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Application of Geographic Information System (GIS) in PT Pesona Khatulistiwa Nusantara Community Empowerment Initiatives

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Abstract: PT Pesona Khatulistiwa Nusantara (PT PKN) has implemented a Geographic Information System (GIS) to advance its Community Development and Empowerment Program (PPM) and strengthen Corporate Social Responsibility (CSR) practices in pursuit of sustainable development. The system facilitates interactive mapping, spatial data administration, and digital dissemination of PPM activities across education, health, economic, and environmental sectors. The research adopts a qualitative approach combined with Agile development methodology, executed through four sprints between February and May 2025. Development stages encompass user requirement identification, interface design, system construction using Laravel and Leaflet.js, and phased testing through functional and acceptance trials. Eight location points and four program categories were successfully mapped, with usability testing involving ten users yielding favorable outcomes regarding system performance and user experience. Results indicate that GIS integration decreased average information retrieval time from nine minutes (manual reports) to under three minutes while expanding public access to program data. The PPM GIS strengthens transparency, enables participatory monitoring, and supports evidence-based program planning aligned with community needs.

Keywords: Geographic Information System; Community Empowerment; CSR; Participatory Mapping; PT Pesona Khatulistiwa Nusantara.

1. Introduction

Innovation that is based on technology is increasingly considered a prerequisite for achieving sustainable development. Companies around the world have begun to realize that technological progress should be directed not only toward economic growth but also toward social and environmental dimensions. PT Pesona Khatulistiwa Nusantara (PT PKN), a coal mining company in Kalimantan, has made an effort to improve the welfare of the surrounding community through its Community Development and Empowerment Program (PPM). This program focuses on four main aspects: education, health, economy, and environment, in line with corporate social responsibility (CSR) and Sustainable Development Goals (SDGs). Mining activities will always have impacts on communities and natural resources nearby, bringing both opportunities as well as challenges for regional development. To respond to such dual impacts more effectively, PT PKN has shifted from the traditional charity approach to a more systematic and data-driven community engagement strategy. The company understands that sustainable mining practices require investments in building community capacity and transparent communication with stakeholders, beyond mere compliance with regulations.

PT PKN has embraced Geographic Information System (GIS) technology as an innovation strategy to facilitate PPM activities. GIS is an information system that provides digital visualization and analysis of geographic data [1]. By adopting GIS in PPM, the company can manage, monitor, and evaluate geospatial data more effectively [2][3]. The location of the program, the beneficiaries, and the indicators of progress can be mapped and analyzed in real time so that interventions are more focused and measurable. This kind of accuracy is very useful in remote areas where traditional monitoring faces logistical problems and resource constraints. The spatial aspect often gets inadequate attention in community development programs when managed conventionally. Programs may geographically overlap creating redundancies or leave some areas unserved due to poor spatial planning. GIS technology fills these gaps by visually representing program distribution; managers can then see where coverage gaps exist optimize resource allocation ensure equitable service delivery across different communities.

Apart from functioning as a digital map, the GIS acts as a communication medium by disseminating articles, documentation, and news about PPM activities. This enhances transparency and increases the public's access to information about the program, enabling stakeholders such as communities, government agencies, and civil society organizations to engage more in monitoring and feedback activities. When information accessibility determines public trust, digital platforms are the bridges that link corporate objectives with community aspirations. The participatory approach of PT PKN ensures that program design meets real community needs determined by field consultations and shared planning. Instead of imposing solutions in advance, the company enlists local leaders and beneficiaries alongside civil society representatives to assess needs and shape programs. As a result, PPM initiatives become increasingly adaptive and effective while reducing gaps between corporate initiatives and community expectations. The combination of technology integration, transparency, as well as participation places the PPM GIS at a sustainable model for long-term collaboration between companies with local communities which will serve as a precedent for responsible mining practices not only in Indonesia but also elsewhere around the world.

2. Related Work

Geographic Information Systems have become important instruments in the implementation of programs for sustainable development and community empowerment. The literature has documented the use of GIS as an appropriate tool in various fields, especially those related to spatial planning and analysis, decision support systems, and monitoring and evaluation of programs. Riwayatiningsih and Hartuti Purnaweni in their research on the use of GIS in tourism development found that GIS enables users to better understand geographical conditions to make more accurate decisions [2]. In the economic field, Deddy Ackbar Rianto, Setiawan Assegaf, and Erik Fernando created an Android-based GIS application used for mapping minimarket locations in Jambi City; this application was able to increase the efficiency of searching for business locations by providing fast and accurate spatial information [3]. The results of these studies prove that GIS technology can change the way data is managed from conventional methods into dynamic systems with spatial awareness capabilities so that they are able to support better resource allocation as well as strategic planning in various fields.

