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Digital transformation for rural empowerment: A web-based application framework to enhance BUMDesa performance

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ABSTRACT. The rapid advancement of digital technology in Indonesia presents both opportunities and challenges for rural economic actors, particularly village-owned enterprises (BUMDesa). While urban MSMEs have increasingly adopted digital platforms, many BUMDesa continue to face structural and managerial barriers to digital integration. This study addresses these issues by developing SIBUDE (Sistem Informasi BUMDesa), a web-based knowledge-sharing platform designed to enhance BUMDesa management capacity through structured knowledge sharing and stakeholder collaboration. Guided by the Knowledge-Based Economy and Pentahelix collaboration model, the system integrates a digital knowledge repository, user role management, web services using XML/JSON, and modules for training, article exchange, and community Q&A. The prototype was developed using the Waterfall method and preliminarily implemented in Gorontalo and North Sulawesi. Results demonstrate that SIBUDE supports real-time communication, knowledge dissemination, and multi-sector cooperation through its modular and role-based architecture. It enables BUMDesa to access a centralized, structured repository that facilitates peer learning, knowledge exchange, and continuous operational improvement. The study concludes that knowledge-driven digital systems can significantly empower rural enterprises by promoting transparency, innovation, and operational efficiency. This study contributes a replicable model for rural digital transformation that aligns with national priorities for inclusive economic growth and digital literacy.

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INTRODUCTION

Digital transformation is critically important in fostering an inclusive and sustainable national economy, particularly in Indonesia, where the government has initiated the National Digital Literacy Program. This program aims to enhance the capability of citizens to navigate the digital landscape effectively, particularly targeting the micro, small, and medium enterprises (MSMEs) sector, which is fundamental to the country's economic framework. The Indonesian MSME sector is indeed the backbone of the economy, and accounts for approximately 99.9% of all businesses in the nation, contributing significantly to job creation and economic resilience (Meilariza et al., 2024).

At the village level, one of the fastest-growing forms of economic institutions that serves as a driving force for the local economy is the Village-Owned Enterprise (BUMDesa). According to data from the Coordinating Ministry for Human Development and Cultural Affairs (Kemenko PMK) as of April 2021, a total of 41,847 BUMDesa had been established across Indonesia. The existence of BUMDesa is regulated under Government Regulation No. 11 of 2021 and is intended to support the improvement of rural community welfare through productive economic activities and public services.

However, field data indicate that many Village-Owned Enterprises (BUMDesa) have not yet been able to develop optimally. Most of them still lack sustainable productive business activities, face challenges related to low managerial capacity, weak quality of human resources, limited digital infrastructure, and constraints in innovation and establishing strategic partnerships with various stakeholders. In fact, some BUMDesa have reportedly experienced stagnation due to the managers' limited understanding of institutional functions and potential business opportunities. Yet in this era of digital transformation, speed and accuracy in accessing and managing information are crucial for decision-making and business innovation. These issues are well-documented in various studies, emphasizing the need for a more strategic approach to enhance the effectiveness of BUMDesa in this digital age.

In Blora Regency, Indonesia, for example, research has identified that establishing BUMDesa can unlock community potential not only economically but also socially. This study highlights the collaboration between the Department of Villages and community support organizations, which aims to build a robust framework for BUMDesa operations (Aini et al., 2024). Yet despite these efforts, many BUMDesa struggle with stagnation attributed to managerial deficiencies, particularly in understanding their roles and recognizing potential business opportunities (Wardhana et al., 2022).

Improving managerial capacity is crucial, as a firm's ability to absorb and apply new knowledge directly impacts their performance and sustainability. This absorptive capacity enables businesses to integrate external information that can lead to innovative practices and sustainable growth (Xue et al., 2019). Moreover, structured training programs and workshops on management practices can empower local managers to navigate the complexities of modern business environments effectively. To address these challenges, a new approach to BUMDesa development is needed—namely, by integrating information technology and knowledge management through a digital platform that facilitates cross-sector collaboration.

