥ 0.900	[78]
PNFI	0.599	≥ 0.500	[79], [80]
PCFI	0.732	≥ 0.500	[79], [80]

The GOF criteria are utilized as a method for assessing the suitability of a model for further analysis. This is achieved through a feasibility test incorporating various indices and predefined cut-off values, as initially suggested [81]. Table 2 presents empirical support indicating that the criteria for goodness-of-fit have been effectively satisfied, thus substantiating the stability of the model and its suitability for further in-depth examination.

4.1.2. Factor Loadings, Composite Reliability (C.R.), and Average Variance Extracted (AVE)

Each latent variable must account for at least 50% of the indicators' variability. Consequently, an absolute correlation exceeding 0.70 is necessary between latent variables and indicators [82]. The measurement model should exclude reflective indicators displaying factor loadings below 0.40 [83]. Table 3 examination reveals that the measurement model's loading factor values are generally satisfactory.

Table 3. Factor Loading, Composite Reliability (C.R.), and Average Variance Extracted (AVE)

Variables	Construct	Factor Loading	C.R	AVE
Activity System (AS)	Trading Activity (AS1)	0.781	0.758	0.877
	Industry (AS2)	0.728		
	Settlement and Education (AS3)	0.765		
Spatial Resource Allocation (SRA)	Trading (SRA1)	0.788	0.735	0.891
	Public Facilities (SRA2)	0.689		
	Social Facilities (SRA3)	0.783		
	Infrastructure (SRA4)	0.681		
Land Use Change (LUC)	Changing Land Area (LUC1)	0.675	0.736	0.860
	Land Cover Change (LUC2)	0.805		
	Green Open Space (LUC3)	0.727		
Environmental Resilience (ER)	Air Pollution (ER1)	0.734	0.711	0.840
	Water Pollution (ER2)	0.708		
	Soil Pollution (ER3)	0.692		
Sustainable Industrial Development (SID)	Economic Sustainability (SID1)	0.827	0.761	0.879
	Environmental Sustainability (SID2)	0.734		
	Social Sustainability (SID3)	0.722		

A concise set of indicators may effectively elucidate the relationship between latent variables, provided specific values fall below a designated threshold. The correlation's strength is gauged by a loading factor surpassing 0.50. Consequently, the reflective construct within the structural model comfortably surpasses the required threshold, rendering the missing latent variables superfluous. Evaluating the measurement model's quality hinges on its validity and reliability. Table 3, the C.R value stemming from the SEM study of the measurement approach exceeds 0.70, signifying satisfactory reliability across all models, instilling confidence in their applicability. The Average Variance Extracted (AVE) value reflects the proportion of variance in the construct represented by the latent variable. To ensure robust convergent validity, a recommended threshold is 0.50 or higher [84]. The findings in Table 3 substantiate positive outcomes, with the AVE value illustrating excellent validity within the structural model. This signifies that the latent explanatory variables account for more than half of the variance in the average indicators, further validating the model's reliability and robustness.

Table 4. Result of Structural Model Analysis

			Estimate	S.E.	C.R.	Prob.
Environmental Resilience (ER)	<---	Activity System (AS)	4.521	1.022	4.424	0.000
Environmental Resilience (ER)	<---	Spatial Resource Allocation (SRA)	1.095	0.282	3.883	0.000
Environmental Resilience (ER)	<---	Land Use Change (LUC)	3.521	1.735	2.029	0.024
Sustainable Industrial Development (SID)	<---	Environmental Resilience (ER)	1.653	0.854	1.936	0.015

Table 5. Results of Hypothesis Test

			Path Coeff.	Hypothesis	Results
Environmental Resilience (ER)	<---	Activity System (AS)	0.121 ***	H1	Significant
Environmental Resilience (ER)	<---	Spatial Resource Allocation (SRA)	0.548 ***	H2	Significant
Environmental Resilience (ER)	<---	Land Use Change (LUC)	0.457 **	H3	Significant
Sustainable Industrial Development (SID)	<---	Environmental Resilience (ER)	0.367 **	H4	Significant

Note: *p<0.05, **p<0.01, ***p<0.001

The study's outcomes indicate a strong and significant correlation between Activity System and Environmental Resilience (Hypothesis 1), as evidenced by the path coefficient value (β = 0.121, p < 0.001). This underscores that a more robust environment significantly influences the activity system within it. In this context, an environment capable of adapting and recuperating from disturbances supports the continued functioning and efficiency of the extant activity system. Activity System (AS) refers to the intricate interaction among components, including humans, technology, processes, and the environment.

Regarding the relationship between Spatial Resource Allocation and Environmental Resilience (Hypothesis 2), the findings indicate a significant relationship (β = 0.548, p < 0.001). This means that environments with better recovery capacity from disturbances tend to support more efficient and sustainable resource allocation. In sustainable development, eco-industrial parks become relevant, given their focus on integrating industries to reduce negative environmental impacts and enhance resource efficiency.

