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Smart villages: a systematic review of trends, models, and metrics

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ABSTRACT

Identifying the smart village model is crucial due to the diverse conditions and landscapes of villages. Rice fields, coastal areas and mountainous regions each require different smart village models. This review of smart village is based on a theoretical analysis of 22 key indices obtained through a bibliometric analysis and a systematic literature search in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines. We first identified a total of 1598 papers from the Web of Science, Scopus, ScienceDirect and Google Scholar databases. In deciding which papers to include in the more detailed analysis of the practical utility of prospective knowledge, 54 papers were identified that met the inclusion and exclusion criteria outlined in the PRISMA model. The adopted criteria cover all major areas, namely technological support, social aspects, ecology and financial security, giving a diverse perspective to problem solving in the context of rural community development. As has been shown when considering the Smart Village paradigm of organisational and social development based on information and communication technology, the aspiration is to achieve the kind of quality of life in the village that is implied and expected by the recognition of cultural and traditional justice. Thus, there are further areas for further research to understand how more can be derived from this metric, in addition to the longevity of the metric as a measure for the realisation of smart village development.

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KEYWORDS
Smart villages; concept of a smart village; a model of a smart village; the framework for smart villages; metric of a smart village

SUBJECTS
Information Technology; Sociology & Social Policy; Urban Studies; Legal, Ethical & Social Aspects of IT; Human Geography

Introduction

Smart Village has therefore emerged as a new approach to rural development that aims to use ICT, sustainability and participation to promote the development of the rural village. Smart villages use ICT to strengthen communities through the organisation of village structures, with a focus on rural areas. This approach takes into account the strengths, weaknesses, opportunities and threats of each (Zhang & Zhang, 2020).

These villages act as role models for sustainable living by supporting the local circular economy through bottom-up strategies and the use of ICT technologies and solutions for various services such as e-health, e-mobility, e-government and e-education (Zavratnik et al., 2019). The function of smart villages considers the issue of transparency, especially financial transparency, to be one of the greatest challenges for the sustainability of villages (Putri et al., 2023).

The use of governance, technology, resources, village services, living standards, tourism, energy, economy and people as approaches to implementing smart villages is intended to provide a comprehensive rural development model in the future. This approach ensures that smart villages not only cover various aspects of villages, but also contribute to the economic and socio-physical development of villages as well as the environment (Li & Zhong, 2022).

As has already been emphasised, for smart villages to be effective, components such as smart economic drives, smart agriculture and the demand for climate-friendly agricultural practises must be

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integrated. These components are critical to economic and social progress through the provision of accessible services in areas such as renewable energy, health, academic facilities, water and sanitation to improve living standards and human security (Maja et al., 2020).

However, the smart village model also includes social technologies and emphasises the active participation of villagers. Residents are encouraged to contribute to the development of the smart economy and the smart village by raising awareness of community characteristics through citizen science modelling. This approach makes the development of smart villages a community-based initiative that takes into account people's needs and wishes and encourages participation and capacity building (Tosida et al., 2023).

As for the essential elements needed to build a smart village concept, we need to look at some core elements without which it is impossible to make the essential progress and implement progress effectively. These components have been derived from theoretical studies on the development of smart villages in the areas of growth, participation, technology and governance. In their work, (Despotović et al., 2020) emphasise well-being, livelihoods and resilience as the central pillars for the development of smart villages that aim to improve the economic and social status of the community.

Smart villages require multiple metrics to function effectively. The metrics discussed in this paper aim to improve the development of smart villages by integrating various sectors such as energy, telecommunications, culture, environment, economy, housing, health, education, finance and transport. These efforts are in line with the principles of Industry 4.0 and the Sustainable Development Goals, emphasising the use of information and communication technology (ICT) to reduce inequalities and improve the accessibility of telecommunications, especially in rural areas.

2. Methods

A systematic literature review is a research method that follows a rigorous approach to identify, review, compare, synthesise and summarise research literature that is relevant to a particular research question or area of interest (Kaur & Parashar, 2022). This technique makes it possible to assess the quality and scope of the information available on a particular topic and thus compare different methods and theories used in a particular discipline (Pathak & Deshkar, 2023). This type of review is based on more precisely defined procedures than a traditional literature review, whereby a systematic review provides more accurate information.

When it comes to smart villages, a systematic literature review is considered necessary to search for the appropriate methodology or theory for future studies on this topic (Anastasiou et al., 2021). This approach in turn guarantees a very rigorous and absolutely fair analysis that directs researchers to the best literature and correctly marks out the terrain of the field (Putri et al., 2023). In addition, systematic literature reviews are effective in mapping the established concepts and technologies in the field of smart villages, including the improvement of smart village indicators in line with the industry (Maja et al., 2020).

In order to achieve the objectives of this research, various procedures are used from the development phase through to the empirical data collection phases, which are illustrated in Figure 1 below. These procedures are described below:

2.1. Planning

This means that the steps for the research in this phase are well organised. This includes procedures such as the following: Determining the parameters for the review of existing literature, defining the required database for the search and establishing the criteria for the selection of studies. This step is very important to ensure that the studies included in the review are numerous and independent of each other.

2.2. Formulate research question

In this phase, the research questions are developed in order to achieve specific objectives. These questions relate to all aspects of the review, including the identification of studies, the criteria and methods for selecting studies, and the process of collecting information. They should be simple, specific and orientated towards the objectives of the study.

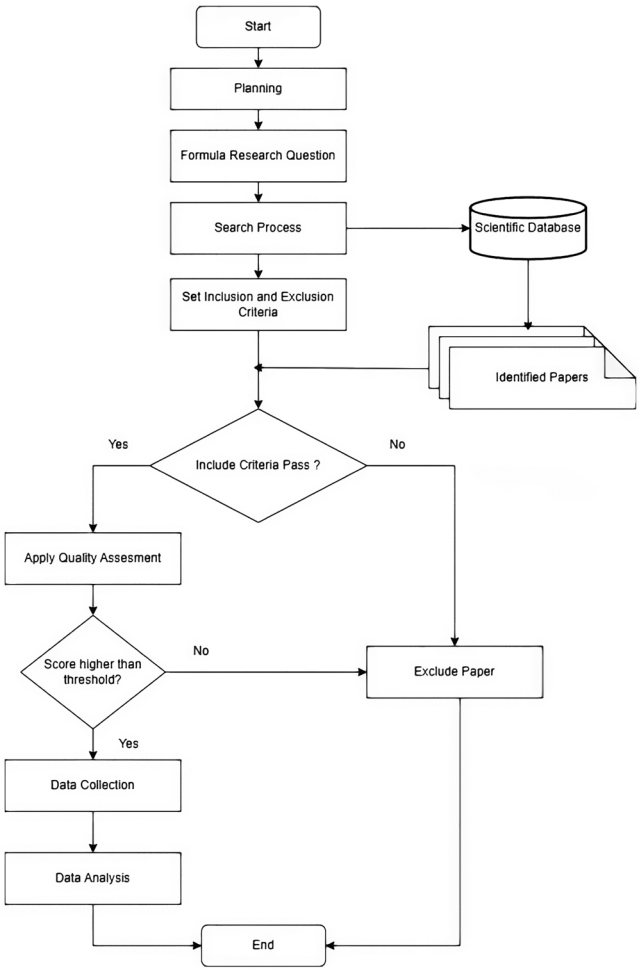


Figure 1. Data Search Process.

2.3. Search procedure

In this step, the researcher must conduct a comprehensive search of the identified databases and other sources to find the actual studies to be included in the analysis.