Digital transformation is a critical factor for BUMDesa development. Implementing digital platforms can significantly enhance information accessibility and operational efficiency. For instance, web applications designed specifically for BUMDesa can streamline processes, enable collaboration with stakeholders, and improve market access for local products, thereby promoting economic resilience (Wardhana et al., 2022).

Numerous scholarly studies have examined the role of digital transformation in public and private sectors, especially in relation to organizational performance, innovation, and knowledge integration. Chen et al. (2016) investigated the effect of a digital portal on the organizational performance of Taiwanese textile SMEs. Their findings highlight the significance of portal interface, B2B functions, and cloud services in improving perceived organizational outcomes. Tahir et al. (2022) proposed a low-cost digital solution for Indonesian SMEs using *Progressive Web Apps* (PWA) in a fog computing architecture. This innovation addresses internet accessibility and cost barriers. In the context of collaboration and innovation, Garmann-Johnsen et al. (2018) emphasized employee co-creation using Web 2.0 technologies as an enabler for digital transformation in healthcare. Ordonez De Pablos and Labra Gayo (2025) examined how information technology and the semantic web contribute to inclusive economies. Their findings highlight the need for open, interoperable, and knowledge-driven digital platforms to support institutional transformation. Further, Gómez-Carmona et al. (2023) examined the development of interoperable digital ecosystems for rural and smart community transformation, emphasizing the importance of context-sensitive infrastructure and service integration in enabling community-based digital development.

Overall, these studies reveal important progress in leveraging digital platforms for organizational improvement. However, few address rural economic institutions such as BUMDesa, nor do they offer integrated systems that combine web services, web mining, and knowledge management for community-based economic empowerment. Moreover, the specific application of the pentahelix model in a digital platform remains under-explored. The pentahelix model—involving academia,

business, community, government, and media—has emerged as a strategic collaborative framework. It fosters synergy between BUMDesa and key actors, enabling knowledge exchange, capacity building, and innovation in a knowledge-based economic ecosystem. This research proposes and develops SIBUDE (Sistem Informasi BUMDesa), a web-based knowledge-sharing platform enhanced with web services and a knowledge repository to support the capturing, sharing, and distribution of knowledge among BUMDesa and their stakeholders. SIBUDE is designed to serve as a digital infrastructure that supports BUMDesa in building institutional capacity and accelerating their inclusion in Indonesia's digital economy.

METHODS

Research Design

This study adopts a developmental research design aimed at creating SIBUDE as a web-based knowledge-sharing platform to enhance the management capacity of BUMDesa through a knowledge repository framework. The research was conducted over a six-month period in the provinces of Gorontalo and North Sulawesi (Minahasa region), areas chosen due to their active BUMDesa participation and potential for digital development. The research is part of a multi-year roadmap, with the current phase focusing on system design, development, and preliminary implementation. The overall research procedure, from problem identification through system development to findings and recommendations, is summarized in Figure 1.

Digital Ecosystem Needs Assessment

The initial phase of the study involved identifying regulatory frameworks and operational characteristics required to establish a digital ecosystem conducive to BUMDesa operations. The needs assessment used purposive stakeholder sampling because the study required informants who were directly involved in BUMDesa management, village governance, digital facilitation, and local economic development. A total of 40 respondents participated in this stage, consisting of village officials, BUMDesa managers, academic advisors, and government representatives from Gorontalo and the Minahasa region of North Sulawesi. Data were collected through structured surveys and brainstorming sessions focusing on legal requirements, operational constraints, digital readiness, knowledge-sharing practices, and expectations for platform features.