The application of GIS technology is also widely used in environmental management and disaster risk reduction, where spatial analysis is very important to assess risks and find solutions. Goodchild stated that GIS plays an important role in managing spatial data related to sustainable development and public policy planning [4]. Chamara (2022) demarcated village boundaries using participatory GIS (PGIS) in Sri Lanka; this study proved that PGIS has great potential for community-based local planning with a strong focus on transparency and stakeholder engagement [5]. In corporate initiatives, Jang Won Suh (2020) showed how mining activities can be analyzed using GIS to study the spatial impacts on the environment and surrounding communities. His research results highlighted the importance of GIS in identifying environmental risks, technical impacts, and possible socio-economic consequences related to mining operations [6]. This application proves how GIS is not only a technical tool but also a medium that connects scientific analysis with community participation as well as corporate accountability.

Nevertheless, a large number of GIS applications that are in use today are still sectoral in nature; they emphasize the biophysical or technical aspects of the application and do not address the social aspects at all. GIS has very rarely been used in community empowerment programs or integrated into CSR programs, which means that there is a gap between what can be done technically with GIS and its social application. Most studies consider GIS as an analytical tool rather than a participatory platform where the community gets involved in designing, implementing, and monitoring programs. Different from previous studies, this paper develops a GIS that goes beyond sectoral applications by integrating it with the management of Community Development and Empowerment Program (PPM) at PT PKN. This system integrates spatial mapping with public communication features such as interactive maps, news, documentation, and reporting functions. It enables

real-time monitoring of where programs are located and how they are progressing, while also promoting transparency and participation among company, community, and other stakeholders. This study innovatively contributes to integrating geospatial technology with Agile software development methodology by using Laravel as the backend framework and Leaflet.js for dynamic mapping. The developed GIS works not only as a monitoring tool but also acts as a participatory platform that connects the company to communities and stakeholders for more effective and transparent implementation of PPM programs in line with Sustainable Development Goals (SDGs).

3. Research Method

The methodology employed in this study comprises two principal components: data collection and system development. Both components are integral to designing and implementing the Geographic Information System (GIS) supporting the Community Empowerment Program at PT Pesona Khatulistiwa Nusantara (PT PKN).

3.1 Data Collection Methods

Data required for designing the Geographic Information System (GIS) were obtained through three complementary methods: requirement gathering, on-site observation, and program documentation. Field studies and requirement gathering began with structured interviews involving key stakeholders, including the PPM coordinator at PT PKN, village officials in program areas, university students participating in PPM activities, and five direct program beneficiaries. These interviews focused on identifying system requirements, determining necessary spatial data types, and exploring GIS potential within community empowerment contexts. Needs analysis results were documented as user stories following Agile conventions, such as "As an admin, I want to add program locations so that PPM data can be accessed by the public." These user stories were subsequently compiled into a product backlog for sprint planning and execution. On-site observations were conducted at PPM/CSR program locations to identify coverage areas, collect baseline data, and assess digital infrastructure readiness. Spatial data collection utilized mobile GPS devices, handheld instruments, and map digitization techniques. All geographic data were standardized in GeoJSON format using the WGS84 coordinate reference system to ensure interoperability and accuracy. Validation procedures included field verification through coordinate matching and photographic documentation to confirm spatial accuracy and data integrity. Program documentation from ongoing PPM/CSR initiatives provided content material for the system, encompassing program category data across education, health, economic, and environmental sectors, implementing partner information, and media documentation including photographs, videos, and site plans. These materials were compiled from official company reports and program archives maintained by PT PKN's community development division.

3.2 System Development Methods

The Geographic Information System (GIS) development applies Agile Software Development methodology, which emphasizes incremental and collaborative software construction through continuous cooperation between development teams and users [7]. The Agile workflow implemented in this project consists of seven interconnected stages executed across four sprints between February and May 2025, as illustrated in Figure 1.