2.4. Set inclusion and exclusion criteria

It is a question of defining the criteria for the inclusion or exclusion of studies with regard to the conceptual questions. Specific eligibility criteria determine which studies are eligible, and the general eligibility criteria exclude those that do not meet the criteria.

2.5. Apply quality assessment

In this step, the author evaluates the criteria for the selected studies to determine the quality of the research and the techniques used. This includes the evaluation of the: How the study was planned, conducted and analysed, the participants or sample and anything that could determine the reliability of the conclusions. A strict quality assurance process is followed and only high quality paper is used for the analysis.

2.6. Data collection

In this step, relevant data is extracted from the included studies using a previously developed data extraction form. It may include study characteristics, methods, results and any other information to be used in the second phase, the analysis.

2.7. Data analysis

The final step is to analyse the extracted data and use it to answer the research questions. This may be a qualitative synthesis, meta-analysis or other method based on the nature of the data and the purpose of the research.

2.7.1. Planning

In the initial planning phase of our research, we identified a model or concept for building a smart village. Our research focussed on the model or concept for building a smart village in accordance with the smart village environment. We ensure that the concept or model to be used is suitable for the shape of the village to be built. This planning phase serves as the basis for the successful implementation of our SLR method.

2.7.2. Formula research question

At this point, we present the research questions that were analysed as part of the systematic literature review. This is a fundamental step in extracting and analysing specific knowledge about smart villages. The research questions are as shown in Table 1.

2.7.3. Searching process

This study uses a combination of databases such as Web of Science, Scopus, Science Direct and Google Scholar in a Systematic Literature Review (SLR) to ensure comprehensive coverage and robust analysis. Web of Science and Scopus are known for their rigorous selection criteria and extensive citation tracking, providing high quality and reliable sources. ScienceDirect provides access to a very large body of peer-reviewed journals, particularly those strong in scientific and technical disciplines, while Google Scholar's inclusive approach covers a broader range of documents, including grey literature and non-English publications (Malik et al., 2022). Using these different databases increases the depth and breadth of the literature search, ensures a more thorough understanding of the research topic and minimises the risk of overlooking relevant studies.

In the first step, the articles were reviewed using the titles, keywords and summaries of the selected articles. The step-by-step analysis of the search process can be found in Table 2.

Table 2 shows the results of a search for scientific articles on the topic of "smart village" The researchers searched for literature from the databases Web of Science, Scopus, ScienceDirect and Google Scholar. Search terms such as "model", "frameworks" or "concept" were used in the search. As a result, 1598 articles with relevant information were found in these databases.

2.7.4. Set inclusion and exclusion criteria

To qualify the relevant studies for this study, certain criteria for the inclusion of studies were defined and must be fulfilled. Several criteria must be met for an article to be included in the review: It is written in clear and concise English and meets the Smart Village definition. Table 3 summarises the detailed inclusion and exclusion criteria for the study.

Table 1. Research questions and motivation.

No	Research Questions	Motivations
RQ1	What is the current situation and trend of the Smart Village model?	To better understand how the current Smart Village situation can address the unique challenges of rural communities, promote sustainable development and make effective policy decisions that empower rural populations.
RQ2	What is the current metric of the model for a smart village?	The purpose of examining the current metrics of the Smart Village model is to understand how these metrics can be used to effectively measure and manage rural development.
RQ3	How can the identified metrics be effectively implemented and adapted in different rural contexts to ensure the long-term sustainability of Smart Villages?	the identified metrics for Smart Villages can be effectively adapted and implemented in different rural contexts to ensure their long-term sustainability and practical impact.

Table 2. Keywords applied on different databases.

Database	Search String	Result
Web of Science	All Field= ("smart village") AND ("model") OR ("framework") OR ("concept")	178
Scopus	TITLE-ABS-KEY ("smart village") AND ("model") OR ("framework") OR ("concept")	137
ScienceDirect	("smart village") AND ("model") OR ("framework") OR ("concept")	284
Google Scholar	("smart village") AND ("model") OR ("framework") OR ("concept")	999
Total		1598

Table 3. Inclusion and exclusion criteria.

	Inclusion criteria		Exclusion criteria
a	Each article must fulfil the scope of the Smart Village model or concept.	a	Studies that are not related to the topic or only to one of the subtopics, such as the concept of the smart city.
b	Any article that fulfils the specified eligibility criteria must fall into either the original article or critical review article category.	b	The research focuses primarily on academic articles and literature reviews, except for conference papers, book chapters and conference reports.
c	Every article must be written in English that is clear and understandable.	c	The article should not be written in a language other than English or be inaccessible.
d	Each article must be published between the years 2019 and 2023.	d	The article is published outside the specified time period.

Table 4. Quality assessment.

	Quality assessment question	Relevant to the research question
QA1	How author(s) present their research problem is crucial to determining whether complete information can be extracted.	RQ1
QA2	How do the author(s) describe the implementation of the methods in their studies?	RQ2
QA3	How do the author(s) present the results of the study, the metrics identified can be applied in different rural areas?	RQ3

2.7.5. Quality assessment

In addition, a more rigorous quality check was performed after the inclusion and exclusion criteria to proceed to the next stage of data collection and analysis. Thus, the main purpose of this assessment was to check whether the authors had answered the main research questions highlighted in the Systematic literature review section. Such an assessment allowed the exclusion of unrelated papers from the sample and enabled the identification of relevant information. A detailed explanation of the five quality assessment queries used to create the quality assessment standards can be found in Table 4.

In the review of the research, a systematic assessment was made against the quality assessment criteria. Using Table 5 as a framework for the assessment, each paper was assigned a numerical score. Only papers that achieved a score of more than two were included in the review, while papers below this score were excluded.

2.7.6. Data collection

The systematic review process in this study consists of three main stages: Identification, Screening, and Eligibility. As shown in Figure 2, a total of 1,598 studies were initially identified from four major databases, namely Web of Science (n = 178), Scopus (n = 137), ScienceDirect (n = 284), and Google Scholar (n = 999). During the identification stage, 328 articles were excluded due to publication years outside the 2019–2023 range. An additional 150 duplicate records were removed, and 9 records were excluded because they were either inaccessible or corrupted. After this process, 1,111 articles proceeded to the screening stage. In the screening stage, a total of 1,057 articles were excluded based on predetermined exclusion criteria. These included 170 articles that originated from a single journal, 174 non-English articles, 711 articles that were outside the scope of the review, and 2 articles that did not have a DOI. As a result, 54 articles were selected for the eligibility assessment stage. In the screening stage, a total of 1,057 articles were excluded based on predetermined exclusion criteria. These included 170 articles that originated from a single journal, 174 non-English articles, 711 articles that were outside the scope of the review, and 2 articles that did not have a DOI. As a result, 54 articles were selected for the eligibility assessment stage. This systematic review process is illustrated in Figure 2.

Table 5. Quality assessment scoring matrix.

