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Research article

Smart village concept in Indonesia: ICT as determining factor

Anindya Puteri Eka Susilowati [a], Rini Rachmawati [b,c,*], R. Rijanta [c]

[a] Graduate Program on Regional Development, Faculty of Geography, Universitas Gadjah Mada, Yogyakarta, 55281, Indonesia
[b] Smart City, Village, and Region Research Group, Department of Development Geography, Faculty of Geography, Universitas Gadjah Mada, Yogyakarta, 55281, Indonesia
[c] Department of Development Geography, Faculty of Geography, Universitas Gadjah Mada, Yogyakarta, 55281, Indonesia

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ABSTRACT

Village development in Indonesia has become the national development agenda prioritized in conjunction with the enactment of the Village Law in 2014. Village development through smart village is considered relevant to the current era's progress and rapid technological advancements. Smart village is often defined as the concept of village development based on the utilization of information and communication technology (ICT). This research aims to identify the locations of smart village and analyze the role of ICT as determining factor for the smart village concept in Indonesia. The data on smart village locations are collected from the regulations of the Ministry of Village and literature obtained through internet browsing. The research was conducted using a quantitative descriptive approach and supported by spatial analysis. The exploration of determining factors for the smart village concept involves 12 variables sourced from the Village Potential data in 2021 and analyzed statistically using factor analysis. The results indicate that there are 1.424 villages developed as smart village until 2023 and their locations are spread across 32 provinces on all islands in Indonesia. The results show that ICT is one of the determining factors in the smart village concept in Indonesia through the utilization of village information systems in government (explained 15,972 % variance), community interest in ICT (explained 10,628 % variance), and the availability of communication access (explained 8509 % variance). However, ICT is not the only determining factor, but there are also internal village factors: community participation (explained 11,299 % variance) and leadership (explained 9137 % variance). From these findings, it implies that smart village development policies need to pay attention to the conditions of society as the subject and object of development, supported by the government's ability to provide adequate infrastructure. This research is a pioneer and provides real innovation in smart village studies so that it can be a reference for similar studies in the future, both in smaller areas (provinces/regencies), or countries with conditions similar to Indonesia.

1. Introduction

The national development, which began with village development, has become a prioritized agenda in line with the emergence of a new paradigm for village development in the Law Number 6 of 2014 concerning Village (Village Law). This law provides greater authority to village governments, both in terms of governance and finance [1]. Decentralization of power from a higher level of

* Corresponding author. Smart City, Village, and Region Research Group, Department of Development Geography, Faculty of Geography, Universitas Gadjah Mada, Yogyakarta, 55281, Indonesia.
E-mail address: rinirachma@ugm.ac.id (R. Rachmawati).

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government to the village as the lowest level of government, is expected to enhance governance and resource management since the village government is considered to be less influenced by special interests [2]. Village Driven Development (VDD), which promotes independent village development by communities and local government, is reflected in the Village Law [3]. Therefore, the transfer of knowledge and innovation is an important strategy in sustainable village development [4].

Technological advances in recent decades have also had an impact on everyday life. Although it has the possibility of some negative social effects, digitalization is considered to be able to improve people's welfare and comfort of life [5]. Unlike in urban areas, rural areas face challenges in the implementation of technology due to an increase in the elderly population, migration of young people from villages to cities, and digital divides [6].

In this context, village development through the implementation of smart village is considered relevant to the current era's progress of technological advancements. Digital connectivity from cities needs to extend to villages to reduce the urban-rural disparities [7]. Smart village are considered capable of reducing urbanization rates by promoting village self-sufficiency in technology utilization, strengthening education, and enhancing vocational training [8]. The smart village approach demonstrates specific interventions at the grassroots level based on community needs, resulting in development plans that align with development targets [9].

The development of smart village is needed to support the implementation of smart city and smart regency at the district and city levels [10]. Smart village are essential for both villages and cities to improve the quality of life and technology [8]. The implementation of smart city in Indonesia has been pursued through the "Movement Towards 100 Smart Cities" program since 2017 [11]. In 2023, the program "Movement Towards Smart Province" was initiated as a follow-up to smart city through integrated collaboration between regions [12]. A smart city is a planned city with structured performance in the economy, social aspects, administration, mobility, environment, and other aspects of life [13].

On the other hand, the development of smart village in Indonesia has not been vigorously pursued due to physical, social, cultural, and economic variations between regions influenced by Indonesia's archipelagic geographical conditions. There are four basic challenges in the development of ICT-based rural areas, namely the availability of data centers (servers), internet network connectivity, ICT devices (PCs, laptops, and smartphones), and human resources (HR) understanding ICT [14]. This indicates that infrastructure availability plays a crucial role in the successful implementation of smart village. A networked society through the internet needs to be seen as a fundamental right and fulfilled starting from the village [15]. Smart village reduce the gaps and vulnerabilities of the population and are more suitable for application in the younger generation with a better understanding of technology [16].

Many villages in Indonesia have already been developed as smart village. The development of smart village in Indonesia has received full support from the central and regional governments through various policies [17], including the "Smart Village" program initiated by the Ministry of Villages, Development of Disadvantaged Regions, and Transmigration (Ministry of Village) of the Republic of Indonesia. In 2021, 350 Smart Village Phase I Location Villages were designated, followed by the designation of 1000 Smart Village Phase II Location Villages in 2022 [18]. In addition to being initiated by the central government through the Ministry of Village, the development of smart village is also carried out by local governments collaborating with the private sector and academia to accelerate village development.

In general, smart village is synonymous with ICT as the main instrument in the concept of regional development. However, there is an assumption that the implementation of smart village does not require an ICT-based approach fully, but rather emphasizes technology that suits the needs of local communities [19]. Therefore, this study aims to explore the role of ICT in the development of smart village and explore the presence or absence of other factors in supporting the development of smart village in Indonesia. This study is interesting and important to prove the role of ICT in the implementation of smart village and as a new finding. Several previous studies have focused on building conceptual models and dimensions of smart village [3,7,20–23].

Based on this background, two research questions were formulated as the following: 1) In which locations are smart village developed in Indonesia? and 2) What is the role of ICT as determining factor for the smart village concept in Indonesia? The locus of smart village development needs to be identified to determine the distribution of locations and the level of smart village development as a basis for national village development planning in Indonesia. This research also tries to formulate the factors determining smart village concept in Indonesia based on existing empirical data as instruments for preparing smart village development policies that pay more attention to the real conditions of villages in Indonesia and do not just rely on ideal conditions based on existing theories.

2. Literature review

2.1. Village and rural area

In Village Law, villages and customary villages or what is called by other names are defined as "a legal community unit that has territorial boundaries that is authorized to regulate and manage government affairs, the interests of the local community based on community initiatives, origin rights, and/or traditional rights that are recognized and respected in the government system of the Republic of Indonesia". The Village Law recognizes and respects the existence of customary law communities and the naming of village administrative areas according to their traditional customs as part of village privileges, such as *huta/nagori* in North Sumatra, *gampong* in Aceh, *nagari* in Minangkabau, *marga* in southern Sumatra, *tiuh* or *pekon* in Lampung, *desa pakraman/desa adat* in Bali, *lembang* in Toraja, *banua* and *wanua* in Kalimantan, and *negeri* in Maluku.