The inclusion criteria for respondents were: (1) direct involvement in BUMDesa operations or policy support, (2) familiarity with local economic development issues, and (3) willingness to provide information on digital needs and institutional constraints. Survey responses were summarized descriptively, while brainstorming results were coded thematically to identify recurring needs related to information access, training, product promotion, stakeholder communication, and system interoperability. These five identified need categories directly informed the design of SIBUDE's five core functional modules: Articles, Training Information, BUMDesa Profiles, Q&A, and Administration, respectively.

An environmental scan was conducted to evaluate existing digital platforms such as village information systems and other public service portals. The findings highlighted major inefficiencies, particularly in manual data entry, poor interoperability, and HTML-based static information formats that hinder knowledge engineering and reuse. Research indicates that manual input not only increases the likelihood of human error but also results in data redundancy and inconsistency (Barchard & Pace, 2011). Furthermore, high operational costs associated with data verification can deter participation from stakeholders (Anggraeni et al., 2019).

A review of relevant literature on BUMDesa participation and governance, rural digitalization, and Pentahelix-based collaboration informed the conceptualization of a digital knowledge ecosystem tailored to rural community enterprises. Studies on rural governance emphasize the importance of

participatory and collaborative strategies in strengthening local institutions (Eprianti & Choiriyah, 2024; Saputra & Havlíček, 2024). Research on rural digital transformation highlights the need for interoperable digital ecosystems, service integration, and context-sensitive infrastructure for smart communities (Gomez-Carmona et al., 2023). In parallel, studies on BUMDesa and Pentahelix collaboration show that sustainable village enterprise development depends on the coordinated involvement of government, academia, business, community, and media actors (Abdullah et al., 2024).

