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Development of a Smart Environment Maturity Model for Green Industry in North Maluku's Mining Villages, Indonesia

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Abstract

The smart environment maturity model for sustainable mining village areas in North Maluku Province has become a primary demand for the transformation towards sustainable green smart villages. North Maluku, one of Indonesia's largest mining industry provinces, includes the Halmahera and Obi archipelagos as sources of nickel, iron ore/sand, gold, and silver mines. This study aims to develop a maturity model that integrates Indonsian regulations to support green industry implementation in mining villages. The methodology employs Systematic Literature Review to identify Critical Success Factors (CSFs), validated through expert judgment using 5-point Likert scale assessment. The research results yield eight key dimensions, 25 sub-dimensions, and five maturity levels: underdeveloped, developing, self-reliant, advanced, and smart villages. Expert validation achieved an overall average score of 3.65/5.0, indicating moderate acceptance with improvement areas identified in local culture and technology dimensions. The developed framework provides a foundation for environmental informatics applications and decision support systems in rural development contexts. The model addresses national regulations concerning green industry while providing an adaptive framework for archipelago regions, serving as a reference for policy formulation and village fund allocation based on environmental indicators.

Keywords : *CSFs, Green Industry, Maturity Model, North Maluku, Smart Environment.*

1. INTRODUCTION

The transformation of mining village areas into sustainable smart villages is a primary imperative, particularly in North Maluku Province Indonesia, which is rich in mineral resources and faces vulnerable environmental resilience issues [1], [2]. These villages, which produce nickel, iron ore/sand, gold, and silver, require a new approach to managing the environmental and social impacts of mining activities. The implementation of the smart environment concept [3], [4] for environmental resilience is expected to be an effective solution to ensure green environmental sustainability and enhance the quality of life for local communities.

The concept of smart environment serves as a key dimension and enabler in realizing sustainable smart villages [5], [6]. Previous studies have developed various smart city frameworks and maturity models for urban contexts [7], [8], with several researchers extending these concepts to rural areas. Zhang[5] proposed smart village frameworks for China, while Zavratnik et al.[9] reviewed smart village initiatives across Europe. Studies by Fatimah et al.[10] and Yuan et al. [11]examined sustainability in mining contexts but concentrated on urban mining and circular economy applications rather than rural village transformation.

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Literature analysis reveals research gaps in current smart village studies. Based on systematic review of relevant literature, only a limited number of studies specifically address mining communities in rural contexts[12], [13], and none were found to focus on archipelagic regions where geographical isolation creates additional challenges[13], [14]. Furthermore, while several frameworks integrate national regulations[15], [16], [17], there appears to be limited application of country-specific regulatory frameworks such as Indonesia's Village Development Index (IDM) within smart environment assessment models[18], [19]. Recent developments in smart environment in informatics[20], [21] and information systems[12], suggest opportunities for developing integrated assessment frameworks, yet existing models often lack the specificity required for mining village contexts[22], [23].

This study aims to develop an initial Smart Environment Maturity Model (SEMM) for mining village areas in North Maluku, Indonesia. This model is formulated through a Systematic Literature Review (SLR) by identifying Critical Success Factors (CSFs) that are validated with expert judgment. The development of this model is expected to yield a standardized assessment scheme that will aid in the implementation and oversight of green industry within mining villages. Ultimately, this will support the achievement of sustainable development and growth objectives in the aforementioned island region.

To comprehensively address the issues within mining village areas, the development of models/policies related to the processes and maturity levels of such areas is essential for their transformation into green smart villages, primarily to preserve environmental sustainability. The smart environment concept[24], [25], is a key dimension (enabler) of smart regions/villages [5], [26] and is also an inseparable part of the SDGs (sustainability village). One effort to preserve the environment in mining village areas requires a maturity model for phased and measurable development and assessment, beginning with the planning, governance, and implementation dimensions. This study aims to develop a smart environment maturity model for sustainable mining village areas in North Maluku, based on applicable regulations and standards in Indonesia. This is intended to assist the green industry implementation process to have a positive impact not only economically, but also socially, on health, and on the preservation of the environment[27].

