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A cloud GIS-based framework implementation in developing countries

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ABSTRACT

Cloud computing technology has successful cost savings, business effectiveness, and higher scalability in various fields, including the government field. The pandemic Covid-19 era has been accelerating the adoption of cloud technology; the enterprises have instructed the employees to work from home to reduce transmission. The cloud-based framework for government in developing countries was developed. However, it was arduous to apply in Indonesia as a developing country, especially in areas where technology infrastructure, human resources, and funding are insufficient. Thus, the study of the cloud implementation framework in developing countries is essential. This paper used the enterprise architecture planning method for designing a cloud GIS-based framework. The developed framework successfully implemented the cloud-based GIS technology in Indonesia with limited ownership and infrastructure of technology, resources, and funding.

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1. INTRODUCTION

Cloud computing technology has success costs savings, business effectiveness, and higher scalability in various fields significantly, and one of them is the government [1]–[9]. The government's priority service is providing technology services that are easy to access, cost-effective, efficient, and timely. And sometimes, the high cost is not an obstacle if it offers significant benefits to the community [2], [10], [11]. On the other hand, the community desperately needs accurate, reliable, and timely information that can be accessed anywhere and anytime to support daily activities [12].

The infrastructure and technology of the cloud are commonly used in government activities considering efficient response times, low costs, and technology solutions in developed countries [11], [13], [14]. Cloud computing plays an essential role in the new era of public service and infrastructure provision. Cloud-based features such as on-demand services, broad network access, and rapid elasticity make government services great and affordable [1], [6]. Cloud computing provides a diversity of services for various industries, large companies, and even governments. Complex problems can be solved by leveraging the latest technological solutions such as data mining, knowledge management, and big data as part of cloud

computing [3], [11]. Cloud computing solutions are generally used for large-scale data storage, application processing, and information sharing cost-effectively compared to other technology architecture solutions currently available [2], [4].

Various problems constrain cloud technology in developing countries, including infrastructure, human resources, security challenges, and technology transfer to cloud adoption [7], [15]–[17]. In some developing countries, cloud technology is limited for the public sector because of a lack of education, income, and age as significant predictors of access to technology [18], [19] and limited access to computers and the internet infrastructure for specific communities [18].

The era of the Covid-19 pandemic has an enormous disadvantageous impact, but also give benefits in accelerating new technology adoption, especially cloud computing [19], [20]. The enterprises or government instructed the employees to work from home to reduce transmission [19], [21]. Almost all sectors, including small, large enterprises, health care, education, and governments, have been forced to change their work approach and business processes. Dependence on the virtual world is getting higher in supporting daily activities. With the pandemic, the demand for online services is increasing rapidly, and the requests for digital services are getting higher [19]. Various online services introduced worldwide make it easier to support work activities, but this needs time to adapt, especially in some developing countries. In decision-making, information is more accurately depicted in a map and easy-to-digest visualization of the Geospatial information system [5], [22]–[24].

The cloud-based framework to support government activities in developing countries was developed [1], [5]. Previous research has proposed the integrated geographical information system (GIS) and hybrid cloud computing framework. This framework collaborates cloud computing concepts to overcome the shortcomings associated with desktop GIS, including high startup costs and storage capacity and provides features accessibility of location independence that can be accessed anywhere and anytime. However, it was severe to apply in some areas of Indonesia as a developing country, especially in areas where technology infrastructure, human resources, and funding are insufficient. The previously developed frameworks require a high mastery of technology so that qualified resources are needed to implement it. In terms of financing, some of the applications developed require paid software which requires a fee to pay for the license for the application. Last, some remote areas have limited technology infrastructure. These facts will be the obstacles to the successful implementation of cloud technology in developing countries. Thus, the study of the cloud implementation framework in developing countries is essential. This paper will discuss a framework that integrates GIS and cloud computing based on cheaper open-source technology that can be implemented in all regions in Indonesia, especially in the government sector.

2. RESEARCH METHOD

2.1. Research method

The research method is a literature review, interview & observation, case study, data collection, data analysis, framework design, system design, application design, and evaluation. The literature review focuses on cloud computing issues in government application [2], [6]–[8], [10], [13], [14], [20], [25], [26], a framework for cloud computing in developed countries [1], [5], [27], and GIS for the enterprise [22], [28].