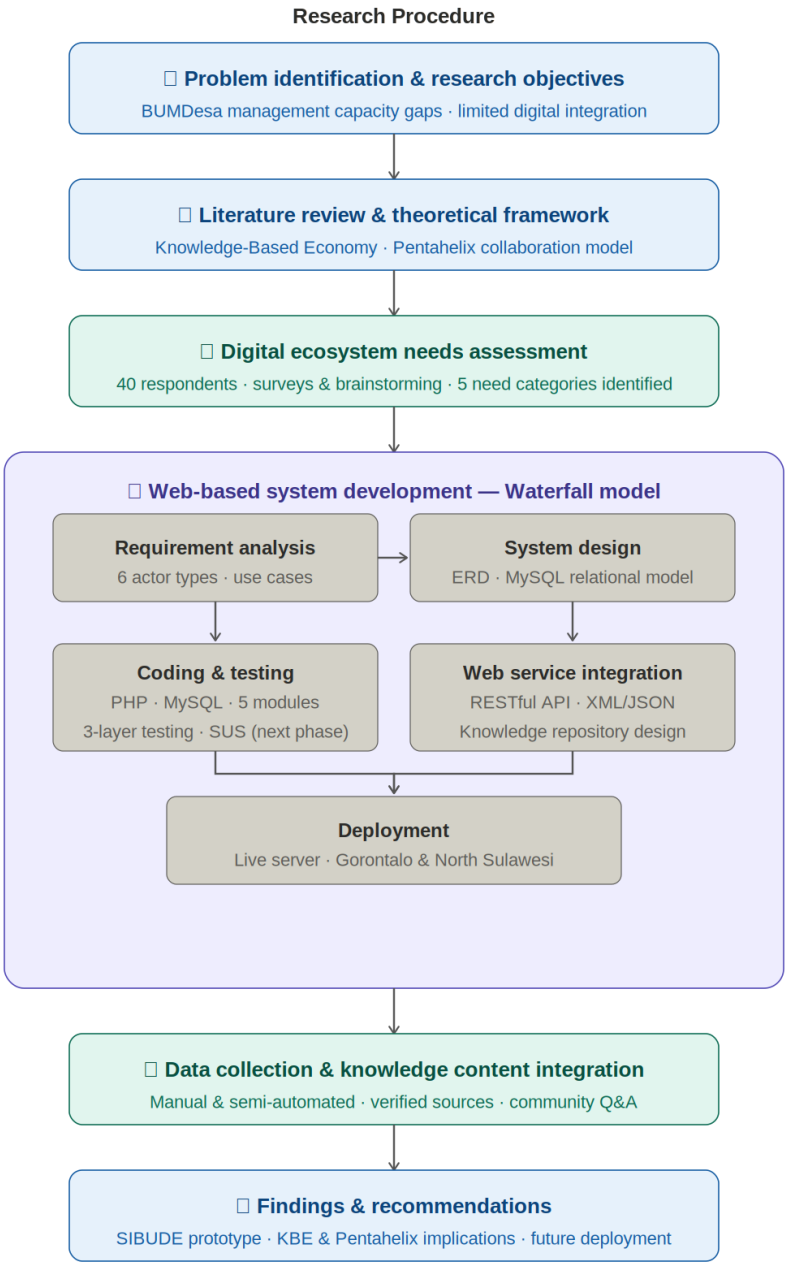

Figure 1. Research procedure

Web-Based System Development Using the Waterfall Model

To guide the system's development process, the research employed the Waterfall model—a linear and sequential software development methodology appropriate for projects with well-defined outcomes. The development stages included:

Requirement Analysis: Use case analysis was performed to define user roles and system interactions. Stakeholders were categorized into six actor types: guest users, BUMDesa managers, other public stakeholders (e.g., government, academics, business), media platforms, external applications, and system administrators.

System Design: Both conceptual and relational data models were constructed. The conceptual model, presented through Entity Relationship Diagrams (ERDs), mapped out entities such as users, articles, BUMDesa products, services, Q&A modules, and user interactions. The relational model translated these into normalized tables within a MySQL database.

Coding and Testing: The system was coded using PHP and integrated with a MySQL relational database backend. Web interfaces were built for five core modules: Articles, BUMDesa Profiles, Training Information, Q&A, and Administration. System testing was conducted across three layers: (1) black-box functional testing, which verified whether each function operated according to the defined use cases, including login, article submission, BUMDesa profile management, training information posting, Q&A interaction, search, and administrative moderation; (2) data accuracy testing, which compared user input, database storage, and displayed output to ensure consistency across modules; and (3) role-based access-control testing, which examined whether guest users, BUMDesa managers, stakeholders, external applications, and administrators could only access functions appropriate to their designated roles. Usability evaluation using the System Usability Scale (SUS) instrument is designated for the subsequent large-scale deployment phase and will be reported in a follow-up study (Hyzy et al., 2022).

Deployment: The prototype was deployed on a live server to simulate real-user interaction and to test automated data capture functionalities.

Web Service Integration and Repository Design

A key innovation of the system was the use of Web Services (WS) to enable seamless data exchange using XML and JSON formats. The design included RESTful API endpoints allowing third-party systems to request or share BUMDesa-related data programmatically. Authentication mechanisms such as API keys and token-based validation were implemented to ensure secure access. The knowledge repository serves as the central database for the system, storing structured data including business articles, training resources, community Q&A, and BUMDesa product listings. The system architecture comprises a Web Server, Database Server, Web API interface, and scheduling modules. This structure supports scalability, especially as usage increases.

Data Collection and Knowledge Content Integration

To populate the repository, the study conducted manual and semi-automated data collection from verified websites, institutional databases, and direct stakeholder submissions. Articles and training resources were tagged and categorized based on topic, source, and user ratings. The Q&A module allows users to pose and respond to business-related inquiries. Voting features enhance content quality by enabling community evaluation. The administrative backend provides control over content visibility, user access, and repository updates.

Results and Discussion

System Prototype: Overview of SIBUDE

The central output of this study is the development of SIBUDE (Sistem Informasi BUMDesa), a web-based knowledge-sharing platform designed to enhance the management capacity of BUMDesa and improve interconnectivity with relevant stakeholders. SIBUDE was developed to address common challenges encountered by BUMDesa, including limited managerial knowledge, low innovation rates, and the absence of structured communication channels for collaboration and knowledge sharing.