2. METHOD

2.1. Data Collection and Analysis

This study utilizes secondary data from international literature databases and relevant national or local regulations to identify key factors in developing a conceptual sustainable smart environment model for mining village areas in North Maluku. The Systematic Literature Review (SLR) method is a structured and methodical approach for comprehensively identifying, evaluating, and synthesizing research findings to address specific research questions [28], [29], namely, to seek a sustainable smart environment maturity model.

The data collection process follows a systematic protocol with the following specific steps:

1. Database Selection and Search Strategy: Three international academic databases were selected, Scopus, ScienceDirect, and Google Scholar. The search strategy employed Boolean operators with specific keyword combinations: ("smart environment" OR "smart village") AND ("maturity model" OR "assessment framework") AND ("mining" OR "sustainability") AND ("rural" OR "village development").
2. Inclusion and Exclusion Criteria: Articles published between 2015-2025 in English, peer-reviewed journals and conference proceedings focusing on smart environment, village development, and sustainability assessment were included. Excluded articles were those focusing solely on urban contexts, non-peer reviewed sources, and studies without empirical or theoretical contributions to maturity model development.

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3. Initial search yielded approximately 850 articles, which were systematically filtered through four stages: (1) title screening (n=124 relevant), (2) abstract review (n=68 selected), (3) full-text analysis (n=41 retained), and (4) quality assessment resulting in 30 primary studies for final analysis.
4. National Regulation Integration: Indonesian regulatory documents including Village Development Index (IDM) guidelines, Village SDGs framework, and Ministry of Villages regulations were collected and analyzed to ensure regulatory compliance and contextual relevance.

The collected data underwent systematic analysis using the following methods:

1. Thematic Analysis: Primary studies were coded using qualitative analysis techniques to identify recurring themes and patterns. A deductive coding approach was applied based on smart environment dimensions, followed by inductive coding to capture emerging themes specific to mining village contexts.
2. Critical Success Factors (CSFs) Extraction: Through content analysis of the 30 primary studies, CSFs were systematically extracted and categorized into dimensional frameworks. Each CSF was validated against multiple sources to ensure reliability and comprehensiveness.
3. Synthesis and Mapping: VOSviewer software was employed to create keyword co-occurrence networks and visualize thematic relationships among identified CSFs. This bibliometric analysis helped identify core dimensions and their interconnections within the smart environment framework.
4. Regulatory Integration Analysis: Indonesian regulations were systematically mapped against identified CSFs to ensure alignment with national standards and policies, particularly the Village Development Index components and Village SDGs indicators.

The SLR process involves three main phases: (1) planning (establishing a protocol with objectives, inclusion-exclusion criteria, and search strategies in trusted databases), (2) conducting (systematic data extraction, study quality assessment, and analysis of findings using qualitative/quantitative techniques), and (3) reporting (transparent reporting of results and limitations). SLR emphasizes replicability and bias minimization through the use of strict protocols, critical assessment of study validity, and organized evidence synthesis, thereby producing an objective and evidence-based literature review for scientific or practical decision-making [29], [30]. The methods and steps in this research are shown in Figure 1.

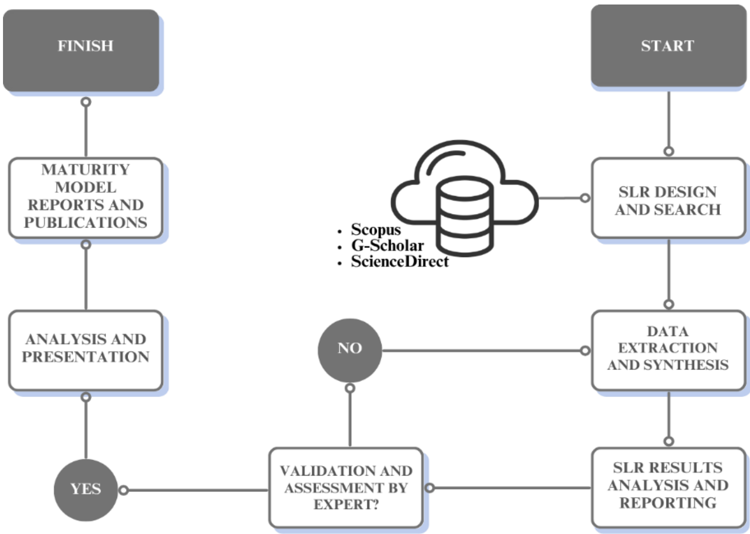

Figure 1. Research Steps with SLR

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Figure 1, illustrates the comprehensive workflow of this research using the SLR approach, examining theoretical foundations and secondary data from relevant literature sources across the three selected databases. The methodology ensures systematic progression from literature identification through CSF extraction to model development and validation.