Today, the choice of cloud computing has grown exponentially in a developing country. Enterprises in the region use cloud computing to provide elevated standardization of their IT infrastructure and the cost-effective delivery of technology solutions. The advantage of using cloud computing in government sectors [20]: i) Reducing costs associated with upgrading legacy technologies; ii) Boosting the agility of governments to respond to the needs of communities and businesses; iii) Improving resilience and recovery capabilities pandemic events; iv) Ensuring that the public sector's human resources keep up with technology development.

GIS is an integrated system of hardware, software, data, method, and people. Moreover, the GIS-based cloud or web GIS has been an approach to upgrade the conventional GIS applications to provide comprehensive services to users across the globe. Web GIS capabilities and services are combined on a cloud infrastructure called GIS Cloud [29]. An example of a GIS cloud is Google map which combines maps, satellite imagery, other geospatial data and presents an application programming interface (API). Another example is ArcGIS Server which allows the deployment of web GIS or GIS Servers. The GIS-based cloud has advanced capabilities in collecting, processing, analyzing, and publishing geospatial data. Most of the mature GIS cloud application is not free and sometimes is expensive for a particular area or region in Indonesia. So if the user is concerned about low-cost services, they can develop their GIS-based cloud or web GIS using open-source software.

Interviews were conducted with the users to get their adoption point of view on the challenge and barriers of cloud computing technology implementation, current problems, and solutions to those problems.

Observations were made to analyze the results of interviews with facts on the ground. After that, particular case studies are determined to be applied in a cloud computing application as a pilot project. Data collection is carried out for a predetermined case study, various data formats have been collected related to the case study. The data consists are non-digital or digital tabular data and spatial data. The non-digital tabular data was converted using the digitation or rectification method. Then converted to spatial data format and join with tabular data. All of the data is stored in a folder. Finally, all data is ready to be standardized spatial data.

The analyzed data was done for collecting data for a particular case study. The data analysis is carried out to design a spatial database system and choose and adopt cloud computing and spatial database technology. The priority of selecting database technology is open-source, which does not require a license. Framework design uses enterprise architecture planning to get a structured diagram that helps organize data and conceptions of a problem to do it more effectively. System design focuses on the various stages of system design, database, and application architecture. Application design focuses on the stage to build the Web GIS and geodatabase application cloud-based. After building GIS Web applications and geodatabase, it was evaluated to assess the satisfaction of what to expect. Furthermore, if there is a shortage, it can be done earlier analysis stage.

2.2. Cloud computing

Cloud computing is a concept in which an organization can "plugin" to a virtual environment and use available computing resources as needed. Applications running on these platforms can be accessed via a web client, while application software and data are stored on the server-side. Scenarios are application components, which are dynamically selected from a pool of services and the coordination. Computation was performed in the cloud, on the client-side, or both. Cloud computing has five key characteristics (on-demand self-service; rapid elasticity; location-independent pooling of resources; ubiquitous network access; and pay-per-use), three cloud computing models, namely software as a service (SaaS), platform as a service (PaaS), and infrastructure as a service (IaaS). Its application can be private, public, community, and hybrid [30].

SaaS enables consumers to deploy applications running on cloud infrastructure. Applications can be accessed from multiple client devices through the web browser, smartphone, PC, laptop, or a program interface. Consumers are limited to control the cloud infrastructures such as operating systems, networks, servers, storage, or application configuration settings. PaaS enables consumers to deploy acquired applications created into the cloud infrastructure by the provider's libraries, services, and instruments. The consumer is limited to managing or controlling the cloud infrastructure, including operating systems, network, servers, or storage, but presides the deployed applications, possibly configuration for the application-hosting environment settings. PaaS allows consumers to provide processing, storage, networking, or primary computing sources where consumers can use and run optional software, including operating systems and applications. The consumer is limited to control the cloud infrastructure, but can handle storage, operating systems, deployed applications, and probably limited control of specific networking components.

Now, cloud computing is significantly solving obstacles in an extensive range of different sectors. It became easier to handle a massive amount of data and services with cost-saving using the utility of pay-as-you-go (PAYG). It is easier for the customer to scale up or scale down, customize, and reserve computing resources, including software, storage, and development platforms where the resource charges are based on the used services. Cloud computing furthermore provides access to these data and services without time or location reliance [5].