In addition to villages, the smallest unit of government in Indonesia at the village level is called a *kelurahan*. Generally, a kelurahan is defined as a village-level administrative area located in the administrative area of a city. Unlike a village, which is led by a village head through a direct election mechanism by the villagers, a kelurahan is led by a *lurah* as a sub-district official who is responsible to the *camat* and appointed by the regent/mayor. However, the existence of kelurahan in the Village Law is not clearly regulated, only

mentioned in the Village Arrangement section. The definition of a kelurahan is regulated in Government Regulation Number 17 of 2018 on Sub-districts, with the meaning as "part of the sub-district as an apparatus of the sub-district". Therefore, the kelurahan is formally considered not the same as the village, although functionally it carries out official affairs and organizes public services [24].

The Village Law also provides a new direction in village development through the development of rural areas, namely "areas that have main agricultural activities, including natural resource management with an arrangement of regional functions as a place for rural settlements, government services, social services, and economic activities". Rural area development aims to accelerate and improve the quality of services, development, and community empowerment between villages in one district/city through a participatory development approach. The development of several villages incorporated in a rural area is expected to be integrated towards the same development goals in order to increase economies of scale and efficiency in the use of resources. Rural area development can be a regional development strategy to improve rural-urban linkages, especially in villages that have good accessibility to cities, adequate facilities and infrastructure, small and medium industrial activities based on local agricultural products, and production-distribution networks from villages to cities [25].

2.2. Smart village

A pragmatic definition of the smart village concept was proposed by the European Commission through the "EU Action for Smart Villages" in April 2017 [26]. According to it, smart village are built on the initiative of rural communities themselves in a bottom-up manner to find practical solutions to problems through optimizing their opportunities. The development of smart village requires encouragement from the community to explore potential and increase capacity in the context of community development and empowerment through the use of information technology [27]. The emergence of the village self-governance movement through the use of ICT shows that development initiatives can be carried out from below according to the needs of each village [28]. Therefore, the aspect of preparing rural policies that support smart village through the involvement of all stakeholders is another important factor [26], as well as analyzing the values, characters, and norms that develop in the local community [27].

Smart village is a new development concept developed by Indian researchers N. Viswanadham and Sowmya Vedula in 2010 [20]. Smart village is an ecosystem consists of a network that brings together professional actors among the community, government, institutions and the availability of infrastructure and resources with the support of information and communication technology services [29].

The focus of the smart village approach is the ability to manage existing resources to meet the needs of local communities, accompanied by the role of technology as a tool to achieve these goals [30,31]. This concept is considered capable of overcoming the problems faced by villages in the modern era so as to alleviate the development gap between villages and cities [30].

However, smart village are not a one-size-fits-all solution [21,32,33]. The implementation of smart village often faces challenges and barriers, such as limited budgets, unsustainable strategies, low collaboration between stakeholders, and lack of knowledge about smart village [9]. The role of leaders is central as decision-makers for the development of their regions. However, many regional heads

Table 1
Definitions of smart village.

Definitions	Dimensions	Sources
A smart village is a village that is able to provide better facilities in education, employment, energy, clean water, health, women's empowerment, as well as transportation and communication for its residents.	• Resources • Technology • Institutions • Sustainability	[38]
Smart village are villages that are oriented towards increasing the capacity of village officials and communities to support the independence of village management and innovation in economic and social activities, while still pursuing aspects of the application of information and communication technology.	• Smart governance • Smart community • Smart economy • Smart environment	[10]
Smart village as a village development concept that aims to improve the standard of living and welfare of the community through strengthening the local economy, using renewable energy, increasing disaster resilience, and alleviating rural-urban inequality.	• Energy • Economy • ICT • People • Governance • Environment • Living	[39]
A smart village is a part of a village ecosystem with a size that is not administratively limited, consisting of villagers who are able to utilize the added value of ICT.	• Conceptual soundness of the smart village debate • ICT and its considerate use • Application and targeted policymaking	[40]
Smart village are villages that utilize technology to provide services, access to information, and energy effectively and efficiently based on village regulations that have been established to facilitate community life and improve economic standards.	• *Gov*ernance • Technology • Resources • Village services • Living • Touris*m*	[20]

Source: Various sources (2024)

are skeptical of the success of smart concepts due to lack of budget and no direction in their implementation [34]. The availability of supporting infrastructure in rural areas that is not as good as in urban areas is also a barrier, which is influenced by low public acceptance of private sector involvement in development and prevailing cultural values in the community [35]. This supports the findings of [36], that the main obstacle to the intensification of smart village implementation is not the coverage of digital technologies, but the lower level of qualification and conservatism of the rural population.

The definition of smart village by various experts may vary considering the unique geographical features, demographics, and social and physical resources of each region [37]. Until recently, the concept of smart village has various definitions from various experts. Table 1 shows some definitions and dimensions of smart village.

There is no clear definition of the smart village concept, which is one of the problems in implementing smart village in Indonesia (Munir, 2017; Ramesh, 2018 in Ref. [27]). Therefore, the smart village concept was built based on a literature review of various literatures that have been published by experts or researchers, with a context that is adjusted to the scope of Indonesia.

Literature on smart village was collected from the Scopus journal database. In the literature search on smart village, the keywords used were "smart village", "smart rural", "digital village", "digital rural" [39], "smart kampung", "smart nagari", and "indonesia". The term "smart kampung" is used to find articles related to the implementation of the smart village concept in Banyuwangi Regency which is branded with the name smart kampung [20]. The term "smart nagari" is used to find articles related to the implementation of the smart village concept in West Sumatra Province, considering that nagari is the term for the administrative unit of the village in the region.

Literature search in the Scopus journal database using the keywords "smart village" OR "smart rural" OR "digital village" OR "digital rural" OR "smart kampung" OR "smart nagari" AND "indonesia" in the article title, abstract, and keywords resulted in 51 articles from the period 2014–2023. The bibliometric network of articles on smart village in Indonesia is visualized using VOSviewer, as shown in Fig. 1. It can be seen that smart village and rural areas are the most frequently appearing topics in articles on smart village in Indonesia. Smart village have a close relationship with digital technology, digital villages, e-government, social and economic impacts, and SDGs. Smart village are also related to village development and regional planning through several instruments, such as GIS, digital technology, artificial intelligence, and are related to the concept of smart city.

From the bibliometric network, it can be seen that the discussion of the smart village concept in Indonesia is generally related to public services, sustainable development, e-government, agriculture, village development, budget management, smart city, environment, and regional planning. This shows that the study of smart village in Indonesia is still focused on its application in various fields. In fact, the study is important to know, even from the early stages of practice, to develop smart village development model. This research is here to fill this gap and become a pioneer in this study. In this study, smart village is defined as a village that is able to utilize technology as a tool or enabler to accelerate village development through the support of community capacity and participation, good governance, availability of digital infrastructure and budget, and the role of related institutions that regulate regulations and build