2.2. Assessment Scheme Design and Validation

The Smart Environment Maturity Model (SEMM) matrix development followed a structured approach integrating literature findings with regulatory frameworks:

1. Dimensional Framework Construction: Based on CSF analysis, eight primary dimensions were identified: (1) Natural Resources, (2) Environmental Resilience, (3) Social Resilience, (4) Economic Resilience, (5) Governance, (6) Village Infrastructure, (7) Technology, and (8) Local Culture. Each dimension was further decomposed into sub-dimensions totaling 25 assessment criteria.
2. Maturity Level Definition: Five maturity levels were established ranging from Level 1 (underdeveloped) to Level 5 (smart villages), with specific indicators and benchmarks defined for each level based on Village Development Index standards and relevant literature.
3. Regulatory Integration: The matrix incorporates the Village Development Index (IDM) from the Ministry of Villages [17], [18] with environmental sustainability principles derived from SLR synthesis. This approach ensures alignment with Indonesian national standards while maintaining academic rigor.

A validation approach was implemented to assess model applicability and relevance:

1. Expert Panel Selection: Three experts were selected based on relevant criteria: (a) experience in rural development, environmental management, or information systems, (b) academic background or professional experience in related fields, (c) familiarity with Indonesian village development contexts, and (d) understanding of sustainability assessment frameworks.
2. Validation Methodology: A structured validation process was conducted:
   - Phase 1: Individual expert review of SEMM dimensions and sub-dimensions using structured questionnaires and feedback forms
   - Phase 2: Discussion session to gather expert opinions and suggestions for model improvement
   - Phase 3: Incorporation of expert feedback into the final model design
3. Validation Assessment: Expert feedback was systematically collected and analyzed to identify areas of agreement and suggestions for improvement. Comments and recommendations were categorized thematically and used to refine the model components.
4. Model Refinement: Based on expert input, the model underwent revision including clarification of assessment criteria, adjustment of indicators, and enhancement of practical applicability. The validation process provided valuable insights for model improvement and practical implementation.

To ensure methodological consistency, several measures were implemented: (1) systematic documentation of procedures and decisions, (2) cross-verification of analysis results, (3) integration of multiple data sources, and (4) transparent reporting of study limitations. The validation process ensures that SEMM provides a practical framework for assessing smart environment maturity in mining villages within the Indonesian context.

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3. RESULT

3.1. Systematic Literature Review (SLR) Result

Following the methodology steps in Figure 1, The SLR protocol, as defined by Kitchenham[30], consists of a series of systematic and repeatable protocols for searching and selecting literature relevant to the research objective. This method is used to identify CSFs in the development of a comprehensive and measurable maturity model. The stages of the SLR conducted are as follows:

1. Defining the research objective: SLR is used to identify CSFs for developing a maturity model focused on sustainable development in mining villages. This model will provide guidance for developmental transformation towards sustainable mining villages.
2. Designing a systematic search protocol:The literature search protocol is clearly designed, including strict inclusion and exclusion criteria to ensure that selected articles are relevant to the research objective.
3. Conducting searches in academic databases: Literature searches are performed on international databases, namely Scopus, ScienceDirect, and Google Scholar, using keywords relevant to the theme of sustainable mining village environmental transformation.
4. Article selection and analysis: The retrieved articles are then filtered using relevance and quality criteria. Qualitative and quantitative analyses are applied to understand each study's contribution to the formation of the maturity model.
5. Synthesizing CSFs into a maturity model: Based on the filtered literature, CSFs are synthesized to formulate a maturity model applicable in the context of mining villages.
6. Expert validation: The resulting maturity model will be validated through expert judgment to provide input and assessment on the proposed model.
7. Revisions based on expert input: Based on expert input, the model is adjusted to better suit the needs of sustainable mining village areas.