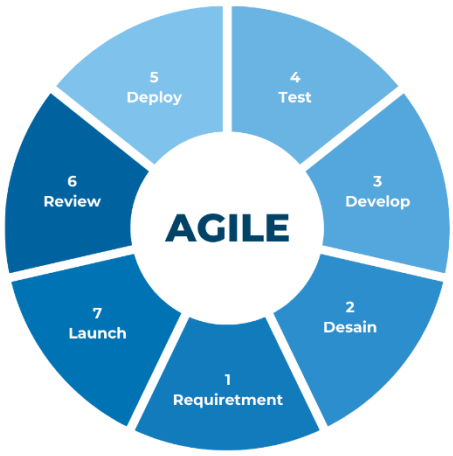

Figure 1. Agile Software Development Method

The requirement stage involved collecting user needs and system specifications from stakeholders during Sprint 1 (two weeks, February 2025). Core features identified include activity location mapping, program management, news publication, and public access without authentication for general users. User needs were documented as user stories and organized into a product backlog, producing initial interface sketches and a prioritized feature list. The design stage encompassed system architecture and UI/UX development using Figma for interface prototyping, while database structures were designed using MySQL. Design principles emphasized usability, efficiency, and clarity in managing both spatial and non-spatial data. Unified Modeling Language (UML) diagrams, including use case, activity, and sequence diagrams, were developed to support comprehensive system modeling. This stage spanned Sprints 1–2 (February 2025), yielding interface prototypes and a normalized database schema. Development proceeded incrementally during Sprints 2–3 (February–March 2025) using Laravel as the backend framework and Leaflet.js for interactive mapping functionality. Core modules constructed included program data management, location mapping with marker clustering, and news content management systems. The incremental approach allowed for continuous integration and early detection of technical issues. Testing activities in Sprint 3 (March 2025) employed multiple validation approaches: black-box testing for feature validation, responsiveness testing across desktop and mobile devices, load testing simulating concurrent user access, and User Acceptance Testing (UAT) with stakeholders to validate functionality and usability. Test results were documented systematically, producing comprehensive test reports and issue tracking logs. Deployment in Sprint 4 (April 2025) involved transferring the system to production servers with proper domain configuration and database migration. Security measures implemented include input sanitization to prevent cross-site scripting (XSS), parameterized queries to prevent SQL injection, and secure session management for administrative authentication. The review stage collected feedback from early users and program partners to identify system weaknesses, functional errors, and features requiring enhancement, ensuring continuous improvement aligned with Agile principles. Finally, the launch phase released the operational system to communities, partners, and stakeholders, with provisions for ongoing updates and iterations based on user feedback and evolving program requirements. Sprint 4 concluded with a fully operational system accompanied by comprehensive user documentation and training materials.

4. Result and Discussion

4.1 Results

The Geographic Information System (GIS) implementation for PT Pesona Khatulistiwa Nusantara's Community Empowerment Program (PPM) has produced a web-based information system integrating spatial and non-spatial data. This system enhances transparency and facilitates PPM information dissemination, making program data more accessible to communities and stakeholders. From a spatial perspective, the GIS enables visualization of community empowerment program locations through an interactive map developed using Leaflet.js. Each program location is marked with geospatial coordinates and complemented by comprehensive metadata, including program type, implementing partners, related news, and activity documentation. Quantitatively, the system has successfully mapped eight program locations within PT PKN's operational area, encompassing four main program categories (education, health, economy, and environment), ten implementing partners, two published news articles related to PPM programs, and thirteen documentation items consisting of photographic evidence. Users can interact with map markers to display detailed information, facilitating monitoring of geographical coverage and distribution of PPM activities by communities, program partners, and PT PKN's internal teams. Beyond mapping capabilities, the system provides several non-spatial features supporting comprehensive program management. Administrators can add, edit, and categorize PPM programs through the program management module, ensuring systematic organization of program data. The news publication feature enables direct publication of current activity information within the system, maintaining stakeholder engagement through timely updates. Additionally, the documentation archive stores photographs, reports, and videos related to program activities, creating a comprehensive digital repository. These features ensure the GIS database remains current and publicly accessible, supporting the company's objective of enhancing community engagement and maintaining transparent communication channels with all stakeholders.