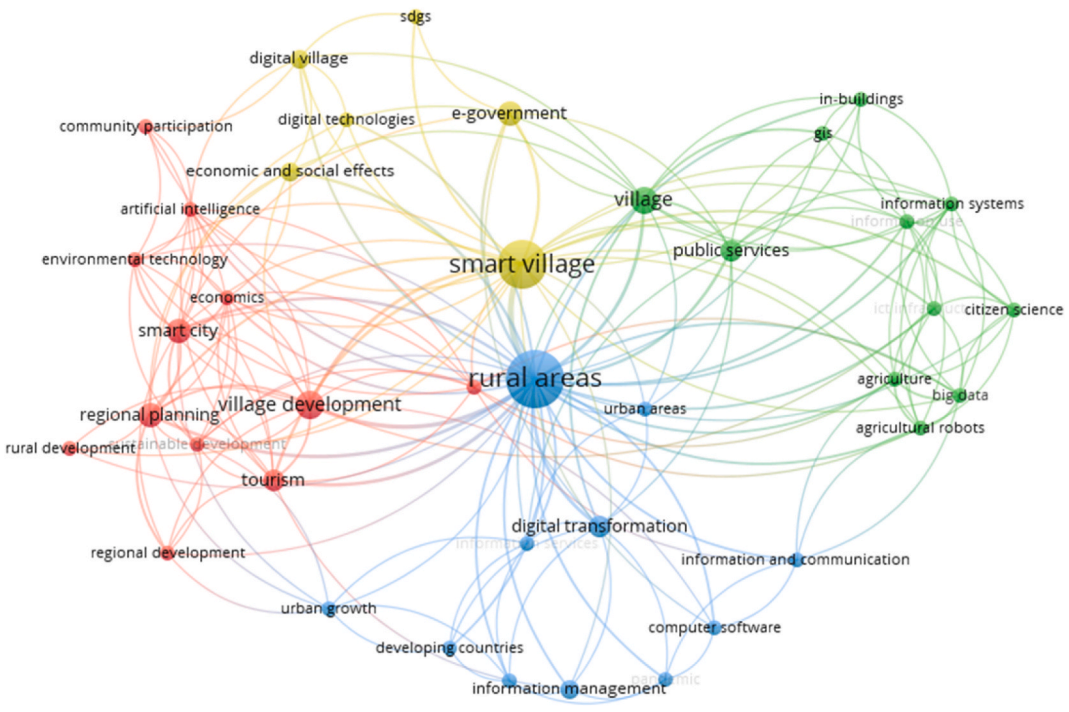

Fig. 1. The bibliometric network of articles on smart village in Indonesia. Source: Scopus journal database processing results using VOSviewer (2024).

partnerships in order to achieve sustainable village development.

2.3. Smart village implementation in Indonesia and other countries

In Indonesia, the smart village concept is adapted by the Ministry of Village through the "Smart Village" program. In practice, the implementation of this program refers to six dimensions, namely smart community, smart governance, smart environment, smart economy, smart mobility, and smart living [41]. The six pillars were established as an effort by the Ministry of Village to localize the goal points in the Sustainable Development Goals (SDGs) to the grassroots level of rural communities [42].

Many countries have accelerated village development through the smart village approach, but its progress in Indonesia has not been as progressive as in other countries, including India, Korea, and European countries [43,44]. In India, the smart village is a concept adopted by the central, regional, and local governments, focusing on holistic village development and referring to Mahatma Gandhi's vision of an ideal village and self-reliance [40]. In Korea, there are Kookdeok-myeon developed as a smart village by integrating ICT into renewable energy management, livestock farming, street lighting, and Muan-eup, which applies participatory community care service for elderly care and waste management [6].

Smart villages have been adopted in a number of other Southeast Asian countries, including Myanmar with a climate smart village (CSV) approach based on participatory action research (PAR) [45], Cambodia which began to examine the digitalization of agriculture and village development in support of achieving digital village [46], and Brunei Darussalam with the revitalization of Kampong Ayer (Water Village) as a tourism potential with strong historical and cultural values [47,48]. As shown in four villages in Myanmar [45], Ngouye and Daga-Birame villages in the Kaffrine region of Senegal [49], and Balikpapan, Indonesia [50], community participation is vital to the successful implementation of smart village, particularly in enhancing adaptation to climate change. Community involvement needs to be accompanied by local government facilitation in providing suitable policies in accordance with available local resources and regional characteristics [51].

There are variations in how smart village are being implemented around the globe. Smart village are frequently implemented to support traditional economies, such agriculture, in underdeveloped or developing Asian countries [52]. In order to preserve cultures and implement significant reforms at the village level, smart village development in African countries, such as Gabon and Botswana, places a strong emphasis on knowledge systems and indigenous traditions [53]. Electrification efforts to close the energy gap between urban and rural areas by providing off-grid energy [54] and local economic development by empowering village entrepreneurs and providing infrastructure [55] require attention in developing smart village.

Using ambient assisted living technology, smart village were developed in Europe to lower the risk of accidents for elderly residents living in rural areas [56]. The implementation of smart village in mountainous and foothill areas with geographical variations and socioeconomic characteristics, such as in the Holy Cross Mountains in Poland, requires good quality human resources as a driver of other resources, including finance, materials and information [57]. In the European Alpine Space, a digital platform tool enabling smart village was developed as an innovation to assist knowledge management and decision making for rural stakeholders [58].

2.4. Information and communication technology (ICT)

ICT refers to a variety of hardware, software, infrastructure networks, and media capable of processing, storing, and sharing information and communication, both between people and between computers, locally and globally [59]. The term "information technology" used refers not only to infrastructure and system components, but also the actual information and data content, as well as procedures that are the main criteria in achieving smart development [60].

Telecommunication systems consist of network infrastructure and infrastructure functions (content/application) [61]. Network infrastructure consists of telephone networks, internet networks, broadcasting networks, and converged networks. After the infrastructure is available, it is then utilized to improve the connectivity of various service needs, such as communication needs (telephone, fax, electronic messages, video calls), electronic media (information media, entertainment, persuasion), social-networking (Facebook, Twitter, e-mail), electronic transactions (online shopping, e-banking, e-ticketing), and public service facilities (e-education, e-health, e-government, e-budgeting).

The development and utilization of computers and ICT have a major impact on society, both in terms of economic management, production operations, and personal life (Zhou & Zhang, 2011 in Ref. [62]). In the 1970s, ICT utilization began with the use of telephones, then developed into the use of mobile phones in the 1990s [63], then the internet became known in 1989 [61]. In Indonesia, the development of internet utilization occurred around 1997–1998 which was marked by the proliferation of internet cafes (*warnet*) in several major cities, such as Yogyakarta, Surabaya, and Jakarta [63]. The use of ICT for regional development, especially in improving the connection between remote and border areas with the capital city through the availability of broadband networks, telecenters, virtual libraries, learning centers, and entertainment facilities so that the digital divide can be minimized [61].

With the development of ICT applications, such as the presence of more mobile cell phones and the use of the internet, it encourages easier communication processes, faster information transfer, and more efficient service improvements, such as the implementation of e-banking and online shopping in Indonesia [63]. This shows that the digital environment brings a rapid surge in growth at various levels, supported by digital networks, software, and new media (Sharma, 2014 in Ref. [64]). The presence of the internet and the World Wide Web (WWW) makes many physical systems and activities shift to cyber-physical [64].

3. Methods

3.1. Research location

The research is located in Indonesia, with the unit of analysis consisting of administrative village areas and traditional villages, also known by other names. This research refers to the division of Indonesia into 34 provinces. Villages located within urban areas were not included in the research delineation due to their status as urban village (*kelurahan*), so this research did not examine the Capital Region of Jakarta, whose entire administrative area consists of urban areas.

The villages within the research delineation are those in Indonesia that have been designated as smart village according to the Decree of the Head of the Village Development and Information Agency, Disadvantaged Areas, and Transmigration Phase I in 2021 and Phase II in 2022. Additionally, villages developed as smart village based on the exploration of journal articles, books, internet news (web browsing), and previous research reports are also included. The data is then input into ArcMap to determine the distribution of the locations of villages developed as smart village in Indonesia in the form of a map.