The adoption of cloud computing is not easy, especially in developing countries. A study by Gartner discovered that interests in data privacy and security as two of the top barriers to cloud adoption in the public sector [31]. In the cloud, cloud services must recognize the behavior of users to prevent the potential disclosure of sensitive data to unauthorized persons [32]. For security reasons, data classification is a tool that governments can use to assign various security models to different categories of data based on their perceived risk impact (the criticality or sensitivity of data). Data classification for security reason is shown in Table 1. Data with a high level of sensitivity is usually a small amount and can be handled by a private cloud. Meanwhile, the public cloud model can handle data with low sensitivity levels that are generally massive.

Table 1. Data classification and government data [20]

Data classification type	Amount of government data	Cloud deployment
Low sensitivity	High	Public cloud
Medium sensitivity	Few	Hybrid cloud
High sensitivity	Rare	Private cloud

2.3. Case description

The case study was conducted in South Ogan Komering Ulu regency, located in South Sumatra Province shown in Figure 1. South OKU regency is 260 KM from the center of the provincial capital and 358 KM from the Indonesian capital. Geographically it is located 103º 22'-104º 21' East Longitude and 04º14'-04º55' south latitude has an area of 5493.94 Km^2 [6]. As an area far from the national and provincial capitals, the available information technology infrastructure is also limited. It has been a challenge in implementing cloud computing in government activities. The topography of the South OKU Regency is primarily hilly and mountainous highlands. The altitude ranges from 45 to 1,643 meters above sea level (masl), with the spread concentration of settlements over several sub-districts, low density.

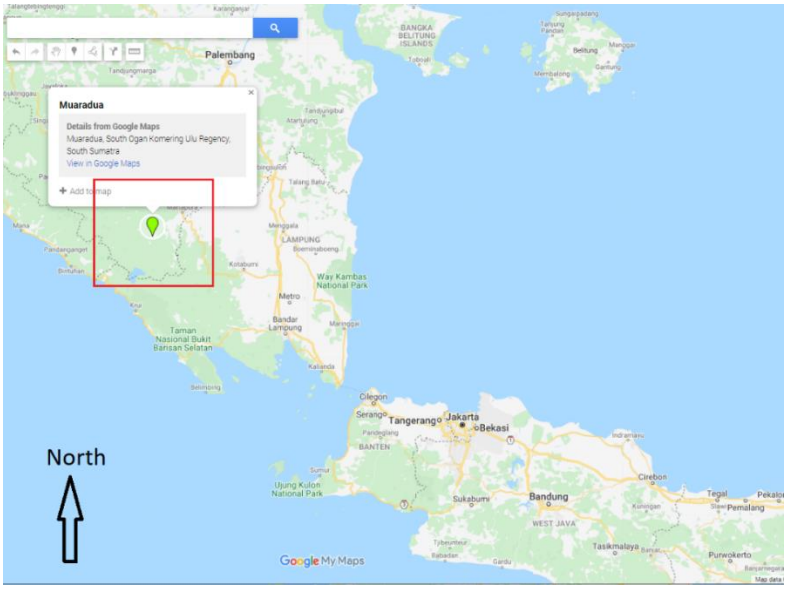


Figure 1. South OKU map location

Interviews and observations were conducted at the Regional Planning and Development Agency and Research and Development. This agency was chosen because it is an excellent center for data processing in South OKU Regency. So, the framework implementation in the agency chosen can be applied to other agencies in the future. The interviews conducted in South OKU Regency were related to the available technology infrastructure, the applications used, and the existing human resources. Questions about the currently available technological infrastructure relate to the internet network, servers, and storage. Questions related to the application used are associated with GIS applications in spatial analysis activities for daily activities. Questions about human resources are whether particular employees manage networks, spatial databases, and operators or analysts who specifically operate GIS applications. The result of the interview and observation is shown in Table 2.

Table 2. The maturity about infrastructure, application, and human resources

Question	Low	Moderate	High
IT infrastructures	V		
GIS application	V		
GIS human resources	V		

2.4. Enterprise architecture planning

The data collected is a particular case study that will be analyzed and used as a reference in developing a cloud-based GIS framework. The data collected with a specific thematic is obtained in various formats, ranging from hardcopy, digital, image, and spatial data already in digital format. Identifying of the collected data is vital to creating the system design, shown in Table 3. In the era of information technology, a system that provides fast and accurate data and information are necessary for government and society. Currently and in the future, there is a need for data that can be accessed quickly, anywhere and anytime,

accurate and integrated, responsive in adapting to changes, and easy sharing or accessing. A good information system is an information system that can produce good quality data and information that supports decision-making systems. To produce quality data and information requires meticulous planning. enterprise architecture planning (EAP) is an approach to produce quality data and information in the information systems planning.