Quality assessment scoring criteria	Score
The author(s) have explained the answers to the specific research questions thoroughly, clearly and simply.	High = H = 1
The author(s) offers an explanation, but lacks the specificity, detail, and clarity needed to answer the specific research question.	Medium = M = 0.5
The author(s) provided minimal or no technical details to answer the specific research question.	Low = L = 0

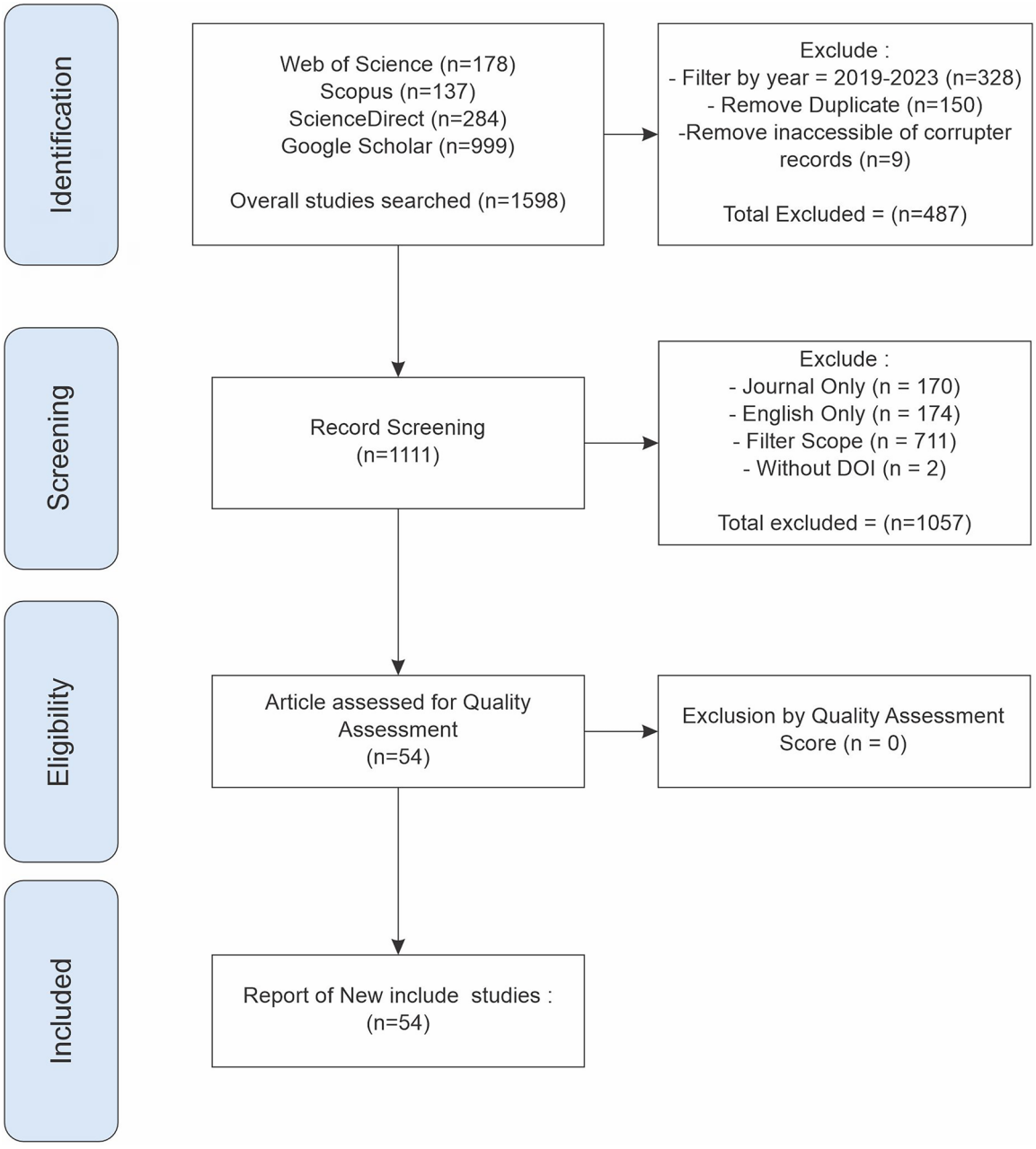


Figure 2. Overview of systematic literature review.

The use of PRISMA in this study brought many benefits to this study in terms of the research process. The study was conducted according to PRISMA guidelines, both in the formulation of the research questions and in the development of the search strategies for the literature search and in the consolidation of the results (Bayala et al., 2021). Therefore, PRISMA enabled a scientific approach to conducting the review according to predefined rules, which helped to avoid a subjective and arbitrary selection of sources and data analysis (Wang, Kang, et al., 2022). By using PRISMA in the study, the study was able to apply and improve the systematics in the research process and thus increase the reliability of the conclusions and recommendations (Ariyanto et al., 2022).

Table 6. Smart Village Metric and Paper ID.

	2019	2020	2021	2022	2023
Tourism (M22)				P32, P33	
People (M21)				P26	P41
Governance (M20)				P26, P33, P37	P41, P49, P50, P53
Community (M19)		P16	P20	P26, P31, P33, P37	P49, P54
Food Security (M18)		P13		P5, P28, P38	
Local Business (M17)		P13			
Road/Rail Network & Transportation (M16)		P11, P12	P20		P41, P50, P52
Finance (M15)		P11		P24	P53
Housing (M14)		P11			
Environment & Safety (M13)		P11, P14	P21, P22	P26, P27, P32, P33, P34	P41, P43, P45, P49
Culture (M12)		P11		P32, P35, P39	P44, P47
Telecommunication (M11)		P11			
Energy (M10)		P11			P41, P52
IoT (M9)		P8		P34, P36,	
ICT (M8)		P7, P9, P10, P11, P12, P14, P17	P20, P21, P22	P23, P29, P31, P32, P33, P35, P40	P45, P47, P51, P52, P54
Agriculture (M7)		P6, P15	P18, P19	P25, P28, P29, P34, P36, P40	P43, P52
Education (M6)	P5	P11, P12, P13		P27, P30, P33	P52
Sustainable (M5)	P5	P9, P16, P17	P18, P20	P23, P27, P37, P39	P42, P43, P44, P48, P51
Economy (M4)	P4	P9, P11, P14, P17	P20, P21	P26, P29, P32, P33, P35, P39,	P41, P44, P45, P46, P47, P50, P54
Rural (M3)	P3, P4, P5	P6, P9, P10, P11, P12, P13, P14, P16, P17	P18, P20, P21, P22	P26, P27, P29, P31, P36, P37, P39, P40,	P41, P42, P44, P46, P50, P51
Climate (M2)	P2	P15		P5, P8, P8	
Healthcare (M1)	P1, P5	P11, P12, P13	P22	P27, P30, P33, P34	P48, P52

The qualitative systematic review used the PRISMA methodology (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) in this study. This way of approaching the literature reduces the amount of potential bias in how the literature is searched for and offers a clear approach in systematically searching through the articles obtained, through the use of inclusion and exclusion criteria. The articles were analysed using the PRISMA process presented in Figure 2 which includes the identification, screening and inclusion of the articles leading to 54 articles from an initial 1598 articles.

2.7.7. Data analysis

This section is the final step of the SLR methodology: data analysis to use the data obtained from each study to answer the three main research questions posed in this research study Appendix 1. shows the results of PRISMA, so 54 papers were obtained to support this research. To facilitate coding when analysing the papers, each paper is given an ID, e.g. the paper with the sequence 1 is given the ID P1. This ID is also used when creating the papers based on the Smart Village metrics, as shown in Table 6.

3. Results and analysis

In the systematic literature review, searching scientific databases such as Web of Science, Scopus, ScienceDirect, and Google Scholar yielded 1598 selected papers. Through the PRISMA process, the research narrowed down the selection to 54 papers that are relevant to the research question.

VOSviewer was used to perform a brief data analysis of the key terms in the titles and abstracts of the 54 articles in order to identify the most important aspects and relationships between them. As can be seen in Figure 3, there are three clusters with red, blue and green colours. Based on the figure, the term 'smart villages' has a red colour and is related to the terms 'smart village concept', 'climate change', 'practise', 'challenge', 'rural area', 'rural development', 'article' and 'implementation'. for the blue colour cluster, there are several terms 'research', 'application', 'smart economy' and 'Indonesia'. The green group has the terms 'village', 'technology', 'smart city', 'sustainable development goal'.