3.2. Data collection

The exploration of determining factors for the smart village concept in Indonesia uses data from Village Potential (*Potensi Desa*) in 2021. Village Potential data is collected by Central Bureau of Statistics (*Badan Pusat Statistik*/BPS) as a data collection of village potential throughout Indonesia in the form of questionnaires and stored by BPS at the district/city level. The results of this data collection are not entirely disseminated or open to the public, but can be found in several sections in the document of "Subdistrict in Figures" and summarized nationally in the document of "Indonesian Potential Village Statistics" published by BPS.

This data is secondary data based on conditions in 2020 and published in 2021. In order to make the resulting study representative in terms of both numerical and spatial data, the 2020 data was utilized to set up the availability of village administrative boundary data in Indonesia in 2020. Furthermore, 2020 was prior to the worldwide Covid-19 pandemic, thus community social activities—some of the variables in the factor exploration—tended to remain normal. Based on the Village Potential data exploration, 12 variables assumed to be related to the smart village concept were selected. The variables used are shown by Table 2.

3.3. Data preparation

Despite being the most comprehensive data source with village units of analysis, many variables from the Village Potential data collection are limited to nominal and ordinal scales. Given that factor analysis, the chosen analysis method, will provide better results on interval or ratio data, this condition influences the choice of variables that can be employed in the study. A phase of data preparation was applied to the selected variables.

The data preparation stages were carried out as follows. First, data selection, is selecting data that is considered relevant to the concepts used and discarding irrelevant data. Second, data transformation, is transforming nominal and ordinal scale data into interval/ratio scale data using Method of Successive Interval (MSI) and dummy variables. MSI is a data transformation method by converting the cumulative proportion of each independent variable into a curve value in the standard normal distribution [65]. In their research, data transformation from ordinal to interval scale using the MSI method resulted in the fulfillment of multiple linear regression model assumptions and a higher coefficient of determination. Data transformation using the MSI method was carried out on the variable of the highest education completed by the Village Head. Meanwhile, dummy variable is a categorical scale data transformation method [66]. Dummy variables can only be represented by the values "0" and "1", which a value of "1" for situations that are considered good and others are given a value of "0" [67]. Lastly, data accumulation, is the formation of a combined variable that represents the cumulative value. Data merging was conducted on the variable Number of types of community institutions in the village.

Before conducting factor analysis, standardization of data values was first carried out because the 12 variables used had different

Table 2
The determining variables for the smart village concept in Indonesia.

Variable	Code
Ratio of households using electricity to total households	Ratio_electricity
Ratio of people using cellular phones to total population	Ratio_phone
Number of mobile phone service operators covering most of the village areas	Operator
Mobile phone signal coverage in most of the village areas	Mobile phone_signal
Mobile phone internet signal coverage in most of the village areas	Internet_signal
Number of village information systems	Village_information system
Number of village financial systems	Village_financial system
Number of village regulations in 2020	Village_regulation
Number of village head regulations in 2020	VH_regulation
Highest education completed by the Village Head	VH_education
Number of village deliberation activities conducted during the year 2020	Village_delib
Number of types of community organizations in village	Comm_organization

Source: Selected from Village Potential data in 2021

units. Z score is one approach to converting raw scores from a group of data to create a composite value with the same units for all variables so as to provide an overall perspective [68].

3.4. Data analysis

Factor analysis aims to simplify a complex set of variables or items to explore the underlying dimensions of the relationship between multiple variables/items based on statistical procedures [69]. Factor analysis is carried out using SPSS software. The method used is Principal Component Analysis (PCA). This method aims to reduce the dimensionality of data without significantly reducing the characteristics of the data by maintaining as much variance as possible in the data set [70]. The PCA method is considered adaptive because in forming new variables, it is determined by the main components in the data set and is able to reduce the eigenvalue problem [71].

Factor analysis using the PCA approach is thought to be the most effective statistical technique for examining existing datasets. In addition to clustering using k-means, PCA is a component of unsupervised learning techniques [72]. PCA simplifies complex data by identifying a small number of principal components with the highest variance [73], whereas cluster analysis clusters data items with similar characteristics and features depending on their distance [74]. Both are used to find patterns in the dataset, but by maximizing variance, the PCA approach can create new variables (referred to as components) that are uncorrelated with one another [71].

Factor analysis has many advantages compared to other statistical methods, one of which is to produce factor scores as initial data for various other data analysis methods. Factor scores (FS) are composite variables that provide information about the positions of individuals on the factors formed [75]. The resulting FS on each factor formed will be multiplied by the percentage of variance in each factor. The formula used is as follows.

$$\text{weighted SV factor} = \text{FS x \% variance}$$

The calculation will produce a weighted factor value that shows the amount of factor contribution to the development of smart village in Indonesia. The factor with the highest value in each village becomes the dominant factor in smart village development in each village.

This study departs from the use of factor analysis in statistical processing of secondary data. Due to the absence of control over data