Table 1. SLR Inclusion and Exclusion Criteria

Criteria	Scope
Inclusion	• Articles that theoretically or empirically develop maturity models for rural areas, specifically within the context of sustainability. • Articles that discuss key factors, indicators, models, frameworks, architecture, or the implementation of smart environments in the context of development and sustainability. • Articles that include regulatory documents or policies relevant to the development of the green mining industry. • Articles published in English and/or Indonesian.Articles that theoretically or empirically develop maturity models for rural areas, specifically within the context of sustainability.
Exclusion	• Articles with subjects in Environmental Science, Computer Science, Agricultural Science, or related fields that do not cover aspects of sustainability and smart environment in mining villages. • Articles that do not focus on mining villages or communities. • Articles that have not undergone a peer-review process or were published in conferences not internationally recognized. • Article types other than relevant scientific journals or international conference proceedings.

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Reporting and Publication: After undergoing the development and validation process, the resulting maturity model will be documented and published to contribute to further research and practical applications in the field. Table 1 outlines the inclusion and exclusion criteria for literature/article searches relevant to this research's objective within the SLR process.

Table 1 outlines the systematic criteria applied during the literature selection process. Inclusion criteria encompassed articles that theoretically or empirically develop maturity models for rural areas within sustainability contexts, discuss key factors and frameworks for smart environments, include regulatory documents relevant to green mining industry development, and are published in English and/or Indonesian. Exclusion criteria eliminated articles from Environmental Science, Computer Science, or Agricultural Science that do not address smart environment aspects in mining villages, studies not focusing on mining communities, non-peer-reviewed sources, and publications other than scientific journals or international conference proceedings.

Based on the inclusion and exclusion criteria, the article search results were obtained as shown in Table 2.

Table 2. Article Search Results Based on SLR Inclusion and Exclusion Criteria

Keywords	Internasional Database			Count
	Scopus	ScienceDireck	Google Schoolar	
“Maturity” OR “Model” AND “Smart” AND“Environment”AND “Sustainability”	45	12	156	213
“Maturity” OR “Model”AND“Village” OR “Mining” AND “Industry”	78	18	234	330
“Maturity” OR “Model” AND “Mining” AND “Village” AND “Sustainability”	32	15	98	145
“maturity” OR “model” OR “csfs” AND “village” AND “mining”AND“sustainability” OR (“Green” AND“Industry”)	28	22	112	162

Based on the defined inclusion and exclusion criteria, comprehensive searches were conducted across international databases. As shown in Table 2, four keyword combinations were systematically applied yielding a total of 850 articles: (1) "Maturity" OR "Model" AND "Smart" AND "Environment" AND "Sustainability" yielded 213 articles, (2) "Maturity" OR "Model" AND "Village" OR "Mining" AND "Industry" produced 330 articles, (3) "Maturity" OR "Model" AND "Mining" AND "Village" AND "Sustainability" resulted in 145 articles, and (4) "maturity" OR "model" OR "csfs" AND "village" AND "mining" AND "sustainability" OR ("Green" AND "Industry").

After defining the search protocol, articles were selected by the authors based on the initial objective: to develop a smart environment maturity model for sustainable mining village areas in North Maluku. The selection protocol involved four steps: (1) reading the titles and abstracts of articles relevant to the research objective, then downloading and saving them; (2) reviewing abstracts, keywords, and conclusions to conduct a literature review based on similarities in objectives, keywords, and relevant research findings; (3) conducting a full reading of the selected main articles to extract their research results as dimensions and sub-dimensions of CSFs; (4) selecting the CSFs from 30 primary studies. The SLR selection protocol and stages are detailed in Figure 2.