The analysis of the relationship between Land Use Change and Environmental Resilience (Hypothesis 3) shows a significant positive relationship (β = 0.457, p < 0.01). These results suggest that more resilient environments have the potential to influence more intensive or diversified changes in land use. Therefore, environments that can recover rapidly from disturbances can be more flexible in accommodating changes in land use within sustainable industrial areas.

The findings from the analysis of the fourth hypothesis indicate a significant relationship between Environmental Resilience and Sustainable Industrial Development (Hypothesis 4), with a path coefficient of 0.367 ($p < 0.01$). This implies that sustainable industrial development positively impacts the environment's ability to recover from disturbances. In this context, well-managed industrial development can contribute to enhancing environmental resilience.

4.2. Discussion and Implication

Environmental Resilience (ER) pertains to the environment's capacity to rebound and adapt post disruptions or alterations. The positive path coefficient finding implies that alterations within the Activity System are associated with heightened Environmental Resilience. Put differently, a more adaptable and effective activity system is aligned with an environment that is more resilient in the face of external disruptions [85]. These research findings underscore the pivotal role of collaborative synergy between Activity System and Environmental Resilience to ensure an unbroken operational continuum. Previous research, exemplified by [86], has illuminated the significance of biodiversity in upholding environmental and activity system resilience. Their findings illustrate that environments harboring diverse species and ecological interactions can withstand changes better. This resilience stems from the availability of alternative species that can assume ecological roles if one species experiences population decline due to disturbances. This aligns directly with your observation that an adaptive and swiftly recuperating environment positively impacts the activity system. [87].

A study has similarly underscored the adaptive capacity approach. They emphasize that systems adept at learning from experience, altering strategies, and promptly adjusting are well-equipped to confront inevitable changes. This underscores that an activity system collaborating with an adaptive environment should inherently possess a robust adaptive capacity. This perspective underscores that the cooperation between Activity System and Environmental Resilience supplements one another in sustaining optimal operational continuity. [88], research demonstrates that a healthy ecological network greatly influences system resilience. This network aids in evenly disseminating the impacts of disturbances, ensuring that the overarching system remains intact if one component is affected. In the realm of the Activity System, this concept translates to the collaborative interplay and interconnection among various system components playing a pivotal role in responding to environmental alterations.

Thus, through an in-depth comprehension of the abovementioned research findings, we discern consistent patterns underscoring the pivotal role of an adaptive and rapidly recuperating environment in bolstering activity system performance. This accentuates how the interrelationship between Activity System and Environmental Resilience ought to mutually enhance one another, with adaptive and collaborative capacities emerging as pivotal components for an optimal operational continuum. These findings bear significant implications for activity system management within an ever-changing environment. Activity system development and refinement strategies should conscientiously address the need to augment Activity Systems and Environmental Resilience. Organizations and stakeholders can leverage these findings to craft policies and practices that maximize system adaptability and resilience.

In the context of sustainable development, these research findings hold crucial implications for environmental and resource management within eco-industrial areas. The principle of resource efficiency serves as the foundation of this paradigm. Well-planned Spatial Resource Allocation (SRA) within these areas can positively impact the environment. Optimal resource allocation creates an environment where natural resources are used efficiently, and waste from one process can be used as input for another [89]. This research's findings affirm this concept by showing that the significant relationship between SRA and ER contributes to improved resource allocation.

Furthermore, these research results also emphasize the pivotal role of environmental resilience (ER) within eco-industrial areas. The ability of these areas to adapt and operate efficiently in the face of environmental challenges signifies a vital aspect in maintaining operational sustainability. Environmental resilience in this context refers to the area's ability to remain operational efficiently even in challenging situations [90]. This research strengthens this view by indicating that a more resilient environment contributes to more efficient and sustainable resource allocation.

The principle of inter-industry collaboration within eco-industrial areas supports overall resilience. This collaboration allows for synergy between industries, where byproducts from one process can serve as inputs for other industries. [91] have shown that such collaboration contributes to the overall resilience of the area. The relationship between SRA and ER in this research aligns with this perspective, as it suggests that a more resilient environment tends to support better resource allocation, which can foster inter-industry.

Ecological resilience is a fundamental principle in ecology, referring to the ability of ecosystems to remain functional and maintain their original characteristics and structures in the face of external disturbances or pressures. In the context of Land Use Change (LUC), this concept is highly significant. Researchers such as [92]–[95] have described ecological resilience as the ability of ecosystems to adapt rapidly to land-use changes. This means ecosystems with strong ecological resilience can maintain their functionality and essential characteristics even when undergoing significant land use changes. Walker illustrates ecological resilience by noting that tropical rainforests with high ecological resilience can quickly recover after intensive tree cutting, preserving biodiversity, stable water cycles, and other ecosystem functions [86].