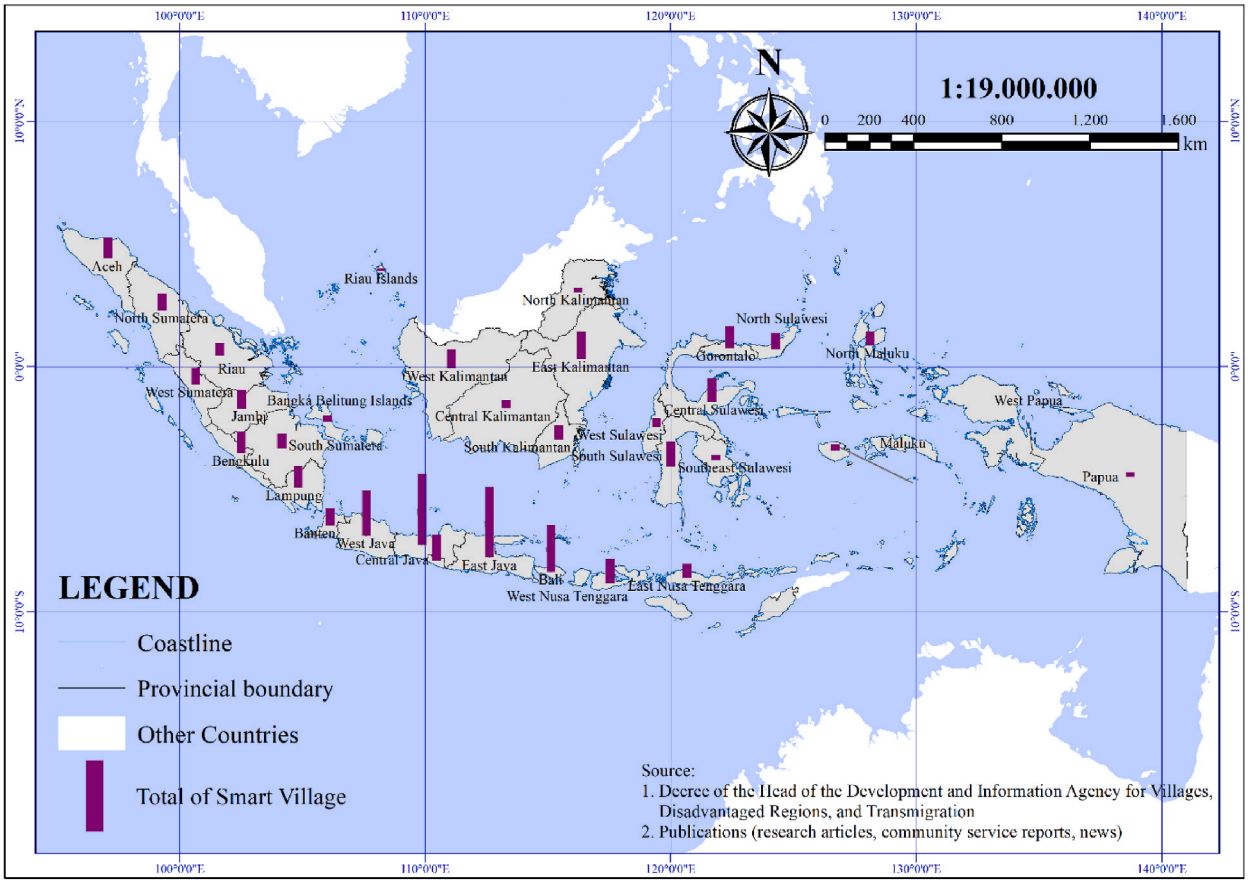

Fig. 2. Distribution of smart village in Indonesia by province. Source: Author's analysis (2023).

quality, a heavy dependence on secondary data—particularly government-collected data—can unavoidably result in bias [76]. To minimize the possibility of bias, the results of the quantitative analysis were supported by qualitative analysis in the following analysis. The determinant factors of a smart village will be demonstrated, clarified, and compared with the field's current circumstances and qualitative arguments drawn from the quantitative study. Furthermore, secondary data may not be able to give researchers all the information they require [77], which could lead to lack of comprehensive in some aspects and the need for additional data processing. After selecting factors that align with the smart village concept and taking the data scale into consideration, data processing is done to make the research findings representative and capable of addressing the goals of the study.

4. Results and discussion

4.1. Identification of smart village in Indonesia

Based on the identification results, there are 1.424 villages in Indonesia developed as smart village. The villages developed as smart village are distributed across 32 provinces in Indonesia. The region with the highest number of villages developed as smart village is in Central Java Province, with a total of 151 villages. Conversely, the region with the lowest number of villages developed as smart village is in the Riau Islands Province, with a total of 5 village. Fig. 2 shows the total of villages developed as smart village by province, with the details shown by Table 3.

The distribution of villages developed as smart village in Indonesia is more prominent on Java Island, particularly in the regions of Central Java and East Java provinces. On Sumatra Island, smart village are more concentrated in the central to southern parts. In Kalimantan, smart village distribution is observed in the northern, western, eastern, and southern parts. The number of villages developed as smart village in East Kalimantan Province is the highest compared to other provinces in Kalimantan Island, with 59 villages. This is indicated to be influenced by the designation of some areas of North Penajam Paser Regency and Kutai Kartanegara Regency as the Nusantara Capital City (*Ibu Kota Nusantara*/IKN). Both districts have the highest number of villages designated as smart village in East Kalimantan Province, with 20 villages each.

On Bali Island, there are quite a few villages developed as smart village, with a dominant distribution in the eastern and southern parts. On Nusa Tenggara Islands, more smart village are found in West Nusa Tenggara Province compared to East Nusa Tenggara Province. On Sulawesi Island, the distribution of smart village is in the southern, central, northern, and southeastern parts. In the

Table 3
The number of villages developed as smart village in Indonesia by province.

Province	Number of Smart Village
West Java	97
Central Java	151
Special Region of Yogyakarta	55
East Java	150
Banten	36
Aceh	45
North Sumatera	35
West Sumatera	35
Riau	26
Jambi	40
South Sumatera	32
Bengkulu	45
Lampung	46
Bangka Belitung Islands	15
Riau Islands	5
Bali	100
West Nusa Tenggara	52
East Nusa Tenggara	30
West Kalimantan	40
Central Kalimantan	18
South Kalimantan	30
East Kalimantan	59
North Kalimantan	10
North Sulawesi	35
Central Sulawesi	50
South Sulawesi	55
Southeast Sulawesi	10
Gorontalo	47
West Sulawesi	20
Maluku	15
North Maluku	30
Papua	10
West Papua	0
Total	**1424**

Source: Author's analysis (2023)

Maluku Islands, smart village are found in Maluku and North Maluku provinces, with 15 and 30 villages, respectively. On Papua Island, there are only 10 villages developed as smart village in Jayapura Regency, Papua Province, located adjacent to each other.

Based on the identification results, there are no villages developed as smart village in West Papua Province. The results of the Village Development Index recommendations for 2023 show that in the super priority category, out of 1.430 villages in West Papua Province, there are still 1.191 villages that require internet access at the village office and 963 villages that require internet access. There are only 239 villages that have fulfilled the need for internet facilities at the village head's office and 467 villages whose residents have internet access. This shows that there is still a need for equal distribution of infrastructure development, especially digital infrastructure and technology in all regions of Indonesia to support the implementation of smart village.

4.2. Exploration factor of smart village concept in Indonesia

Factor analysis was conducted on 12 variables from the Village Potential data in 2021 assumed to be related to the smart village concept. Data from 1.424 villages developed as smart village in Indonesia were used. Factor analysis was performed to reduce the number of variables and identify the main factors determining the smart village concept in Indonesia.

Table KMO and Bartlett's Test serve to assess the feasibility of a variable for further processing using factor analysis, as indicated by Table 4. The KMO MSA value is 0,636, and Bartlett's Test of Sphericity has a value of 0,000. Tested variables have a KMO MSA value greater than 0,5 and a Sig. Bartlett's Test of Sphericity value less than 0,5. This means that the variables used are suitable for testing, and factor analysis can proceed.

Anti-image Matrices table is used to determine variables suitable for use in factor analysis. Interpretation is based on the Measures of Sampling Adequacy (MSA) values. Communalities indicate the contribution of variables in explaining the formed factors, as shown by the Extraction values. Variables are considered capable of explaining factors if they have Extraction values greater than 0,5. The smaller the Extraction value, the weaker the relationship between the variable and the formed factor. The MSA and Communalities values shown by Table 5.

All the variables used have MSA values greater than 0,5, indicating that the variables are suitable for use, and factor analysis can proceed. Next is the Total Variance Explained, which indicates the value of each variable. There are several methods to determine the number of factors retained, one of which is the Eigenvalue rule of more than 1, which was proposed by Kaiser in 1960 [78,79]. This method is standard in SPSS software in determining the number of factors formed. Variables that have Total Initial Eigenvalues of more than 1 will be retained, while variables that have Total Initial Eigenvalues of less than 1 will not be included. This assessment is based on the assumption that variables with Eigenvalues of more than 1 account for more variance than a single item so it is advisable to combine these items into a factor [80].

It can be seen in Table 6 that of the 12 variables explored, it was reduced to 5 factors with an Eigenvalue of more than 1. The amount of variance that can be explained by the 5 factors formed is 55,546 %, as shown by the Extraction Sums of Squared Loadings. Meanwhile, Component 6 to Component 12 is not included as a factor because it has an Eigenvalue of less than 1. This shows that from the 12 variables used, 5 determining factors for the smart village concept in Indonesia are formed.

Component Matrix as shown in Table 7 shows the correlation value between each variable and the factors formed. The analysis was carried out by limiting the value of the factor loadings coefficient that appeared to a minimum of 0,5 to facilitate interpretation of the data processing results. Factor loadings are the magnitude of the correlation between the factors formed and a variable [68]. Various studies have shown that factor loadings greater than 0,5 provide better results and are statistically acceptable [81,82].