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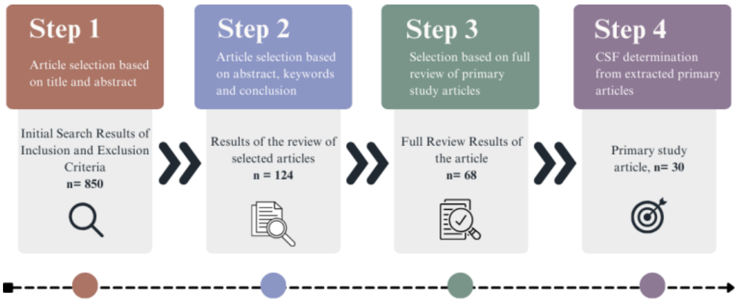

Figure 2. Protocol for Determination of 30 Primary Studies

Critical Success Factors Identification: Through thematic analysis of the 30 primary studies, the research identified key themes and patterns relevant to smart environment development in mining village contexts. The content analysis process extracted Critical Success Factors (CSFs) which were systematically categorized into eight primary dimensions based on frequency of occurrence and relevance to mining village sustainability.

Keyword Mapping and Visualization Results: The VOSviewer analysis of the selected literature revealed four distinct thematic clusters as shown in Figure 3(a). The keyword co-occurrence network identified: (1) blue cluster focusing on technology and infrastructure, (2) red cluster emphasizing community involvement and social aspects, (3) green cluster highlighting environmental sustainability, and (4) yellow cluster representing governance and policy frameworks. This mapping confirmed the multi-dimensional nature of smart environment frameworks for mining villages.

The analysis of 30 main studies from the SLR results indicates that the CSFs for sustainable mining villages include village government vision and programs, community involvement, family values, preservation of local languages, tribal conflict management, adequate village infrastructure (electricity, telecommunications, internet), environmental governance, public services, and the engagement of industry and communities. These findings assist in formulating a comprehensive strategy for sustainable village development. Furthermore, the results of the SLR mapping are visualized using VOSviewer v.1.6.20 software, as shown in Figure 3.

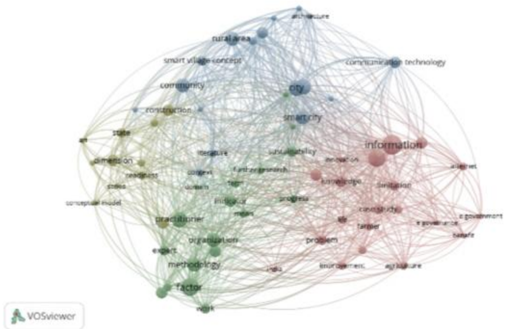

Figure 3. SLR Result Keyword Mapping

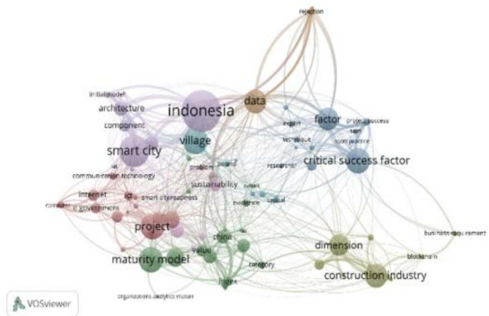

Figure 4. Mapping of SLR Text Analysis Results

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Figure 3 and Figure 4, displays four color clusters (blue, red, green, and yellow), indicating that the development of the smart mining village model identifies technology, community involvement, and sustainability, with a focus on the environment, as key domains/dimensions. For smart mining villages in North Maluku, it is crucial to engage the community, adopt appropriate technology, and build strong partnerships. Figure 4 shows that Indonesia, from the visualization results, is closer to the word "village" due to the fact that administratively, there are more villages. It consists of 7 color clusters that show proximity to several related terms in the SLR paper. The CSF results are summarized in the Appendix of this paper.

3.2. SEMM Model Development and Validation

Based on the systematic analysis of CSFs and regulatory integration as described in the methodology, the Smart Environment Maturity Model (SEMM) was constructed and subsequently validated through expert judgment.