SIBUDE is conceptualized as a knowledge-based infrastructure, incorporating five core functional modules: Articles, BUMDesa Profiles, Training Information, Q&A, and Administration. These modules were designed to support both the dissemination and acquisition of business and operational knowledge in a collaborative, open-access environment. The system enables users to publish and interact with business articles, manage BUMDesa profiles, access training materials, and participate in community-driven discussions.

The primary goal of SIBUDE is to build a shared digital knowledge repository that enables rural enterprises to benefit from the collective knowledge and innovations developed across the country. By leveraging this repository, BUMDesa managers and stakeholders can learn from each other's practices and apply proven solutions in their respective local contexts.

User Requirements and Use Case Analysis

As described in the requirements analysis phase, six actor categories were identified to guide SIBUDE's access model: guest users, BUMDesa managers, stakeholders, media systems, external applications, and administrators. Use case elaboration confirmed that these actor roles translated consistently into the system's role-based interface structure, with each role accessing only the functions relevant to their operational scope. These use cases informed the interface design and guided the construction of database schemas to support multi-user interactions and role-based access control.

Technical Architecture and System Infrastructure

The technical architecture of SIBUDE consists of four interconnected layers: Web Server, Database Server, Web API (Application Programming Interface), and a Scheduling Agent. All system components operate over an internet-based network and are accessible through web browsers on both desktop and mobile devices. When a user initiates a request (e.g., to view an article), the Web Server processes the request by querying the Database Server, assembling the response, and sending back an HTML-rendered page. For data exchange with third-party applications, the Web API enables authorized systems to make secure calls using structured formats (XML or JSON). Authentication is handled through API keys and token verification protocols (Figure 2).

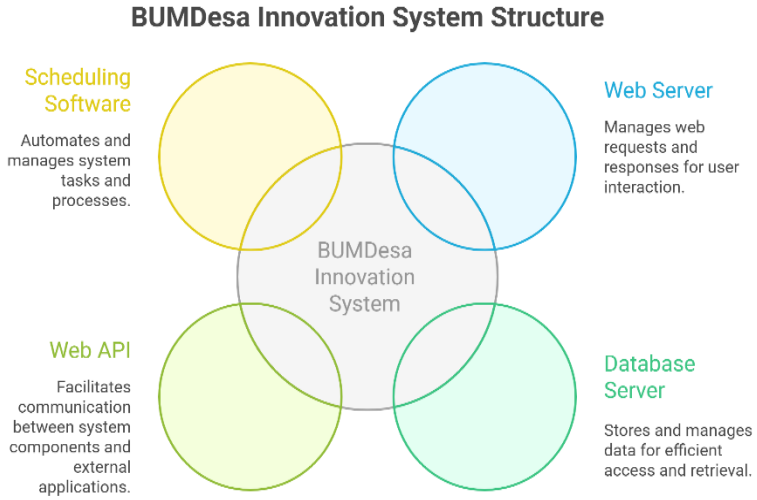

Figure 2. Architecture diagram of SIBUDE

The design supports both centralization and distribution. In smaller deployments, all components can be hosted on a single server, whereas larger-scale implementations can allocate tasks across separate physical or cloud-based servers for scalability. The database system was constructed using MySQL, with key tables covering users, BUMDesa profiles, products and services, articles, comments, votes,

training information, and system logs, which supporting multi-user interaction and content management across all modules.

Interface Design and Feature Integration

The SIBUDE user interface was designed to be intuitive and accessible, with visual consistency across modules and responsive layout for various devices. The interface includes navigation bars, search functionalities, interactive forms, and real-time content updates. The following modules constitute the core interface of SIBUDE. Screenshots illustrating user journeys across these modules are presented separately as Figures 3–6, covering login, knowledge content access, Q&A interaction, and BUMDesa profile browsing.