The visualisation in Figure 3 not only describes the terms in one colour, but also shows the relationship to the terms in other colours, which illustrates the relationship of the research in the field.

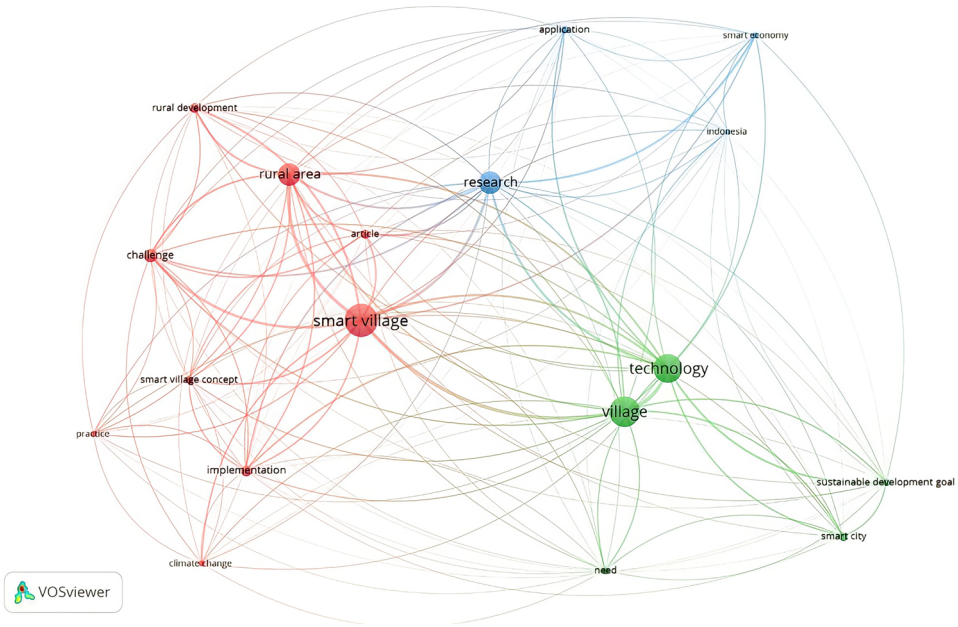


Figure 3. Keyword co-occurrence networks.

3.1. RQ1 What is the current situation and trend of the Smart Village model?

When analysing the research results, two main elements were identified that contribute significantly to the observed upward trend. The first factor concerns the emergence of the Smart Village model, a reaction to the limitations inherent in the existing model, which make it incapable of realising the desired smart village concept. The second factor involves technological advancement and the community's increasing dependence on technology, which affects various aspects of daily routines. Figure 3 to Figure 8 describe the evolution of research trends ranging from co-occurrence networks between words, the most relevant keywords, the number of publications per year, the number of articles published based on journal names, treeMap keywords and word clouds created based on article titles and abstracts.

Figure 4 shows the number of publications based on the data collected during the selection of contributions. The year 2022 has the highest number of publications with 18 papers, followed by 2023 with a total of 14 papers. The next year in order is 2020 with 12 selected papers. The lowest values are recorded for 2019 and 2021. This data reflects fluctuations in the number of publications, which could be due to various factors such as COVID-19 and other research-related topics.

Figure 5 shows the most important words of the bibliometric analysis. In the table, the keywords are organised according to their frequency, with 'smart village' occurring most frequently (23 times), followed by 'smart villages' (9 times) and 'rural development' (7 times). Other keywords such as 'smart city', 'climate-friendly smart village' and 'rural area' were mentioned less frequently, occurring between 2 and 5 times. This diagram illustrates the meaning of the term 'smart village' and its variations in the context of the research analysed. The presence of two similar words such as 'smart village' and 'smart villages' shows how the authors of the individual articles created the keywords they wanted.

Based on Figure 6 and the explanation above, the results show which top 10 journals focus more on the topic of Smart Village and which journals could be potential candidates for publishing articles in this area.

Figure 7 shows a TreeMap indicating what percentage of a word appears based on the results of the paper selection. the highest word shows that it is much discussed in recent research. 'smart village' takes the highest position, followed by 'smart villages'. Based on this data, the use of plural and singular words affects the database results. Rural development, rural areas, smart cities, smart cities, sustainability and other words are also topics that play a role in recent research. Therefore, the researcher can conclude that the brief background and methodology used in the primary study are valid and the results show that the primary study focuses on the topic and the review based on this study is valid.

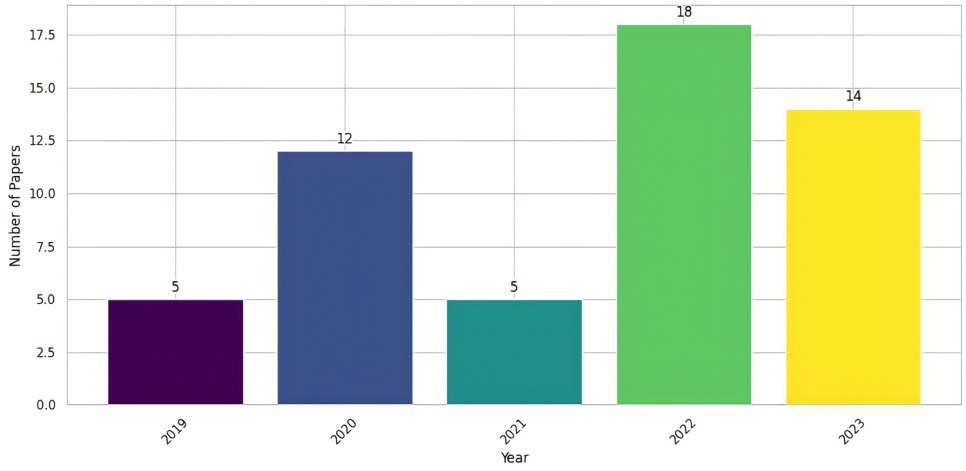


Figure 4. Number of publications.

Figure 8 describes themes and ideas associated with the Smart Village paradigm. Notable terms such as 'village', 'smart', 'rural', 'development' and 'model' indicate a focus on using the Smart Village concept as a basis for promoting rural development. Key terms such as 'technology', 'sustainable', 'environment', 'framework' and 'system' emphasise the importance of incorporating cutting-edge technologies to create sustainable and resilient rural communities. The word cloud also shows considerable academic interest with frequent references to 'research' and 'study', suggesting that the Smart Village model is an important topic for academic enquiry. In addition, terms such as 'climate', 'sustainability', 'resources' and 'agriculture' emphasise the focus on environmental sustainability and efficient resource management. Terms such as 'community', 'local' and 'participation' imply that successful Smart Village endeavours are based on active community involvement and local engagement. Finally, the use of terms such as 'challenge', 'approach', 'implementation' and 'solution' suggest that while the Smart Village model offers promising solutions, there are also obstacles that need to be addressed, particularly in the areas of policy, governance and practical application.

3.2. RQ2 What is the current metric of the model for a smart village?

To answer RQ2, this study found 22 metrics for the development of a smart village model. Each paper provides support for each existing metric so that a table can be created, as shown in Table 6, which explains the relationship between the paper and the name of the metric. Meanwhile, the metric name is followed by the metric code in M format, followed by the metric number.

Table 6 shows the supporting metrics of the Smart Village model. In this study, there are 22 metrics based on supporting reference papers. Table 6 shows that the metric 'Rural area' is discussed most frequently in several studies, followed by other metrics. From the number of papers published in 2022 and 2023, it is also evident that there are numerous papers on the smart village indices that have contributed to the development of new indices in terms of current technologies and ongoing research in the smart village field.