Dimensional Model Construction: The model comprises eight key dimensions with 25 sub-dimensions: (1) Natural Resources (Land and Sea Wealth), (2) Environmental Resilience (environmental quality and disaster management), (3) Social Resilience (health, education, and security facilities), (4) Economic Resilience (trade facilities, tourism, economic institutions), (5) Governance (local/regional and central administration), (6) Village Infrastructure (public facilities, transportation, utilities), (7) Technology (electricity, internet, renewable energy), and (8) Local Culture (traditional practices and community values). Each dimension encompasses specific sub-dimensions as follows: Natural Resources (3 sub-dimensions), Environmental Resilience (4 sub-dimensions), Social Resilience (3 sub-dimensions), Economic Resilience (4 sub-dimensions), Governance (2 sub-dimensions), Village Infrastructure (6 sub-dimensions), Technology (3 sub-dimensions), and Local Culture (2 sub-dimensions), totaling 25 comprehensive assessment criteria, as illustrated in Figure 5.

Maturity Level Structure: Following the development process outlined in Section 2.2, five maturity levels were established: Level 1 (Underdeveloped Village), Level 2 (Developing Village), Level 3 (Self-Reliant Village), Level 4 (Advanced Village), and Level 5 (Smart Village). Each level incorporates specific indicators and benchmarks aligned with the Village Development Index (IDM) model and derived from literature synthesis[15], [18].

Table 3. Expert Judgment Validation Results for SEMM Dimensions

Dimension	Expert Judgment			Average
	A	B	C	
Natural Resources	4.0	4.2	3.8	4.00
Environmental Resilience	4.3	4.1	4.0	4.13
Social Resilience	3.5	3.8	3.7	3.67
Economic Resilience	3.2	3.6	3.4	3.40
Governance	4.1	3.9	4.2	4.07
Village Infrastructure	3.8	4.0	3.6	3.80
Technology	3.0	3.4	3.2	3.20
Local Culture	2.8	3.1	2.9	2.93

Expert Validation Results: Following the validation methodology described in Section 2.2, three experts assessed the SEMM framework using structured questionnaires with 5-point Likert scale (1=strongly disagree, 5=strongly agree) [5], [31]. Table 3 presents the validation results for each dimension. As shown in Table 3, dimension scores ranged from 2.93 to 4.13, indicating varied expert perspectives on different aspects of the framework. Environmental Resilience achieved the highest

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average score (4.13), while Local Culture received the lowest score (2.93), suggesting areas for refinement. The overall average score of 3.65 indicates moderate expert acceptance with clear improvement opportunities identified.

Model Refinement Based on Expert Feedback: Based on expert input, several revisions were implemented including enhancement of local culture indicators, clarification of technology assessment criteria for archipelagic contexts, and strengthening of environmental resilience sub-dimensions. Figure 5, shows the final SEMM matrix structure incorporating expert feedback and SLR findings.