Resilience strength is one aspect of ecological resilience related to how well an ecosystem can withstand and recover from disturbances such as land use changes. Resilience strength can be measured by examining an ecosystem's ability, under specific conditions, to maintain the stability of wildlife populations and plant productivity when facing changes in land use [96]. In other words, ecosystems with high resilience strength can better maintain their stability and productivity when faced with disruptive land use changes.

Resilience limit refers to the level of external disturbance or pressure at which an ecosystem can no longer maintain its original structure and characteristics. In the context of LUC, the resilience limit is when land use changes become too extreme or excessive, resulting in permanent and detrimental environmental impacts. For instance, when more than 50% of a tropical rainforest is converted into agricultural land, the ecosystem may have exceeded its resilience limit, leading to a significant decline in its ability to maintain biodiversity and ecological functions [86], [97].

Land cover and diversity within land cover are also critical factors in ecological resilience. The level of ecological resilience can be influenced by the types and extent of land cover and the diversity within that land cover [96], [98]–[100]. Changes in land use that reduce diversity or disrupt various land cover types can diminish ecological resilience. Therefore, a holistic understanding of ecological resilience, resilience strength, resilience limit, and the role of land cover and diversity is essential for maintaining environmental resilience in the face of increasingly frequent land use changes worldwide. Considering these concepts, we can plan and manage land use changes more wisely to protect and preserve the environment. Several previous studies, such as those conducted by [101]–[104], have provided additional support for our findings. These studies indicate that sustainable industrial practices can enhance the environment's capacity to address various environmental pressures. These findings positively support our conclusion that sustainable industrial development can have a positive impact on environmental resilience.

However, some research also indicates complexity in the relationship between sustainable industries and environmental resilience. Research by [105] found that the influence of sustainable industries on environmental resilience can vary depending on factors such as industry scale, environmental policies, and local environmental characteristics. This suggests that the effects of this relationship are not always uniform in various contexts. Research by [106], [107] has provided a foundation for understanding that the development of sustainable industries positively affects the environment's ability to recover. Elaborating on these findings strengthens the claim that the concept of Environmental Resilience is strongly correlated with Sustainable Industrial Development, where sustainable industries play a role as agents of environmental recovery.

Furthermore, research by [108], [109] provides further insight into how sustainable industry practices can create positive economic impacts while reducing environmental impacts. This supports the findings in this research, which link Environmental Resilience with Sustainable Industrial Development and affirm that sustainable industrial practices can be drivers in enhancing environmental resilience. In cross-sector collaboration, research by [110], [111] underscores the importance of collective efforts in achieving sustainable industrial development goals. Elaborating on these findings with the concepts of Environmental Resilience and Sustainable Industrial Development shows that when industrial development is conducted within the sustainability paradigm, the synergy between responsible industrial practices and collaborative efforts of stakeholders will be more effective in producing positive outcomes for environmental resilience. Finally, the research findings conducted by [112], which emphasize the application of green technology in the context of sustainable industries, can be further elaborated with the results of this research. Integrating green technology into sustainable industrial practices, which is an integral part of Sustainable Industrial Development, not only aids resource efficiency but also makes a positive contribution to Environmental Resilience.

The primary implication of this research is that sustainable industrial development, particularly within eco-industrial areas, has a beneficial impact on the environment, provided there is efficient resource allocation and wise resource utilization within these eco-industrial zones. By minimizing waste, optimizing resource usage, and adopting innovative practices, these industries can reduce their environmental footprint and establish more robust production systems. This contribution becomes ever more vital in the face of increasingly urgent climate change and dwindling natural resources. Industries that prioritize resource efficiency and innovation will aid in mitigating harmful environmental effects. Sustainable industrial development also positively influences the environment's capacity to recover from disruptions. When industries incorporate environmentally conscious practices like resource efficiency, prudent waste management, and renewable energy, the environment will be better equipped to confront external changes and disturbances. Well-managed industries within the eco-industrial context drive economic and social growth and critical components in environmental recovery and resilience improvement. This provides a solid groundwork for the planning and implementing of sustainable industrial strategies that align with overarching sustainability development objectives.

5. CONCLUSION

The development of sustainable industries, especially in ecological industrial areas, positively impacts the environment, provided that resources are allocated efficiently and used wisely within these ecological industrial zones. By reducing waste, optimizing resource utilization, and adopting innovative practices, these industries can reduce their environmental footprint and establish stronger production systems. This contribution becomes increasingly important while pressing climate change challenges and dwindling natural resources. Industries prioritizing resource efficiency and innovation will help mitigate adverse environmental impacts. Sustainable industrial development also positively impacts the environment's capacity to recover from disturbances. When industries adopt environmentally conscious practices such as resource efficiency, wise waste management, and renewable energy, the environment becomes better equipped to face external changes and disruptions. Well-managed industries within the context of ecological industries act as drivers of economic and social growth and are critical components in environmental recovery and enhancing environmental resilience. These findings provide a strong foundation for planning and implementing sustainable industrial strategies aligning with sustainability development goals.

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