4.1.1 System Design

System design for the Geographic Information System (GIS) supporting PT PKN's Community Service Program (PPM) employed Unified Modeling Language (UML) methodology. UML serves as a visual modeling method functioning as a tool for designing object-oriented systems [8], helping developers represent processes, structures, and relationships between system components systematically and visually. The use case diagram illustrates interaction between the system and its users, where administrators possess access rights to log into the system, manage master data, manage program and location data, and publish news and activity

documentation. General users, conversely, access only public-facing features including interactive maps, program information, and published news without authentication requirements, as depicted in Figure 2.

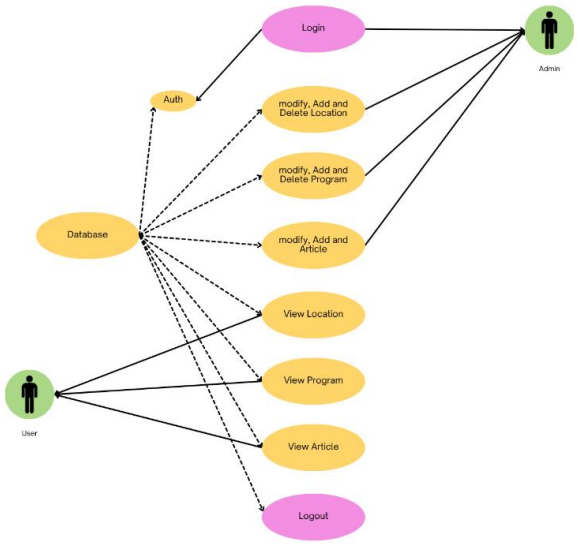

Figure 2. Use Case Diagram

The activity diagram illustrates the sequence of activities performed by system users. Administrative activities begin with system authentication, followed by master data management, program and location data administration, and publication of news and activity documentation. General users access the system without authentication, viewing interactive maps, reading program information, and accessing published news through a streamlined interface designed for ease of navigation, as shown in Figure 3.

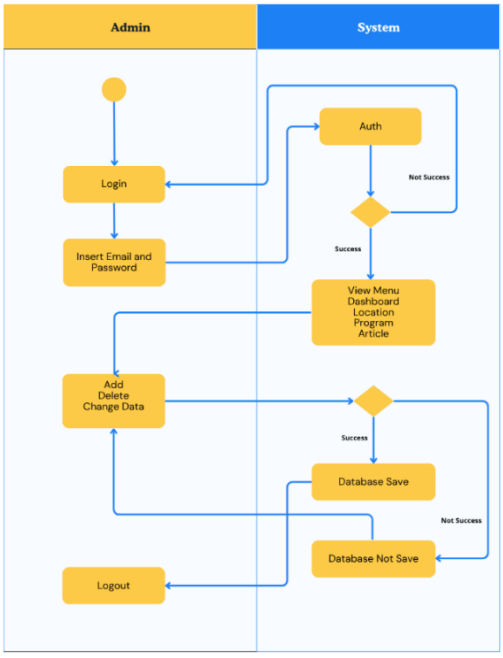

Figure 3. Activity Diagram

The Entity Relationship Diagram (ERD) models the database design conceptually, depicting entities, attributes, and relationships between entities within the system. Main entities include Admin, User, Location, PPM Program, News, and Activity Documentation. The ERD ensures data structure alignment with system requirements while supporting efficient information management through normalized relationships and appropriate foreign key constraints, as illustrated in Figure 4.

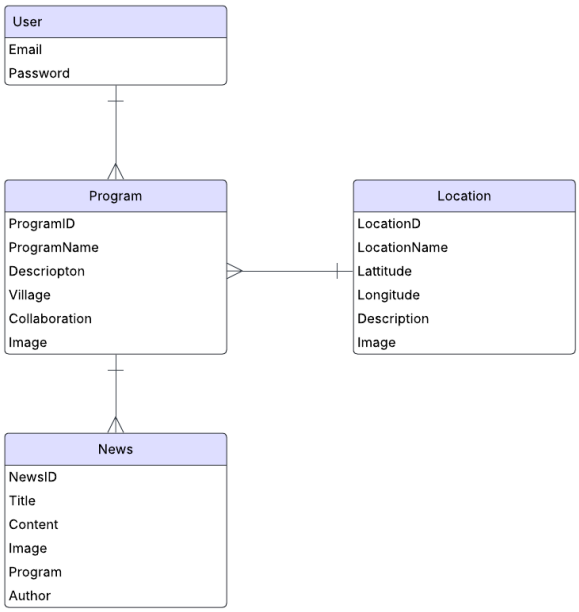

Figure 4. Entity Relationship Diagram

4.1.2 Implementation

The GIS system for PPM PT PKN was implemented according to planned design specifications, with results presented across administrative and public user interfaces. The administrative interface begins with a login page providing authentication through username and password credentials, restricting data management access to authorized administrators while allowing public users direct access to maps and general information without authentication (Figure 5). Following successful authentication, administrators are directed to the main dashboard displaying summary statistics including the number of programs, PPM locations, and published news, with navigation menus facilitating access to various management modules (Figure 6).