Unrotated component matrix shows factor loadings that are not perfect and difficult to interpret because many variables do not have a correlation with the factors formed, and there are no variables that correlate with factor 3. This happens because the factors formed serve to explain as much variance as possible, often placed on the first factor among independent groups of interconnected variables [83]. The provisional results show that the variable Number of mobile phone communication service operators that cover most of the village area is correlated with factor 1, the variable Number of village financial systems and Number of village information systems are correlated with factor 2, the variable Number of village deliberation activities conducted during 2020 and the highest education attained by the Village Head is correlated with factor 4, and the variables Mobile phone signal in most of the village area and Mobile phone internet signal in most of the village area are correlated with factor 5. Therefore, it is necessary to rotate to clarify and simplify the results of factor analysis [84].

The Rotated Component Matrix as shown in Table 8 shows the factor loadings of each variable which serves to determine the variables included in the factors that have been formed. Rotation is done around the origin until each factor is maximally collinear with a different group of factors [83]. The rotation method used is Varimax as one of the most popular orthogonal rotation methods [85]. Factor analysis using PCA with Varimax rotation makes factors easier to interpret because Varimax performs statistical inference [86].

Table 4
KMO and Bartlett's test.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0,614
Bartlett's Test of Sphericity	Approx. Chi-Square	947,809
	df	66
	Sig.	0,000

Source: Processed via SPSS (2024)

Table 5
MSA value on anti-image matrices and extraction value on communalities.

Variable	Anti-image Matrices	Communalities
	MSA	Extraction
Ratio_electricity	0,646	0,531
Ratio_phone	0,605	0,741
Operator	0,631	0,561
Mobile phone_signal	0,615	0,408
Internet_signal	0,637	0,559
Village_information system	0,549	0,692
Village_financial system	0,511	0,711
Village_regulation	0,680	0,465
VH_regulation	0,633	0,602
VH_education	0,664	0,480
Village_delib	0,647	0,475
Comm_organization	0,635	0,439

Source: Processed via SPSS (2024)

Table 6
Total variance explained.

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1917	15,972	15,972	1917	15,972	15,972
2	1356	11,299	27,271	1356	11,299	27,271
3	1275	10,628	37,900	1275	10,628	37,900
4	1096	9137	47,037	1096	9137	47,037
5	1021	8509	55,546	1021	8509	55,546
6	,936	7799	63,345			
7	,877	7311	70,656			
8	,793	6608	77,264			
9	,756	6301	83,564			
10	,728	6071	89,635			
11	,662	5514	95,149			
12	,582	4851	100,000			

Source: Processed via SPSS (2024)

Table 7
Component matrix.

Component Matrix[a]					
Variable	**Component**				
	1	**2**	**3**	**4**	**5**
Operator	,649				
Internet_signal					
Village_regulation					
Village_financial system		,773			
Village_information system		,645			
Ratio_mobile phone					
VH_regulation					
Village_delib				,521	
VH_education				-,503	
Ratio_electricity					
Mobile phone_signal					,732
Comm_organization					

Source: Processed via SPSS (2024)

4.3. Analysis of ICT as determining factor for shaping the smart village concept in Indonesia

A variable is included in a factor when it has a factor loadings value of more than 0,5. Each factor is then given a name that represents the set of variables forming the factor. The analysis is explained as follows.

Factor 1 is formed by the variables Number of village financial systems and Number of village information systems, then called as the **Factor of Information Systems Utilization in Government**. The Village Information System is a platform for village

Table 8
Rotated component matrix.

Rotated Component Matrix[a]					
Variable	**Component**				
	1	**2**	**3**	**4**	**5**
Village_financial system	,833				
Village_information system	,818				
VH_regulation		,680			
Village_regulation		,645			
Village_delib		,587			
Ratio_electricity			,762		
Ratio_mobile phone			,742		
Comm_organization				,638	
VH_education				,608	
Operator					
Mobile phone_signal					,844
Internet_signal					,571

Source: Processed via SPSS (2024)

governments to manage data and information supporting planning and budgeting in a data and evidence-based manner so as to encourage improvements in village governance [87]. One form of e-government in public services and village governance is through the use of village information systems [88]. Meanwhile, the Village Financial System (*Sistem Keuangan Desa*/Siskeudes) is an instrument from the Ministry of Home Affairs and the Financial and Development Supervisory Agency for village financial management, which has been regulated in Ministry of Home Affairs Regulation Number 20 of 2018 concerning Village Financial Management. The use of Siskeudes that utilizes ICT allows village governments to be more productive and innovative, increase service effectiveness, and provide efficiency in the decision-making process [89].

Factor 2 is formed by the variables Number of village head regulations in 2020, Number of village regulations in 2020, and Number of village deliberation activities conducted during 2020, then called as **Factor of Community Participation**. In Ministry of Home Affairs Regulation Number 114 of 2014 on Village Development Guidelines, village regulations are laws and regulations stipulated by the village head after discussion and agreement with the Village Consultative Body. Furthermore, in Government Regulation Number 43 of 2014 on the Implementation Regulations of the Village Law, draft village regulations are initiated by the village government, with the Village Consultative Body able to propose draft village regulations to the village government, and must be consulted with the village community for input. Meanwhile, the village head regulation is an implementing regulation of the village regulation. This shows the involvement of the community through a process of dialog and deliberation in determining the direction of village development policies. The existence of a village planning mechanism based on community aspirations and participation in the preparation of village regulations reflects the state's partiality in upholding village rights [90].

One of the keys to the success of smart village implementation is the active participation of the community and all stakeholders [43,91]. Community participation in the development process can be significantly enhanced through the role of ICT, which is able to bring together the community and the government [50,92]. This facilitation is done in various ways, such as using social media to share information, engaging in collaborative application development, empowering village websites, and organizing digital skills training [93]. Essentially, smart village need to emphasize the interaction between technological infrastructure and civic engagement [94]. However, it is not just about participating, but regularly participating to ensure sustainability [93]. Inclusive participation is also a concern, especially for vulnerable groups whose interests are often overlooked [95]. Developing a smart village requires active community involvement through community organizations or institutions that represent the interests of each group [96], which can be conveyed through the village deliberation forum.

Factor 3 is formed by the variables Ratio of families using electricity to the number of family heads and Ratio of residents using cellular phones to the total population, then called as **Factor of Community Interest in ICT**. Research by Ref. [97] shows that energy consumption increases along with ICT utilization. This is influenced by the energy source of ICT devices coming from electricity and not many alternative energy sources have been used. The massive use of smartphones facilitates the digitization process in the South Asia and Southeast Asia regions [98]. The use of smartphones for various daily activities is also supported by the increasing and improving availability of mobile internet services, driven by the Covid-19 pandemic that opens up digital connectivity [98,99].

Factor 4 is formed by the variables Number of types of community institutions in the village and the highest education completed by the village head, then called as **Factor of Leadership**. Research by Ref. [100] shows that the level of education of village officials has a positive and significant effect on the performance of village officials. Village heads need to have adequate education in order to be able to carry out their duties and obligations in village financial management [101]. Research by Ref. [102] shows that the education level of the village head in managing the Village Fund has a significant effect on the development of village status. The effectiveness of Village Fund management will increase, in accordance with changes in the average Village Development Index score, when the village head has an education above high school (diploma/undergraduate and postgraduate) [102]. Leaders have an important role in maintaining the sustainability and success of smart village development through charisma, integrity, innovation, consistency, and cooperation [103]. Leadership transformation is needed as a first step in implementing smart villages to be more disciplined, transparent, and innovative in improving the quality of public services [31]. Leadership types are proven to play a significant role in several

different aspects of rural digitalization in Hunan Province, China [104]. The implementation of cutting-edge technologies, such as blockchain and IoT technologies, also requires the role of local leaders to mobilize community support and participation [105].