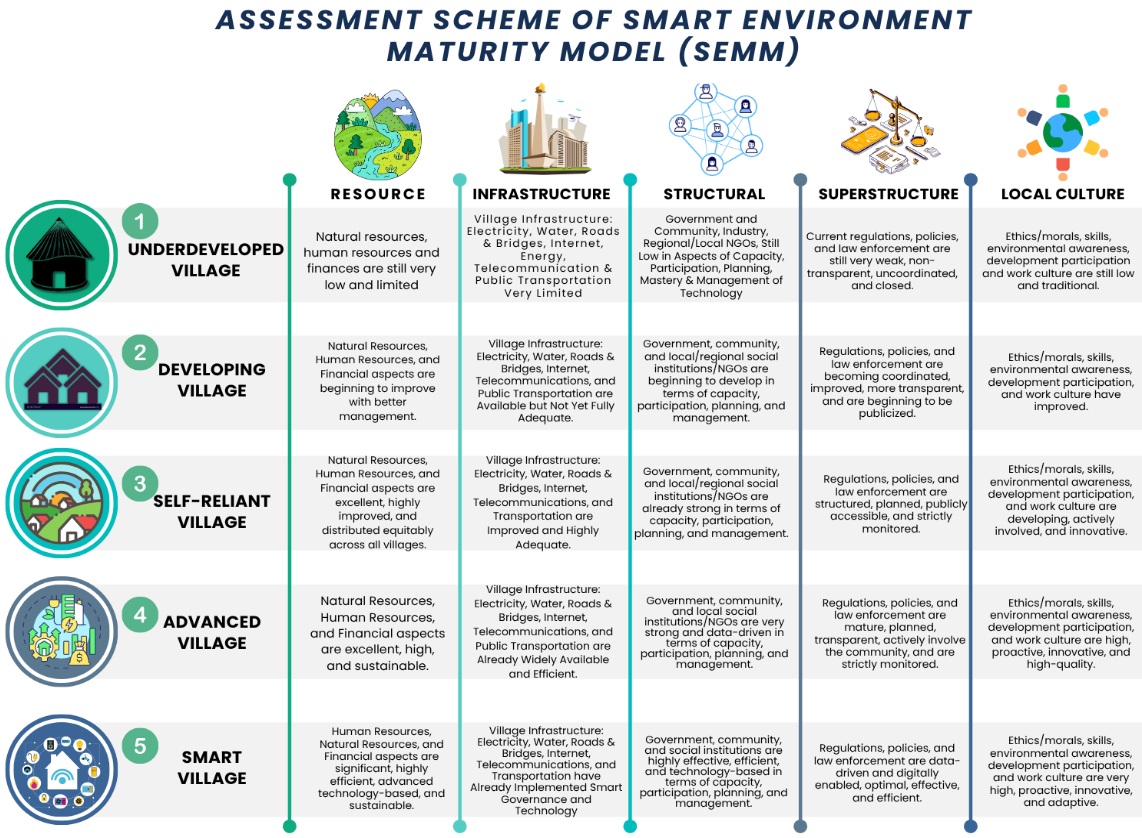

Figure 5. Smart Environment Maturity Model Scheme

Figure 5, illustrates the comprehensive SEMM assessment framework, demonstrating the progressive maturity levels from underdeveloped to smart villages across five key categories. The matrix shows how each village level is characterized by specific capabilities and indicators within the Resource, Infrastructure, Structural, Superstructure, and Local Culture dimensions. For instance, an Underdeveloped Village (Level 1) exhibits limited natural resources management and very basic infrastructure, while a Smart Village (Level 5) demonstrates optimal resource utilization, advanced technology integration, and highly effective governance systems. The framework provides clear benchmarks for village administrators to assess their current maturity status and identify specific areas requiring development interventions. This structured approach enables systematic progression through maturity levels while ensuring alignment with Indonesian Village Development Index standards and sustainable mining village requirements in archipelagic contexts.

3.3. Implementation Scenario

The application of this smart village maturity model is designed with three policy scenarios aimed at testing the system's response to different interventions: 1) Business as Usual (BAU) as a basis for comparison by maintaining existing development trends[32], 2) Adaptation, which integrates

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environmentally friendly policies (e.g., green infrastructure and sustainable resource management), and 3) Village Transformation, which emphasizes low-carbon technological innovation and holistic community participation[33]. Further simulation of system dynamics can be performed using an application that incorporates demographic, environmental, and socio-economic parameters tailored to the local research site context. Subsequently, sensitivity analysis is conducted to identify key factors (e.g., local natural resources, uniqueness) that significantly influence the model output. The simulation results, in the form of projected regional maturity indices and environmental impacts, are then compared across scenarios to evaluate policy effectiveness. Policy recommendations are formulated based on simulation findings, considering technical feasibility, institutional capacity, and resource availability. Validation is performed through focused group discussions (FGDs) with stakeholders to ensure practical relevance and social acceptability. This integration of quantitative (simulation) and qualitative (FGD) approaches aims to strengthen the model's validity in dynamic and complex policy contexts.

To implement this maturity model, three implementation scenarios were developed involving various stakeholders, including local governments, mining companies, and local communities. These scenarios encompass concrete steps, such as improving technological infrastructure, training communities on sustainable environmental practices, and developing supporting policies. The implementation of this model is expected to enhance environmental quality, strengthen the local economy, and ensure the long-term sustainability of mining villages. Regular evaluations will be conducted to monitor progress and adjust strategies based on the achieved results.

4. DISCUSSION

4.1. Interpretation of Key Findings

The development of Smart Environment Maturity Model (SEMM) through systematic literature review identified eight key dimensions and twenty-five sub-dimensions specifically designed for mining villages in archipelagic regions. This comprehensive framework addresses unique environmental challenges faced by mining communities in North Maluku, extending beyond conventional smart city island approaches.