Based on (Maja et al., 2020), a smart village framework developed to assess and facilitate the development of smart villages. This concept aims to connect various important areas required for the progressive and sustainable development of a village. These areas include energy systems, which deal with sustainable energy and renewable energy systems, and telecommunications, that play a central role in providing a connection for information exchange. The preservation of traditions, social harmony and unity are also taken into account, as are environmental protection and safety standards that guarantee a safe lifestyle.

Economic development is one of the most developed areas and its role includes the promotion of the economic process, employment and financial stability. Another area is housing, which is emphasised by the requirement for accessible, affordable and suitable housing units. The above metric also includes elements such as healthcare and recreational facilities for the well-being and quality of life of residents in the villages, as well as the availability of education and learning for the entire life cycle of an individual. Financial systems, including banking and investment, are essential to support

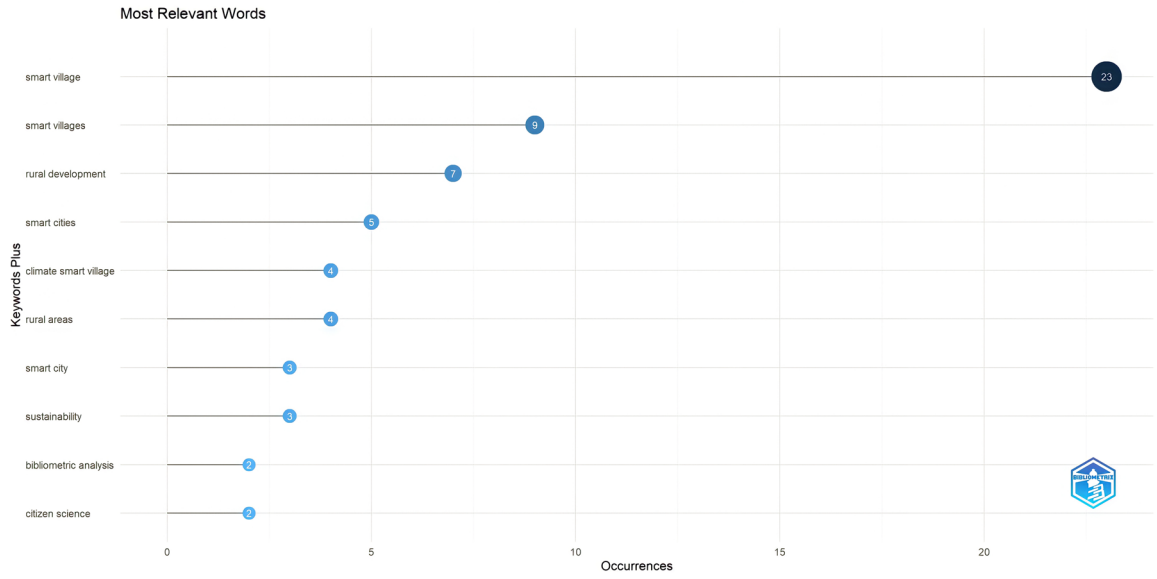


Figure 5. Most relevant word.

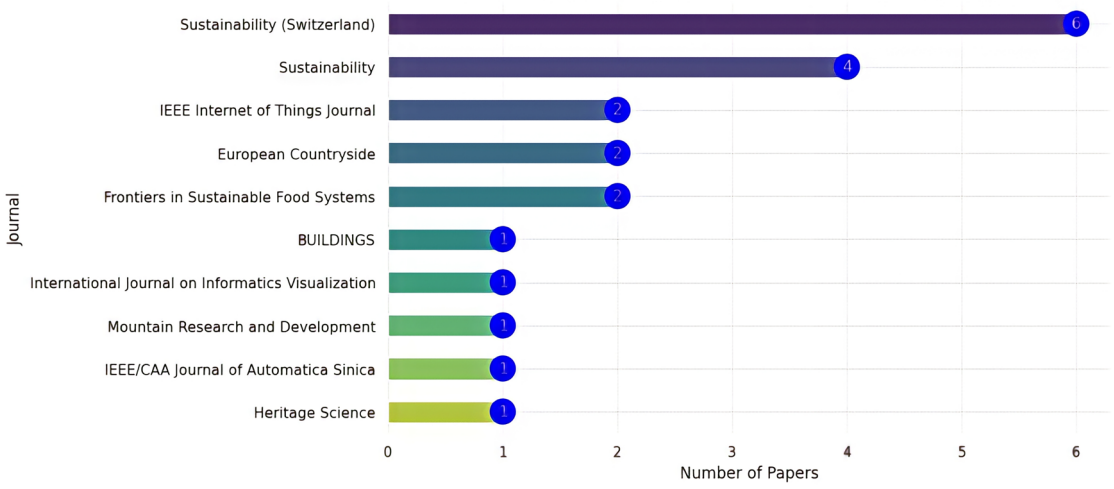


Figure 6. Top 10 Number of publications by Journal.

economic growth, while transport infrastructure such as road and rail networks ensure mobility and accessibility within the village.

3.3. RQ3 How can the identified metrics be effectively implemented and adapted in different rural contexts to ensure the long-term sustainability of Smart Villages?

This research shows the use of several studies, the implementation of several metrics used to develop smart villages, it seems that to identify metrics that can be implemented and adapted in different smart village contexts, it can be seen from the shape of the environment, such as villages on the beach, mountains or plains such as rice fields and fields. based on the 22 metrics obtained in this paper, can be implemented and adopted to build a smart village that is environmentally diverse and long-term sustainability, here are some approaches that can be taken:

Contextual Adaptation: To ensure the long-term sustainability of Smart Villages, it is essential to tailor strategies to the specific needs, resources and challenges of each rural area. Local conditions, culture and existing infrastructure must be taken into account.

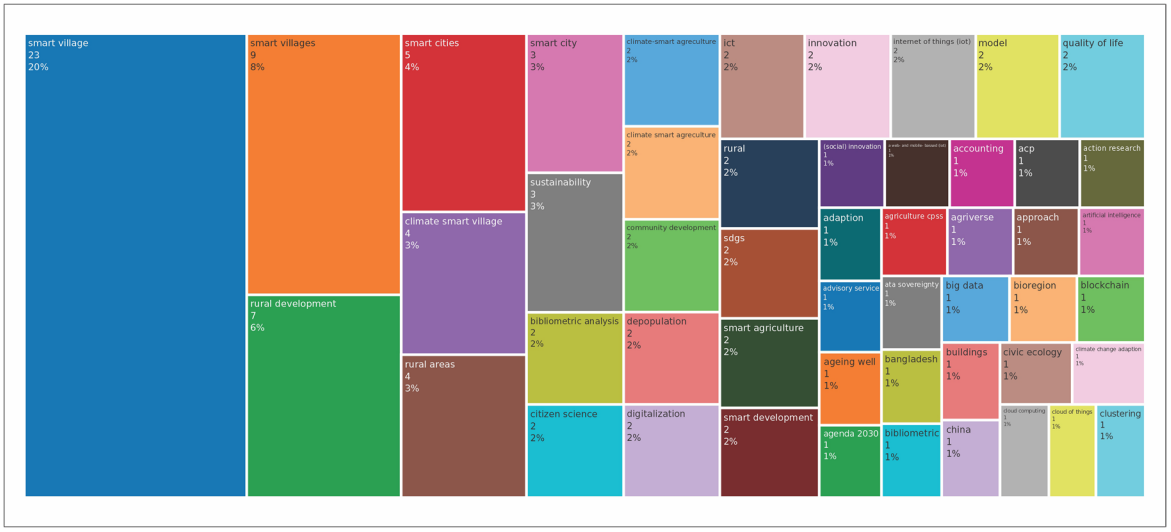


Figure 7. TreeMap keyword.