Factor 5 is formed by the variables Mobile phone signal in most areas of the village and Mobile phone internet signal in most areas of the village, then called as **Factor of Communication Access Availability**. On a global scale, based on data compiled by Ref. [99], almost half the population in Asia Pacific is connected to the mobile internet. The mobile internet usage gap in the region has narrowed significantly from 60 % in 2017, to 47 % in 2022, indicating that there is increasing affordability of digital devices and skills. To support the availability of internet access and communication, the Indonesian Ministry of Communication and Information is building digital infrastructure to the frontier, outermost and disadvantaged areas with a target completion in 2023 [106].

Based on the five factors formed, it can be simplified into two main factors, namely ICT factors and internal village factors. The role of ICT can be seen in the Factor of Information Systems Utilization in Government, Community Interest in ICT, and Communication Access Availability. Meanwhile, internal village factors are indicated by Factor of Community and Leadership. This shows that ICT is not the only determining factor in the development of smart village in Indonesia, but other determining factors are also needed from within the village community itself.

The implementation of smart city and smart village, which is synonymous with ICT as the core of implementing smart concepts in regional development, in reality does not make ICT the exclusive and only criterion in the concept [33,107]. This finding supports the definition of smart village according to Refs. [26,27], where the development of smart village is built on community encouragement or initiative through optimizing the use of ICT. Implementation of ICT in smart village can focus on improving human resources to encourage village independence and innovation [10]. The description above also shows that building a smart village is not just about providing digital infrastructure, but needs to touch more deeply on the socio-cultural aspects of the community [108] which need to transform along with the penetration of technology in everyday life.

To find out the dominant factors that play a role in the development of smart village in each village, a calculation was made between the factor scores and the percentage of variance in each factor. Table 9 shows the number of villages in each dominant factor that plays a role in smart village development. The Factor of Information Systems Utilization in Government is the most dominant factor in the villages developed as smart village, which is found in 618 villages. In contrast, the Factor of Community Interest in ICT is the smallest dominant factor among the villages developed as smart village in Indonesia, which is only found in 35 villages.

The distribution of the dominant factors that play a role in the development of smart village in Indonesia is shown in Fig. 3. It can be seen that in almost all provinces, the Information Systems Utilization in Government is the dominant factor in the development of smart village. Only villages in Papua Province do not make this factor the dominant factor in smart village development. The high number of Information Systems Utilization in Government as the dominant factor in smart village development is influenced by the use of Village Information System, which has been mandated in the Village Law so that almost all villages in Indonesia have used it.

Other factors, such as the Community Participation, Leadership, and Communication Access Availability are equally present in almost all provinces. This shows that these factors have been present from the conditions and characteristics of the village itself and can support the development of smart village. Meanwhile, the Factor of Community Interest in ICT is only a dominant factor in several villages in West Java, Yogyakarta, East Java, Aceh, North Sumatra, West Sumatra, South Sumatra, Bengkulu, East Nusa Tenggara, West Kalimantan, Central Sulawesi, South Sulawesi, Gorontalo, North Maluku, and Papua. This shows that the Community Interest Factor in ICT is only found in villages with high demand or interest in using technology from the community.

The determinants of the smart village concept in Indonesia can be a reference in the preparation of the next smart village policy. The Information Systems Utilization in Government factor is the dominant factor owned by most smart village in Indonesia so that this factor can be optimized to improve the development of villages in Indonesia as smart village. There are several mechanisms for developing SID, either by the provincial, district or village governments themselves [87]. An example of SID developed by the provincial government is demonstrated by Aceh Province through the Gampong Information System (*Sistem Informasi Gampong*/SIGAP). The provincial government's approach to SID development provides an opportunity to integrate information systems from the village level to the province [87].

The factor of Community Interest in ICT is the dominant factor that is least owned by villages developed as smart village in Indonesia, but plays a major role in the development of smart village that are already in the high category. High community interest in ICT devices needs to be balanced with good digital literacy capacity and skills. The youth with their openness to technology have an important role in building smart village through strengthening digital literacy. Therefore, the quality of education and ICT literacy needs to be improved as the main points in smart village implementation [19,36]. The quality of human resources needs to be managed and developed through the implementation of talent management, especially village digital talent [109]. Greater participation in the use of digital tools will support the achievement of better digital literacy [110].

Table 9
The number of villages in each of the dominant factors that play a role in smart village development.

No	Factors	Total of Villages
1	Information Systems Utilization in Government	618
2	Community Participation	308
3	Community Interest in ICT	35
4	Leadership	195
5	Communication Access Availability	269

Source: Author's analysis (2024)