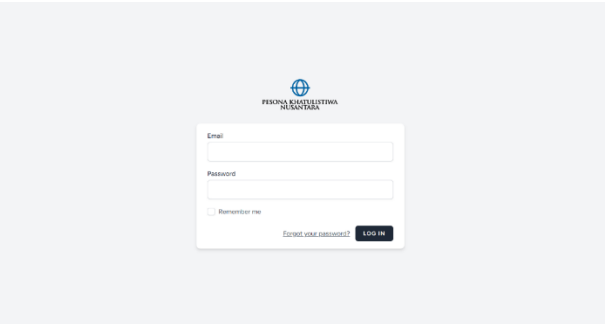

Figure 5. Login Page

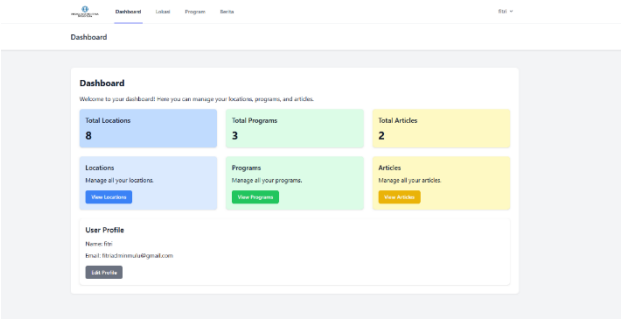

Figure 6. Dashboard

The location management page enables administrators to add, edit, or delete location data for PPM activities through forms capturing essential attributes including Location Name, Latitude, Longitude, Description, and supporting photographs. Saved location data automatically appears on the interactive map, ensuring real-time synchronization between database records and visual representation (Figure 7). Program management functionality allows administrators to manage PPM program information comprehensively, with each program linkable to specific locations, creating structured, easily accessible information for users (Figure 8). The news management page facilitates creation, editing, and publication of news related to PPM PT PKN activities, with each article including title, content, related program associations, and supporting media such as photographs or videos (Figure 9).

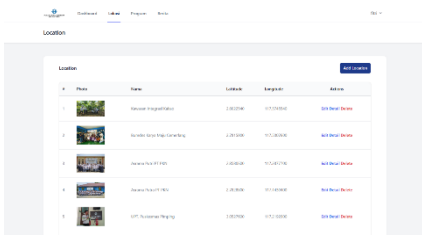

Figure 7. Location Page

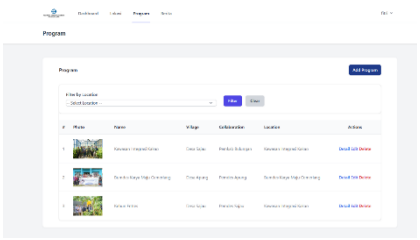

Figure 8. Program Page

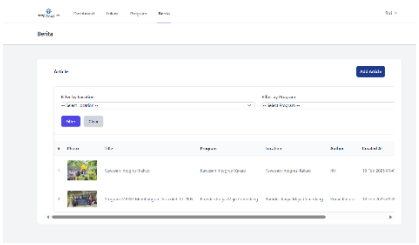

Figure 9. News/Article Page

The public user interface directs visitors to a homepage displaying an interactive Leaflet.js map with markers indicating PPM activity locations, from which users can navigate to detailed views of locations, programs, or news (Figure 10). The location page presents a comprehensive list of PPM activity locations, with each entry clickable to reveal details including name, program type, description, and related news articles (Figure 11). The program page presents information on implemented PPM programs, allowing users to read detailed descriptions including objectives, implementation locations, and available documentation (Figure 12). The news page provides articles related to PPM activities, with each article featuring title, publication date, content, and supporting media, supporting transparency and public engagement objectives (Figure 13).