Figure 8. Smart Village word cloud.

Holistic Approach: A successful Smart Village strategy includes economic empowerment (supporting local businesses and promoting local products), social inclusion (ensuring access to e-learning and basic services), environmental sustainability (implementing circular economy practises) and the promotion of tourism and culture.

1. *Digital Technologies*: The utilisation of existing and new digital technologies is crucial. This includes improving e-literacy skills, enhancing connectivity and using ICT to improve services and livelihoods.
2. *Collaboration*: They should be implemented effectively by involving the public through locally recognised and supported community bodies, particularly in areas that have been recognised as Smart Villages. When carried out in collaboration with others, such intentions result in change efforts being driven at a higher level than when carried out individually.
3. *Funding and Synergies*: The initiation of Smart Village funds can be achieved by evaluating the cooperation between the private sector, universities and government to establish harmony between these funds, that will lead to an increase in impact.

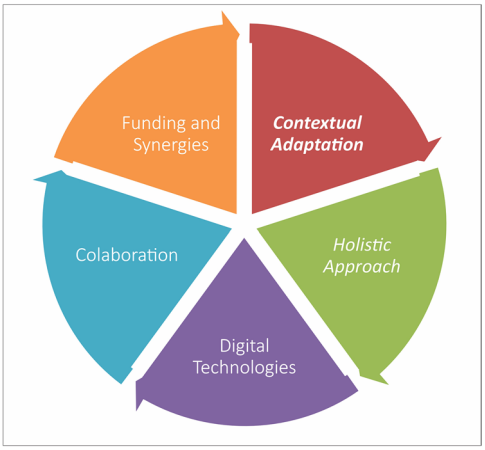


Figure 9. Metrics to Smart Village approaches.

Figure 9 illustrates that the identification of metrics can be effectively implemented and tailored to any type of smart village to achieve sustainability.

4. Conclusion

This study presents the metrics used in the development of a model for a Smart Village along a framework that describes the main ways to construct and maintain such a model among the 22 metrics. These metrics relate to one or another aspect of the desired technologically advanced and supportive village community in terms of participation and interaction with the environment, as well as economic vulnerability or not. In the study, all these factors are presented as an interrelated, closed loop that reveals the essence of developing a self-sustaining village economy. For these reasons, modern technology in the villages covering the above areas can be of great importance in improving the quality of life of the inhabitants without losing the cultural essence of the villages.

This study also explores the possibilities of using the Smart Village paradigm as a framework for rural development. Thus, in applying these metrics, more emphasis should be placed on weighty approaches to planning and communication with communities to ensure that such endeavours are both technologically sophisticated and socially and environmentally responsible. There are also areas that can be taken up in future research, namely improving these indices, applying and studying smart village practises over time, and analysing the impact of the proposal on rural communities.

This study describes the metrics used to develop a Smart Village model within a framework that describes the steps to build and maintain such a model using 22 metrics. These metrics address various aspects of a technologically advanced and supportive village community, including participation, environmental interactions, and economic vulnerability. The study synthesises these factors into a coherent, closed loop that outlines the essence of developing a self-sustaining village economy. Modern technology in villages that addresses these areas is critical to improving the quality of life of residents while preserving the cultural essence of villages.

The study also explores the potential of the Smart Village paradigm as a framework for rural development. In applying these metrics, the focus should be on robust approaches to planning and communicating with communities to ensure that these efforts are both technologically advanced and socially and environmentally responsible.

Future research could focus on improving these indices, applying and studying smart village practises over time and analysing the impact of these proposals on rural communities.

By integrating modern technology and community participation, the Smart Village model aims to create a sustainable and self-sustaining village economy that improves the quality of life of residents without jeopardising their cultural heritage.

It should also be noted the three elements of environment, economy, and society are instrumental in the concept of smart villages. Environmental concern includes policy concerning renewable energy,

Table 7. Alignment of Smart Village Contributions with Sustainable Development Goals (SDGs).

SDG	Smart Village Contribution
SDG 7	Deployment of solar energy and energy-efficient solutions in rural areas
SDG 9	Development of ICT infrastructure to enable smart governance and digital transformation
SDG 11	Inclusive community planning, improved access to services, and participatory development
SDG 13	Adoption of climate-smart practices to enhance resilience against climate change impacts

Table 8. Main Concept of Smart Villages and Indicator.

Main Concepts of Smart Villages	Indicators	Implementations
Technology	Digital infrastructure, IoT, telecommunications	IoT systems for smart farming
Economy	Development of MSMEs, digital marketplaces, tourism	Digitalization of local products
Social	Online education, ICT-based healthcare services	E-health programs in remote villages
Environment	Renewable energy, water efficiency	Solar energy systems in remote villages
Governance	Transparency, data management	Blockchain-based village financial systems

sustainability of our natural resources, and practicing on the effects of climate change. On the other hand, the economic perspective focuses on the growth of the micro, small and medium enterprises (SMEs) and enhancing the use of technology in the delivery of financial services for local economy development. The social aspect revolves around improving the social welfare of the people courtesy of education, health, and information communication technology community competence upliftment.

4.1. Smart Villages and the sustainable development Goals

By the Smart Village Metric illustrated in Table 6, the following correspondences between the smart village projects and the sustainable development goals have been proposed by this research. Implementation of renewable energy (RE) technologies is also linked to use of effective RE to which is in-line with SDG 7 regarding provision of clean and efficient energy especially to rural populace. Consequently, the integration of blended and smart learning initiated through the combination of ICT for governance and education also contributes to target, which is leveraging information technologies to enhance research and infrastructure. New smart village frameworks also advance the cause of SDG 11 since it assures sustainable rural communities to participate in governance and be socially included. Finally, climate change measured and addressed by climate smart practices and by the use of Renewable Energy in agriculture is a method by which Smart Villages provide solutions to climate change challenges that are global hence meeting the requirement of SDG 13.

Table 7 shows the correspondence between the approaches implemented within the framework of the formation of smart villages and their relation to the Sustainable Development Goals (SDGs). Consequently, each identified SDG is accompanied by various delivered contributions of smart villages including renewable energy technologies, development of ICT, effective and inclusive planning of the communities, and Climate resilience. This alignment also underscores the orientation of smart villages toward a diverse and complicated set of global sustainability issues.

4.2. Successful implementations of Smart Villages

In the Table 8, the author made a synthesis of the main concepts and key indicators connected with the smart village frameworks. The ideas are related to particular quantifiable elements known as indicators and the displays of the concept implementation experienced in practice. This synthesis will therefore seek to consolidate our understanding of what smart villages are and how they respond to technological, economic, social, and governance, and environmental imperatives towards rural development.

In the Table 8 this research provided an example of the type of research questions that can be distinguished and their relation to the particular dimensions of the Smart Village concept. Every topic presents different achievements in terms of promoting and developing smart village ideas in technological, social, governing, economic, and environmental perspectives. For example, in the technology category, the use of GIS for building in Minangkabau, West Sumatra highlights on on how effective spatial data systems for village planning. In the social dimension, this study of the preferences of the elderly customers in Malaysia reveals smart retirement villages to improve the quality of life. A number

Table 9. Research topics and categories of Smart Village Applications in ASEAN Countries.