EAP defines the architecture to optimize information to support business processes and plan to implement the architecture. The main components of EAP are architecture and planning. Architecture can be the form of blueprints, designs, or models. The architecture in EAP is divided into three parts: data, applications, and technology architecture. As well as in the architecture also defines planning so that the EAP can be implemented in an organization correctly.

Data architecture aims to define and identify data related to the database system model to be built. It's the first stage in EAP because quality data is the main foundation in developing information systems/database systems. Data is the basis for the physical, logical design and implementation of the spatial database system. Data architecture is related to a conceptual data model, conceptual schema, conceptual database design, enterprise data model, global data model, object definition, logical data model, and information model [33]. The steps in the data architecture stage are as follows: i) create a list of candidate entities; ii) define entities, attributes, and relationships; iii) relate entities into business functions; iv) istribute data architecture from data collected

Excellent data analysis will provide suitable identification and definition, resulting in a good database system model built. In the era of the data paradigm, data is very decisive in developing applications needed to support information needs for an organization. Then data is classified using a decision tree method to create an appropriate classification. The data classification was used as a reference in the spatial database system design. The application architecture defines the applications needed in management and analysis data to support the information needs of an organization. Technology architecture discusses matters related to planning, designing, and implementing spatial database systems.

Table 3. Summary of data collection format

Name	Format	Type
Regency administration	shp	spatial
District administrations	shp	spatial
Province road	shp	spatial
District road	shp	spatial
Local road	shp	spatial
Land cover	Shp	spatial
Infrastructure	shp	spatial
Infrastructure description	Excel	Non spatial
Infrastructure photo	Image	Non spatial
Road photo	Image	Non spatial
Work program	Excel	Non spatial

3. RESULTS AND DISCUSSION

During a time of accelerating digital transformation and fast adoption of the digital era, the government is adjusting to the new paradigm brought by the coronavirus disease (COVID-19) pandemic. Internet and digitally connected communities demand the best and fastest service from their government to support their businesses with the latest digital tools. Governments worldwide respond to the change by modernizing their services, improving their data analytics capacities, and realizing digital economy development plans.

The era of the Covid-19 pandemic has forced the adoption of cloud technology. The use of cloud computing significantly increases the volume, speed, variation of data generated in the world of several applications and services. Those data are classified as structured, semi-structured, or unstructured data. Data is stored in various formats that are not easy to integrate due to the size and speed of data flow [34]. A digital transformation era needs fit technologies, while the present abilities might not advise them well. Organizations require to control the challenges associated with big data to persist in the new digital era.

To successfully design and implement cloud-based GIS framework implementations, this adopts the framework for cloud migration by Frost and Sullivan [9]. There are three-stage in this framework are identify stage, implementation stage, and improve stage. The identify stage is to determine which can be private and shared with the public. The implement stage is to aggregate the demand of users and ensure to integrate the existing infrastructure. Moreover, the improve stage clearly conveys the successes and failures to the user, as shown in Figure 2.

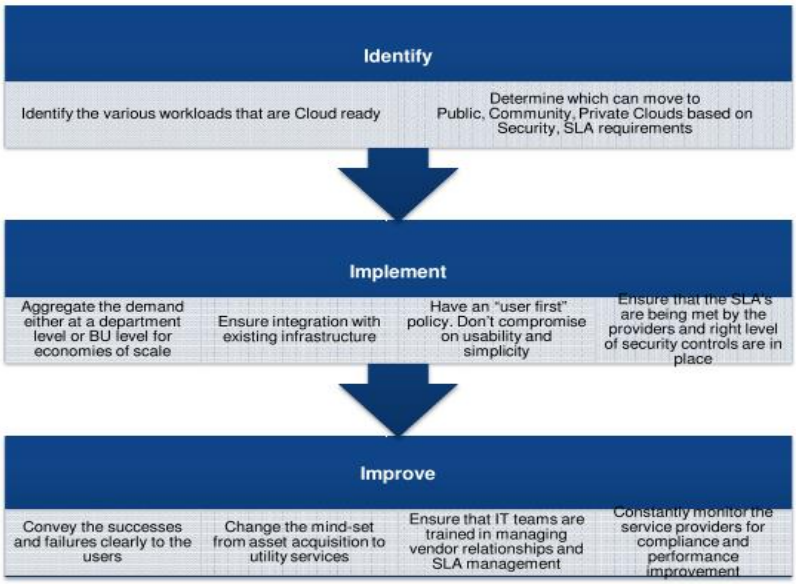


Figure 2. A framework cloud migration [9]