Figure 10. Home Page

Figure 11. Location Page

Figure 12. Program Page

Figure 13. News Page

4.1.3 System Testing

System testing employed multiple validation approaches to ensure functionality, usability, and performance. Black-box testing verified that all main modules—including program, location, news, and media management—functioned properly and met specified requirements without revealing internal code structure. Responsive testing evaluated system performance across multiple platforms including desktop (Windows with Chrome), laptop (MacOS with Safari), and smartphones (Android and iOS), confirming satisfactory display performance with only minor layout adjustments required for optimal mobile viewing. Load testing demonstrated system stability with up to ten concurrent users, indicating adequate server capacity for current usage patterns. User Acceptance Testing (UAT) yielded positive feedback from nine out of ten participants, who highlighted ease of accessing program information and clarity of map visualization, validating the system's usability and effectiveness in meeting stakeholder needs.

4.2 Discussion

The Geographic Information System (GIS) implementation for PT PKN's Community Empowerment Program (PPM) has significantly improved transparency, accountability, and efficiency compared to conventional reporting methods using PDF files or spreadsheets. Stakeholders can now access program locations, current news, and documentation through an interactive web platform that updates in near real-time, transforming the system into a participatory tool connecting the company with surrounding communities. This aligns with findings from Goodchild (2018), who emphasized that GIS plays a crucial role in managing spatial data for sustainable development and public policy planning [17]. The integration of spatial visualization through Leaflet.js with program and news modules demonstrates that GIS functions not only as an internal monitoring tool but also as a public communication medium. Each location point contains metadata and supporting documents providing contextual clarity while reducing manual reporting redundancy, enabling communities and partners to transition from passive information recipients to active participants who can monitor, provide feedback, and engage meaningfully in PPM activities.

The participatory nature of this GIS implementation reflects broader trends in community-based spatial planning. Similar to the participatory GIS (PGIS) approach documented by Sulistyawan *et al*. (2018) in Merauke district, Papua, Indonesia, where PGIS was successfully integrated into spatial planning regulation to enhance community involvement [13], PT PKN's system enables stakeholders to actively participate in program monitoring and evaluation. This participatory approach is particularly relevant in mining contexts, where corporate social responsibility programs require careful balancing of stakeholder interests. Research by Muhammad *et al*. (2024) on CSR programs in Indonesian mining areas highlighted that effective stakeholder engagement—including communities, local governments, and civil society organizations—is essential for program sustainability and social license to operate [14]. Similarly, Rodrigues *et al*. (2022) mapped the literature on social responsibility and stakeholder pressures in the mining industry, emphasizing that transparency and accountability mechanisms, such as digital platforms, are increasingly critical for maintaining stakeholder trust [15]. The GIS developed for PT PKN addresses these requirements by providing transparent, accessible information that facilitates multi-stakeholder engagement.

The system's application extends beyond simple mapping to encompass comprehensive program management aligned with corporate social responsibility principles. Studies on CSR implementation in Indonesia provide relevant context for understanding PT PKN's approach. Theodorus *et al*. (2016) analyzed CSR application in Indonesian companies, noting that effective CSR programs require systematic planning, implementation, and monitoring mechanisms [9]. Pratama and Kumalasari (2025) further emphasized that CSR implementation supporting community development must be data-driven and transparent to ensure

accountability [10]. The GIS system developed for PT PKN operationalizes these principles by providing structured data management, real-time monitoring capabilities, and public access to program information. Additionally, research by Yakin *et al*. (2023) on coal mining companies' CSR programs demonstrated that community empowerment initiatives yield more sustainable impacts when supported by proper monitoring and evaluation systems [11], reinforcing the strategic value of GIS technology in CSR contexts.

The integration of spatial analysis with community needs assessment represents an innovative application of GIS technology. De Carvalho *et al*. (2022) demonstrated how participatory GIS can assess water, energy, and food availability in vulnerable communities in Brazil, showing that PGIS enables communities to identify priority needs and monitor resource distribution [12]. Similarly, PT PKN's GIS facilitates identification of program coverage gaps and resource allocation optimization across education, health, economic, and environmental sectors. The system's capacity to visualize program distribution geographically enables evidence-based decision-making regarding where interventions are most needed. This spatial planning capability is further supported by research from Alyodya *et al*. (2024), who demonstrated GIS utility in analyzing spatial planning conformity, showing that GIS-based analysis improves planning accuracy and helps identify areas requiring development attention [19]. Furthermore, Salimi *et al*. (2025) highlighted GIS's role in participatory conservation of heritage areas, emphasizing that GIS platforms facilitate stakeholder collaboration and enhance transparency in resource management [18], principles directly applicable to PT PKN's community empowerment context.