Research Topic	Category	Country Apply
Development of GIS for Buildings in the Customary Village of Minangkabau Koto Gadang, Agam Regency, West Sumatra (Afnarius et al., 2020).	Technology	Indonesia
Elderly customers' preferences and relocation intentions for smart retirement villages in Malaysia (Tan et al., 2021).	Social	Malaysia
Development of enterprise architecture for smart village implementation in the Sragen Regency, Indonesia, using the TOGAF ADM 9.2 framework to achieve e-Government goals (Alhari & Fajrillah, 2022).	Government	Indonesia
Measuring the success of implementing the Village Financial System (SISKEUDES) to support sustainable information society development in Bali, Indonesia (Ariyanto et al., 2022).	Government	Indonesia
Assessment of the impacts of the COVID-19 pandemic on four Climate Smart Villages in Myanmar through household surveys and participatory action research (Barbon et al., 2022).	Environment	Myanmar
Assessment of technology-based village development in Kabandungan Sub-district, Sukabumi District, West Java Province, Indonesia, to support smart economy initiatives through ICT-driven innovations and citizen science (Tosida et al., 2022).	Government	Indonesia
Analysis of the implementation of the smart village concept to address rural development and community vulnerability in Indonesia, focusing on socio-economic resilience and reducing developmental disparities (Muhtar et al., 2023).	Economic	Indonesia
Comprehensive review of 30 years of village corruption research, exploring its evolution, influential themes, and the role of accounting in addressing corruption and achieving village sustainability globally (Putri et al., 2023).	Government	Indonesia
Application of citizen science and fuzzy C-means clustering to assess readiness for smart village initiatives in the Kemang District, Bogor Regency, Indonesia, focusing on developing a smart economy ecosystem (Tosida et al., 2023)	Government	Indonesia

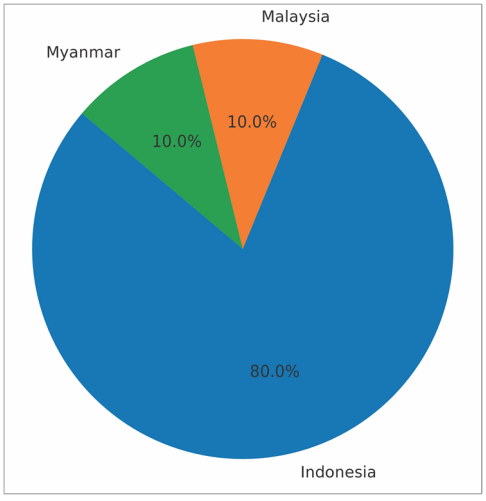


Figure 10. Proportion of research applications in ASEAN countries.

of governance related research works like the case of SISKEUDES in Bali and enterprise architecture in Sragen Regency establish the significance of opaque and efficient structure in country administration. Examples are environmental studies like the assessment of Climate Smart Villages in the Myanmar context when the world is facing COVID-19 pandemic. Lastly, economics identify the role of ICT and citizen science in enganging economic resilience and sustainabillity, whereforec smart economy interventions in West Java.

Table 9. are examples in implementing the concept of smart villages in the ASEAN region that demonstrates how countries have adopted the different solutions for addressing the besetting problem and opportunities in developing smart village in rural areas of respective countries.

Based on Table 9. provided to depict the proportion on the chart is based on the research applications in ASEAN countries as following: The data highlights the distribution as show in Figure 10: Indonesia takes the largest share of the research applications comprising 80% possibly due to its strong emphasis and participation in smart village projects in the multiple dimensions including technology, government, and economy. Malaysia constitutes 10% of the applications; individual contributions include areas such

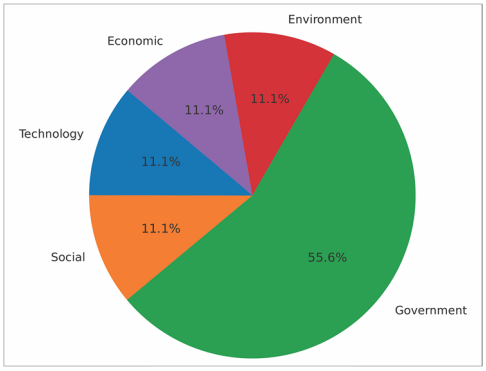


Figure 11. Proportion of research applications by category.

as social innovation and community's welfare. Myanmar also accounts for10%, it is focused on the climate smart village and pandemic effects.

Figure 11 of types of research application under the title of 'Proportion of Research Applications by Category' gives a clear indication of the proportion of research topics researched and the ASEAN region and those that are not. Each of such pie segments corresponds to a category while the size of each segment is determined by the number of studies conducted within that category. The sub-theme of government being dominant shows that most of the research applications regard development of smart villages with an anchor on governance, policies and administrative structures.

Technology, Social, Environment, and Economic categories are also included which show the difference nature and efforts made for the execution of the smart village concept. In the light of the Figure 11, it is critical to notice that smart village research is a complex phenomenon where technological, social and environmental advancements go hand in hand with governance and economies at the countryside.

This work also establishes the proposition that the innovation of smart villages should be multi-sectoral, adopting technology, economy, society and the environment. Based on this research, which concentrates on the ASEAN context, the stakeholders will be given proper direction to implement digital technology for sustainability. The above operational recommendations can provide directions on how best to implement smart villages as more inclusive and effective uses of technology.

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Author contributions

Apri Junaidi: He conceptualized the study, curated the data, performed PRISMA analysis methodology, and drafted the original manuscript.

Mohd Shahizan bin Othman: He conducted the investigation for the keyword research strategy and contributed to the methodology.

Siti Zaiton Mohd Hashim: She supervised the study, validated the findings, and approved the final manuscript.

Mohd Murtadha Mohamad: He contributed to the visualization of the study by creating the graphs.

Deni Danial Kesa: He reviewed and edited the manuscript.

Ari Nurfikri: He conceptualized the research plan and research questions.

All authors critically reviewed the manuscript for intellectual content, approved the final version for publication, and agree to be accountable for all aspects of the work.

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Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request. Due to ethical/privacy/commercial restrictions, some data may not be publicly available. However, aggregated or anonymized data can be shared to support the results presented in this article. Please contact the corresponding author for further information.

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Appendix 1. Document search result.