The identification stage is used to determine the existing conditions to determine the supporting and inhibiting factors in cloud computing implementation. The method used in this stage is interviews and observation of the study location to find more details and facts about the success of cloud computing implementation. The data and information generated in this stage is the primary key to building a framework using EAP. The implementation phase is carried out for alignment and integration between business processes and existing infrastructure with business processes and infrastructure planned to be implemented. After the framework is built and tried to be implemented in new business processes, the existing functions and benefits or shortcomings can be seen to be evaluated and improved. The results of data from the interview and observation analysis show that the readiness of infrastructure, technology, human resources, and financing is at a low level. However, if implemented cloud-based using the previous framework [1], [5], it seems extremely hard to implement because the three main success factors in the case study are not enough to support implementing these frameworks.

First, the technology infrastructure in the case study area is limited to meet the requirement of these frameworks. The area study has limited infrastructure such as computer server infrastructure and network infrastructure. Second, there are no human resources are mainly work as the network and gis application specialists. Last, it is not easy to buy expensive software licenses for web gis server application and desktop gis in terms of limited financing. Need modifications or redesign from the previous framework to be implemented by adjusting the South OKU Regency condition. One of the solutions to these problems is selecting open source technology as an alternative in developing a cloud-based gis. By utilizing cloud technology, gis functions can be implemented properly according to user requests, making daily work easier. Regarding the COVID-19 pandemic, where employees have to WFH, the resulting cloud technology implementation framework can be an excellent alternative to encourage the rapid adoption of technology. Moreover, to keep developing the effectiveness of work without being interrupted by the pandemic. Cloud technology allows work anywhere and anytime by connecting to data and applications using the internet network.

There are two main parts in the framework, namely on the client-side and the server-side. Three interfaces are used to communicate with data and applications: Web GIS, Desktop GIS, and spatial database interfaces. On the server side, spatial database servers and backend applications are using an open-source platform. The open source reduces costs during application development and implementation. The database applications used PostgreSQL as an open source relational database system that is reliable in managing and storing complex data, one of the most famous is excellent spatial data management. And one that makes it reliable in managing spatial data is the PostGIS extension, which provides the primary support in managing geographic or spatial data.

In the backend applications used GeoDjango as a module of the Django framework specifically made for creating web applications to manage or display spatial data in web GIS. Django is a programming framework based on the Python language. With ease and open source, it is hoped that the development or implementation of the framework is easy and possible to be applied in areas with limitations in purchasing software licenses.

On the client-side, to display spatial data in the form of web gis using OpenLayers, renders spatial data from PostgreSQL converted in GeoJSON format. To display, access, and manage data in desktop mode using open-source desktop GIS software QGIS as one of the leading in spatial data processing currently available. PgAdmin or PostgreSQL Maestro software is reliable for data and user management in management, data management, and users on the client-side. Finally, and most importantly, besides being reliable, it is open source. The proposed framework is shown in Figure 3.

Based on the framework that has been built, then create a spatial database and application for case studies in spatial infrastructure data of South OKUS. The spatial database and application could be accessed through several media: personal computer (PC), tablets, and smartphones. The ease of access from several of these devices is simulated. Where in the field, you can input data with a smartphone or tablet, or PC. Then for the leveraging stage, it is done using QGIS as an open-source desktop GIS Figure 4(a). And the information is displayed to the public using web GIS in Figure 4(b). And for managing data and users used by PgAdmin shown in Figure 4(c).