These eight dimensions align with the comprehensive frameworks for sustainable rural development emphasized[5], [31]. However, SEMM distinguishes itself by focusing on mining villages and integrating Indonesian regulatory requirements. Whereas [6], [34]proposed smart-village initiatives centered primarily on technology adoption, SEMM embeds local culture and environmental resilience as core dimensions, reflecting the complex socio-ecological dynamics of archipelagic mining areas.

In comparison with existing maturity models—such as the smart-city frameworks developed by Liu et al[35]. SEMM offers three main advantages. First, it integrates the Indonesian Village Development Index (IDM) and Desa SDGs, ensuring alignment with national regulations. Second, unlike generic smart-city models that target urban contexts, SEMM addresses the specific challenges of mining villages, including environmental degradation, community displacement, and resource management. Third, the five-level maturity progression (from underdeveloped village to smart village) provides a structured pathway tailored to rural settings rather than urban ones.

The SLR analysis revealing four color clusters (technology, community involvement, sustainability, and environment) corresponds with findings from Fatimah et al by title: regarding critical success factors in sustainable resource management[10]. However, SEMM extends this understanding by incorporating local culture and governance dimensions that are often overlooked in international frameworks but crucial for Indonesian village contexts.

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4.2. Theoretical and Practical Implications for Information Systems

The Smart Environment Maturity Model (SEMM) proposed in this study offers a conceptual framework that seeks to bridge the domains of environmental informatics and rural development. Drawing on findings from a systematic literature review (SLR) and expert validation, the model identifies eight dimensions and twenty-five subdimensions that are particularly relevant to mining villages in archipelagic regions. These findings suggest a potential extension of smart city paradigms to rural contexts with distinct geographical and socio-economic characteristics. By integrating traditional environmental management practices with contemporary information technologies, SEMM contributes to the evolving discourse on applied informatics, especially within the context of developing countries.

The results of this study indicate that SEMM may serve as a structured assessment tool for local governments to evaluate the maturity level of smart environmental practices. The proposed five-level progression provides a basis for self-assessment and targeted development planning. The alignment of SEMM's indicators with national regulatory frameworks—such as the Village Development Index and the Village SDGs—further underscores its practical relevance for policy implementation and resource allocation at the village level.

The study's findings also highlight opportunities for developing information systems that support digital assessment and monitoring of a smart environmental initiatives in rural areas. The multidimensional structure of SEMM can be integrated into data-driven information systems and inform the design of user interfaces and interaction models tailored to rural technological capacities. This approach may facilitate the gradual adoption of information technologies in village governance and environmental management.

While the model demonstrates contextual relevance, its geographic specificity—focused on mining villages in Indonesia's archipelagic regions—may limit its direct applicability elsewhere without adaptation. Future research is recommended to empirically validate the model through field implementation, conduct comparative analyses across diverse rural settings, and explore the integration of SEMM into intelligent information systems that support adaptive and sustainable decision-making.

5. CONCLUSION

This study developed a Smart Environment Maturity Model (SEMM) for sustainable mining villages in North Maluku through systematic literature review and expert validation methodology. The research identified eight key dimensions and twenty-five sub-dimensions across five maturity levels, progressing from underdeveloped to smart villages. Based on expert validation results (average score 3.65/5.0), the model demonstrates moderate acceptance with areas for improvement, particularly in local culture and technology dimensions. The framework integrates Indonesian Village Development Index standards with smart environment principles, providing an assessment tool that addresses the specific challenges of mining villages in archipelagic regions. The systematic approach combining literature synthesis with regulatory integration offers a structured methodology for developing context-specific maturity models in rural development contexts.

The developed SEMM contributes to environmental informatics by providing a framework that can support the development of decision support systems and assessment tools for rural contexts. The model's structured assessment criteria offer potential applications for data-driven evaluation platforms and information management systems in village development planning. From a practical perspective, the framework provides policymakers with a reference tool for formulating management strategies and allocating village funds based on environmental indicators. The integration of traditional environmental management with technology assessment creates opportunities for developing appropriate information systems that match different village maturity levels. While the model shows promise based on expert feedback, future empirical validation in actual mining villages will be essential to confirm its practical effectiveness and broader applicability in archipelagic mining communities.

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