Paper ID	Author	Document Title	Source	Cite by
P1	(Gahlot et al., 2019)	Review of smart health monitoring approaches with survey analysis and proposed framework	*IEEE Internet of Things Journal*	59
P2	(Jagustović et al., 2019)	Contribution of systems thinking and complex adaptive system attributes to sustainable food production: Example from a climate-smart village	*Agricultural Systems*	59
P3	(Philip & Williams, 2019)	Healthy Ageing in Smart Villages? Observations from the Field	*European Countryside*	19
P4	(Thackara, 2019)	Bioregioning: Pathways to Urban-Rural Reconnection	*She Ji: The Journal of Design, Economics, and Innovation*	22
P5	(Zavratnik et al., 2019)	Living Labs for Rural Areas: Contextualization of Living Lab Frameworks, Concepts and Practices	*Sustainability*	36
P6	(Adesipo et al., 2020)	Smart and Climate-Smart Agricultural Trends as Core Aspects of Smart Village Functions	*Sensor*	41
P7	(Afnarius et al., 2020)	Development of GIS for buildings in the customary village of Minangkabau Koto Gadang, West Sumatra, Indonesia	*ISPRS International Journal of Geo-Information*	11
P8	(Chanak & Banerjee, 2021)	Internet-of-Things-Enabled SmartVillages: An Overview	*IEEE Consumer Electronics Magazine*	40
P9	(Despotović et al., 2020)	Demographic revitalization of montenegrin rural areas through the smart village concept	*Agriculture and Forestry*	5
P10	(Lytras et al., 2020)	Social media mining for smart cities and smart villages research	*Soft Computing*	14
P11	(Maja et al., 2020)	Development of Smart Rural Village Indicators in Line with Industry 4.0	*IEEE Access*	68
P12	(Murty & Shankar, 2020)	Towards a scalable architecture for smart villages: The discovery phase	*Sustainability (Switzerland)*	12
P13	(Edgars et al., 2020)	Smart and Sustainable Local Communities in Global Covid-19 Pandemic Conditions	*Landscape Architecture and Art*	4
P14	(Sept, 2020)	Thinking Together Digitalization and Social Innovation in Rural Areas: An Exploration of Rural Digitalization Projects in Germany	*European Countryside*	32
P15	(Tetteh et al., 2020)	Perceptions of weather variability and climate change on goat producers' choice of coping and adaptation strategies: evidence from climate-smart and non-climate-smart villages in the Jirapa and Lawra districts	*Climate And Development*	8
P16	(Zavratnik et al., 2020)	Sustainable and community-centred development of smart cities and villages	*Sustainability (Switzerland)*	36
P17	(Zhang & Zhang, 2020)	How do smart villages become a way to achieve sustainable development in rural areas? Smart village planning and practices in China	*Sustainability (Switzerland)*	46
P18	(Anastasiou et al., 2021)	Territorial and human geography challenges: How can smart villages support rural development and population inclusion?	*Social Sciences*	17
P19	(Bayala et al., 2021)	Multi-Actors' Co-Implementation of Climate-Smart Village Approach in West Africa: Achievements and Lessons Learnt	*Frontiers in Sustainable Food Systems*	6
P20	(Ogryzek et al., 2021)	Public participation as a tool for solving socio-spatial conflicts of smart cities and smart villages in the sustainable transport system	*Remote Sensing*	12
P21	(Stojanova et al., 2021)	Smart Villages Policies: Past, Present and Future	*Sustainability*	60
P22	(Tan et al., 2021)	Elderly Customers' Open Innovation on Smart Retirement Village: What They Want and What Drive Their Intention to Relocate?	*Journal of Open Innovation: Technology, Market, and Complexity*	3
P23	(Alhari & Fajrillah, 2022)	Enterprise Architecture: A Strategy to Achieve e-Government Dimension of Smart Village Using TOGAF ADM 9.2	*International Journal on Informatics Visualization*	5
P24	(Ariyanto et al., 2022)	The Success of Information Systems and Sustainable Information Society: Measuring the Implementation of a Village Financial System	*Sustainability (Switzerland)*	9
P25	(Barbon et al., 2022)	The mitigating role of climate smart villages to the impacts of COVID-19 pandemic in the Myanmar rural communities	*Current Research in Environmental Sustainability*	4

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Appendix 1. Continued.

Paper ID	Author	Document Title	Source	Cite by
P26	(Budziewicz-Guzlecka & Drozdz, 2022)	Development and Implementation of the Smart Village Concept as a Challenge for the Modern Power Industry on the Example of Poland	*Energies*	15
P27	(Gerli et al., 2022)	What makes a smart village smart? A review of the literature	*Emerald Insight*	60
P28	(Ghimire et al., 2022)	Institutional Innovations for Climate Smart Agriculture: Assessment of Climate-Smart Village Approach in Nepal	*Frontiers in Sustainable Food Systems*	5
P29	(Kasinathan et al., 2022)	Realization of sustainable development goals with disruptive technologies by integrating industry 5.0, society 5.0, smart cities and villages	*Sustainability*	74
P30	(Kaur & Parashar, 2022)	A systematic literature review of blockchain technology for smart villages	*Archives of Computational Methods in Engineering*	30
P31	(Komorowski, 2022)	Smart Initiatives in a Suburban Community: An Example from the Holy Cross Mountains in Poland	*Mountain Research and Development*	3
P32	(Li & Zhong, 2022)	Development of a smart tourism integration model to preserve the cultural heritage of ancient villages in Northern Guangxi	*Heritage Science*	13
P33	(Malik et al., 2022)	Village 4.0: Digitalization of village with smart internet of things technologies	*Computers & Industrial Engineering*	83
P34	(Sarkar et al., 2022)	Ubiquitous on-demand Water Reservoir Tracking System for Smart Village	*Universal Journal of Agricultural Research*	4
P35	(Satoła & Milewska, 2022)	The Concept of a Smart Village as an Innovative Way of Implementing Public Tasks in the Era of Instability on the Energy Market-Examples from Poland	*Energies*	16
P36	(Shaikh et al., 2022)	Recent trends in internet-of-things-enabled sensor technologies for smart agriculture	*IEEE Internet of Things Journal*	69
P37	(Tosida et al., 2022)	Investigating the effect of technology-based village development towards smart economy: An application of variance-based structural equation modeling	*International Journal of Data and Network Science*	9
P38	(Turyasingura & Chavula, 2022)	Climate-Smart Agricultural Extension Service Innovation Approaches in Uganda: Review Paper	*International Journal of Food Science and Agriculture*	26
P39	(Wang, Luo, et al., 2022)	Increased Attention to Smart Development in Rural Areas: A Scientometric Analysis of Smart Village Research	*Land*	17
P40	(Wang, Kang, et al., 2022)	DeCASA in AgriVerse: Parallel Agriculture for Smart Villages in Metaverses	*IEEE/CAA Journal of Automatica Sinica*	26
P41	(Bokun & Nazarko, 2023)	Smart villages concept - A bibliometric analysis and state-of-the-art literature review	*Progress in Planning*	7
P42	(Calzada, 2023)	Smart Rural Communities: Action Research in Colombia and Mozambique	*Sustainability (Switzerland)*	3
P43	(Hossain et al., 2023)	Haor (Wetland) Community in Bangladesh: Problems/Needs, Resources and Potential for Employing Smart Village Ideas	*International Journal of Community and Social Development*	0
P44	(Jakobsen et al., 2023)	A literature review of smart technology domains with implications for research on smart rural communities	*Technology in Society*	6
P45	(Karli et al., 2023)	ICT-supported applications in rural area planning: Vodafone Smart Village model*	*Journal of Agriculture Faculty of Ege University*	0
P46	(W. Li et al., 2023)	The Evolution Model of and Factors Influencing Digital Villages: Evidence from Guangxi, China	*Agriculture (Switzerland)*	8
P47	(Lombardo et al., 2023)	Smart technological tools for rising damp on monumental buildings for cultural heritage conservation. A proposal for smart villages implementation in the Madonie montains (Sicily)	*Sustainable Futures*	5
P48	(Meng et al., 2023)	Promoting Elderly Care Sustainability by Smart Village Facilities Integration-Construction of a Public Service Field with Introduction of Fall Posture Monitoring	*Buildings*	1
P49	(Muhtar et al., 2023)	Smart villages, rural development and community vulnerability in Indonesia: A bibliometric analysis	*Cogent Social Sciences*	10
P50	(Pathak & Deshkar, 2023)	Transitions towards Sustainable and Resilient Rural Areas in Revitalising India: A Framework for Localising SDGs at Gram Panchayat Level	*Sustainability (Switzerland)*	4

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Appendix 1. Continued.

Paper ID	Author	Document Title	Source	Cite by
P51	(Hlavácek et al., 2023)	Barriers for and standpoints of key actors in the implementation of smart village projects as a tool for the development of rural areas	*Journal of Rural Studies*	4
P52	(Pinki & Yadav, 2023)	Chandlai Village Jaipur-A Study Of Sustainable Development &Research Approach Towards Smart Village	*Journal for ReAttach Therapy and Developmental Diversities*	0
P53	(Putri et al., 2023)	Thirty Years of Village Corruption Research: Accounting and Smart Villages for Village Sustainability as Future Research Direction	*Sustainability*	2
P54	(Tosida et al., 2023)	Modeling of citizen science cluster in making decision for readiness towards bogor smart village: An application of fuzzy c-means algorithm	*Decision Science Letters*	0