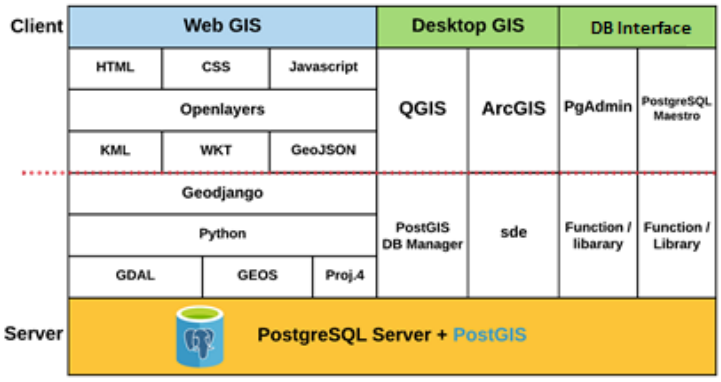
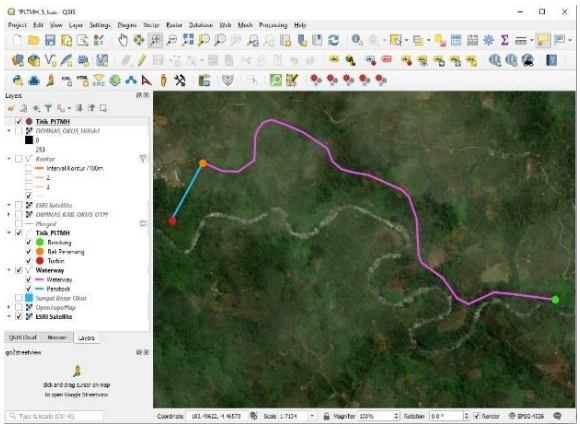
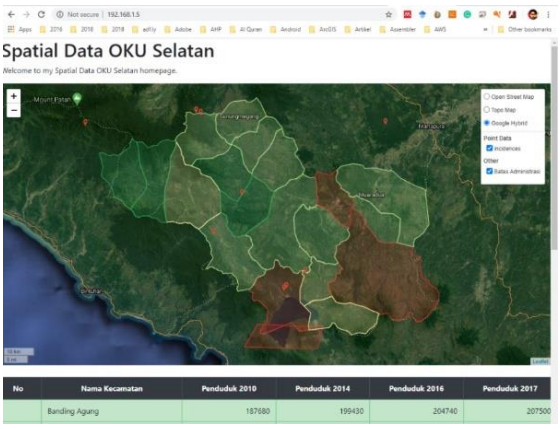


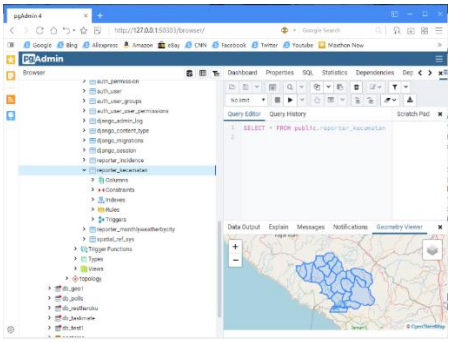
Figure 3. A cloud GIS-based framework proposed



(a)



(b)



(c)

Figure 4. The applications interface (a) QGIS interface, (b) web GIS interface, and (c) spatial database management interface

One of the main points used in the design of this framework is the use of an open source in cloud technology implementation because one of the success factors for implementing cloud is in areas with limitations in infrastructure, human resources, and financing.

With the developed framework, it is easier to apply in these areas because it is cheaper financing. However, even though it is more affordable, it is not inferior in terms of features or capabilities compared to non-open-source technology. With cloud computing technology, it is still possible to stay productive during a pandemic because it can still be accessed from anywhere and anytime as long as it is connected to the internet.

4. CONCLUSION

The framework has been designed using EAP method, which is the main point to note is that it is based on open source. In this framework on the server-side and client-side using open-source software. PostgreSQL and PostGIS for spatial database management, GeoDjango for creating web applications to manage or display spatial data in a web GIS, and QGIS as open-source desktop gis used for visualizing and managing and spatial data analysis. Based on the framework that has been built, a spatial database and application were successfully implemented, which can be accessed by a smartphone, PC, laptop using the internet connection anytime and anywhere. Based on the framework in obstacles in the implementation of cloud computing, especially the limitations of infrastructure and costs can be minimized.

For further research can evaluate performance such as speed, security, and readiness of the system's adaptation, which is not done in this research. It is hoped that the framework created can be implemented in various regions in Indonesia as a developing country.

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