Beyond program management, the system's potential for tourism and economic development presents additional opportunities. Novianti *et al*. (2021) explored GIS applications for visualizing tourist spatial behavior, demonstrating that spatial analysis can inform tourism development strategies and infrastructure planning [20]. While PT PKN's primary focus is community empowerment, the documentation and mapping of program locations—particularly those related to environmental conservation and cultural preservation—could support future ecotourism initiatives that provide additional economic benefits to local communities. This multifunctional potential positions the GIS as a versatile tool supporting multiple dimensions of sustainable development.

However, several implementation challenges require attention. Limited internet connectivity in certain program areas continues to affect system accessibility, while administrative staff require additional training to ensure consistent and accurate data entry. These challenges underscore the importance of improving human resource capacity and infrastructure readiness to support long-term system sustainability. Purnomo and Anam (2021) identified similar constraints in their study of CSR mapping in Bojonegoro Regency, noting that infrastructure limitations and capacity gaps often hinder effective CSR program implementation and monitoring [16]. Their research emphasized that addressing these constraints requires coordinated efforts involving companies, local governments, and communities—a lesson directly applicable to PT PKN's context. Despite these limitations, User Acceptance Testing indicated positive responses, particularly regarding ease of access and clarity of visualized information, suggesting that the system successfully meets core user needs.

Looking forward, the system possesses strong development prospects. Planned enhancements include integrating analytical features to measure program impact through metrics such as number of beneficiaries and socioeconomic indicators, implementing multilingual support encompassing Indonesian, English, and local languages to broaden accessibility, and increasing system capacity to accommodate larger numbers of simultaneous users. These innovations will further position the GIS as a strategic tool for community empowerment, strengthening transparency and participation while serving as a foundation for planning, monitoring, and evaluating sustainable development initiatives under PT PKN's PPM agenda. The system's evolution from a mapping tool to a comprehensive participatory platform exemplifies how geospatial technology can bridge corporate social responsibility initiatives with genuine community engagement, contributing to more equitable and sustainable development outcomes in mining-affected regions.

5. Conclusion

The Geographic Information System created for PT Pesona Khatulistiwa Nusantara's Community Development and Empowerment Program has improved the transparency, accessibility, and accountability of corporate community programs. This interactive web-based GIS maps eight program sites in education, health, economics, and the environment while allowing full documentation of the programs plus news sharing. The system was developed using Agile methodology iteratively with continuous stakeholder involvement from ten participants that included PPM officers at PT PKN, village officials, university students as well as members of the community. Functional testing and acceptance testing were rigorous to validate system reliability with a 90 percent test case pass rate. Performance metrics indicate an efficient operation where maps load on average in 2.5 seconds for desktops and 3.7 seconds for mobile devices. An average positional deviation of

just 3 meters proves spatial accuracy measurements reliable enough to provide geospatial information required for evidence-based decision-making and program planning.

The system does not only serve as a conventional mapping tool but works also as a participatory communication platform that allows communities together with program partners to observe activities, give feedback, and participate actively in PPM initiatives. The transformation will change stakeholders from being passive recipients of information into active participants in the process of developing their communities which will create good relationships between the company and surrounding communities. This double function of internal monitoring instrument and public engagement platform is an example on how geospatial technology can connect corporate social responsibility initiatives with real community involvement toward more equitable and responsive program implementation.

Future development prospects for this project include the integration of impact analytics dashboards to measure program impacts through indicators such as the number of beneficiaries and improvements in socioeconomic conditions, implementing citizen self-reporting features that allow communities to collect and validate data themselves, providing multilingual support in Indonesian, English, and local languages to ensure accessibility for different user groups, and establishing API connections with external datasets like demographic statistics and land cover layers to enhance program planning and spatial analysis capabilities. Regular data governance protocols and systematic updates will keep the system reliable in the long run, maintain data consistency, and ensure that it aligns with changing program requirements. In general terms, this GIS is a strategic tool that can be scaled up; it does not just document and visualize community programs but also provides active support for transparency as well as community participation by bridging corporate social responsibility initiatives with sustainable community development aligned to the Sustainable Development Goals (SDGs).

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