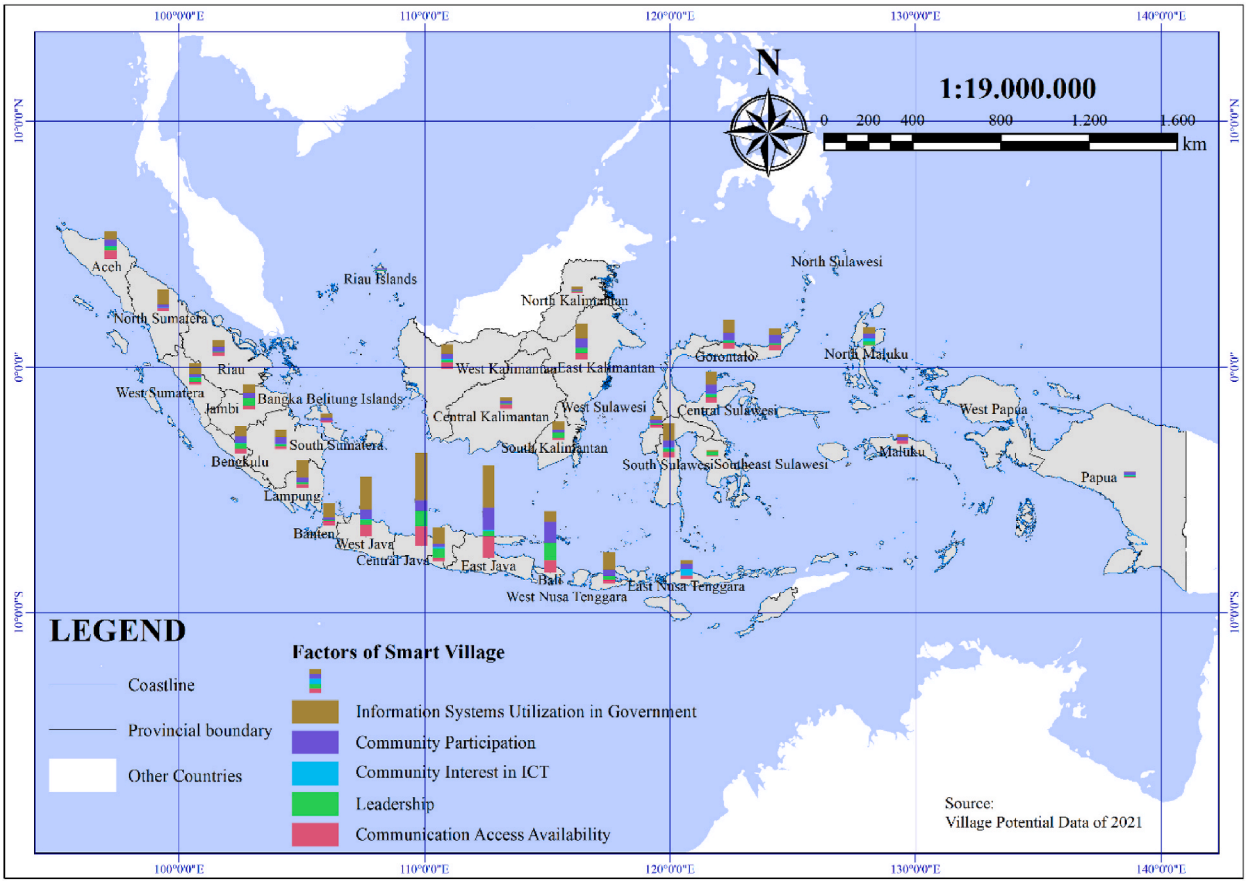

Fig. 3. Distribution of dominant factors that play a role in the development of smart village in Indonesia Source: Author's analysis (2024).

The current smart village development in Indonesia tends to be top-down with initiatives coming from the central and local governments. With the state of Indonesian villages, which still need knowledge transfer to fully implement the smart village idea, supralocal stakeholders' support is still required [111]. However, without independent initiative and involvement from village communities, village readiness is still low in supporting smart village implementation. Development plans designed by outsiders in a top-down approach risk that the activities implemented do not meet the real needs of the community [112]. Smart village should be developed by combining a bottom-up approach through village resources and local community knowledge, along with a top-down approach through the implementation of innovative policies from supra-village governments, according to the needs and conditions of each village [113]. Initiatives coming from the government act as a driver for community participation to be involved in village development activities towards smart village, until finally they have independent awareness and initiatives based on the characteristics of each village.

Banyuwangi Regency, East Java Province, is an example of smart village development that combines ICT and internal village factors, with a synergistic development direction from the regency government. As part of the "Movement Towards 100 Smart Cities", Banyuwangi Regency has been one of 25 pilot regencies/cities in Indonesia that adopted smart city concept from 2017. With the "Smart Kampung" program, which has been in place since 2016, Banyuwangi Regency leads the way in creating smart village that support smart city. The initiative to develop a digital-based Banyuwangi Regency came from the regent at the time [114], thus showing the role of leadership is very important in initiating the transformation of regional development.

The smart kampung program is implemented in public services and regional branding as an effort to achieve economic growth inclusively [115]. As a public service, smart kampung is developed as an integrated service portal that can be accessed online through https://smartkampung.id/. Improving the quality of public services is sought to achieve good governance [116]. The local government also involves state-owned enterprise in the telecommunications sector to participate in providing a comprehensive internet network [114]. As a regional brand, smart kampung has become a tagline to promote local tourism [117], including the customs and culture of the Osing tribe, which is promoted on social media [118].

Based on these findings, this study has answered the research question, with the significance of this study lying in the exploration of factors that shape the smart village concept based on empirical conditions in Indonesia and emphasizing the role of ICT in smart village development. This research is a pioneer in examining factors related to smart village implementation based on data within a region so that it can serve as a reference for future research. According to the findings, ICT generally acts as a catalyst for advancements in smart

village development [31], meaning that community participation as a subject and object of development is still required. The ICT factor in the smart village concept has a positive and significant correlation with the village development outcome in Indonesia, particularly for villages outside of Java that suffer from low population density and spatial inefficiency [119]. These results also support the findings of [21,52], that the conceptualization and implementation of smart village in villages in Asia and developing countries still do not focus on the dominance of ICT, but rather emphasize the utilization of existing resources, namely people and nature in the agricultural sector.

5. Conclusions

There are 1.424 villages in Indonesia that have been developed as smart village until 2023. The villages developed as smart village are distributed across 32 provinces in Indonesia. Only West Papua Province does not yet have a smart village. This shows that there is still a need for equal distribution of infrastructure development, especially digital infrastructure and technology in all regions of Indonesia to support the implementation of smart village.

From the 12 variables explored, five determining factors shape the concept of smart village in Indonesia. These factors are the Information Systems Utilization in Government, Community Participation, Community Interest in ICT, Leadership, and Communication Access Availability. It shows that ICT is one of the determining factors in the smart village concept in Indonesia through the utilization of village information systems in government, community interest in ICT, and the availability of communication access. However, ICT is not the only determining factor, but there are also internal village factors, namely community participation and leadership, that play a role in the development of smart village in Indonesia.

The Factor of Information Systems Utilization in Government is the dominant factor that is most widely owned by smart village in Indonesia, influenced by the use of Village Information System which has been mandated in the Village Law and almost all villages have used it. Therefore, this factor can be optimized to improve the development of villages in Indonesia as smart village. High public interest in ICT needs to be accompanied by the development of digital literacy capacity and equal distribution of infrastructure in all regions. However, not only strengthening the ICT side, but also paying attention to the socio-cultural conditions inherent in the village area through the role of leaders, both village heads and regional heads, who have political will in policy making and mobilizing inclusive community participation.

This research provides novelty in research on smart village, by collecting location data of villages developed as smart village and generating empirical determinant factors of the smart village concept, specifically with condition in Indonesia. It is hoped that the results of this study can serve as a theoretical reference for the smart village development policies in the future. The implications of these findings for the next policies are the importance of paying attention to the conditions of the community as actors and aims of development in the village, accompanied by the government's ability to provide adequate infrastructure, both physical, social, and regulatory. The realization of urban-rural linkages needs to be made to ensure the success of smart village implementation.

This study can be said to be the first to examine the role of ICT in the development of smart village, along with investigating the role of other factors that contribute to it. This study fills the gap in previous smart village studies, which focus on describing the implementation of smart village in various fields and compiling smart village models or dimensions based on various methods.

There are several limitations in this study, including being influenced by the use of secondary data that has limitations in the flexibility of variable types, predominantly quantitative analysis, and a very large regional scope in one country. This causes this study to not be able to flexibly describe the actual social, cultural, and economic conditions of the community, and does not represent the diversity of development levels between regions in Indonesia. However, this research does aim to provide an overview of the determinants of the smart village concept in Indonesia. Further research can examine this study in a smaller area at the province, regency, or comparing between two regions (Java and outside Java Island) to provide a more specific development analysis. Case study method can be used for further research, supplemented by primary data based on smart village determining factors generated from this study. Next research will also examine the impact of smart village development on social, economic and ecological aspects.

The findings of this research also suggest that smart village initiative does not revolve solely around the use of ICT, but rather encompasses many other factors, especially the capabilities of the community and the condition of village resources. The complex issue of village development requires a multidisciplinary approach to smart village development to accommodate all existing potentials and problems. Many aspects of the smart village initiative can be studied and explored in the future as an effort for village development to achieve national development.

CRediT authorship contribution statement

Anindya Puteri Eka Susilowati: Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Rini Rachmawati:** Writing – review & editing, Supervision, Methodology, Conceptualization. **R. Rijanta:** Writing – review & editing, Supervision, Methodology, Conceptualization.

Data availability statement

Data will be made available on request by contacting the corresponding author.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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