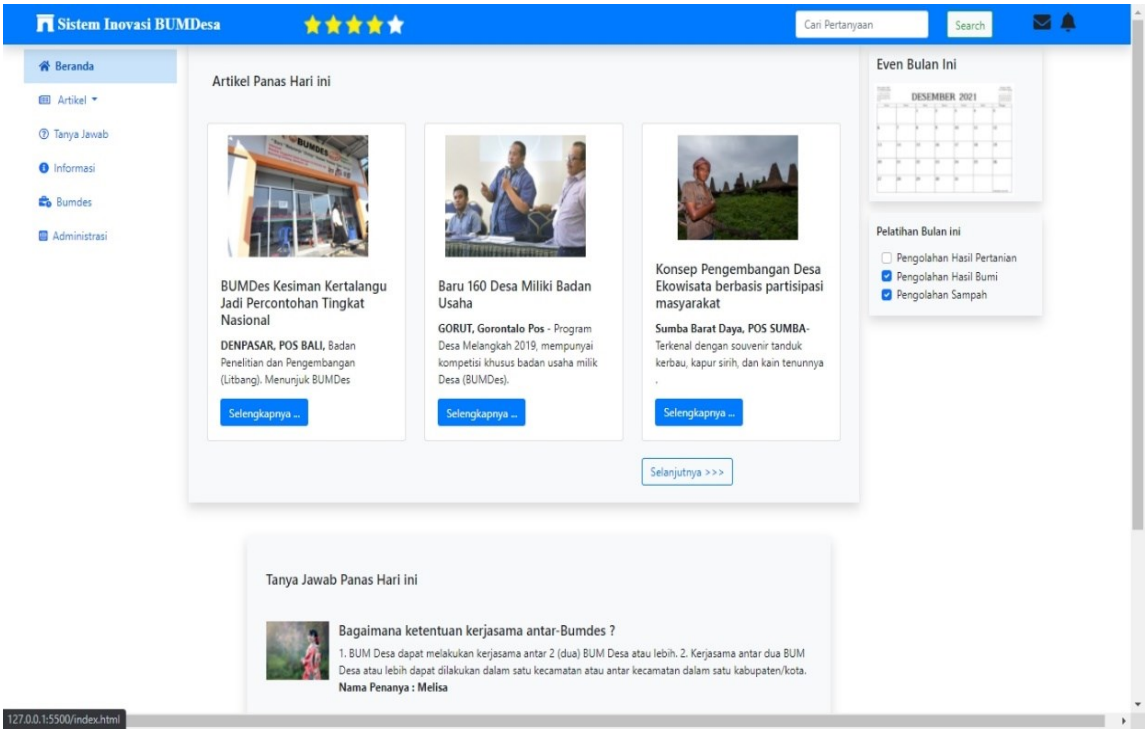

Figure 3. Dashboard and initial access interface of SIBUDE

Homepage (Dashboard): Displays recently posted articles, trending discussions, and highlights from BUMDesa profiles. Content is sortable by date, popularity, or relevance.

Article Module: Allows users to browse, search, and contribute articles related to business development, digital marketing, legal compliance, and financial literacy. Articles are categorized and searchable by tags and keywords.

BUMDesa Module: Features profiles of registered BUMDesa, including their services, achievements, and products. This module promotes visibility and cross-learning among village enterprises.

Information Module: A space for posting or requesting training and capacity-building opportunities. Stakeholders can advertise available training sessions or respond to BUMDesa requests for specific skills.

Q&A Module: Enables interactive dialogue where users can pose and answer questions related to operational challenges. Questions and answers can be upvoted or downvoted, creating a reputational metric for user contributions.

Administration Module: Provides backend access for system moderators to manage content, users, data flows, and service integration. The admin panel includes filtering tools, analytics dashboards, and user management capabilities.

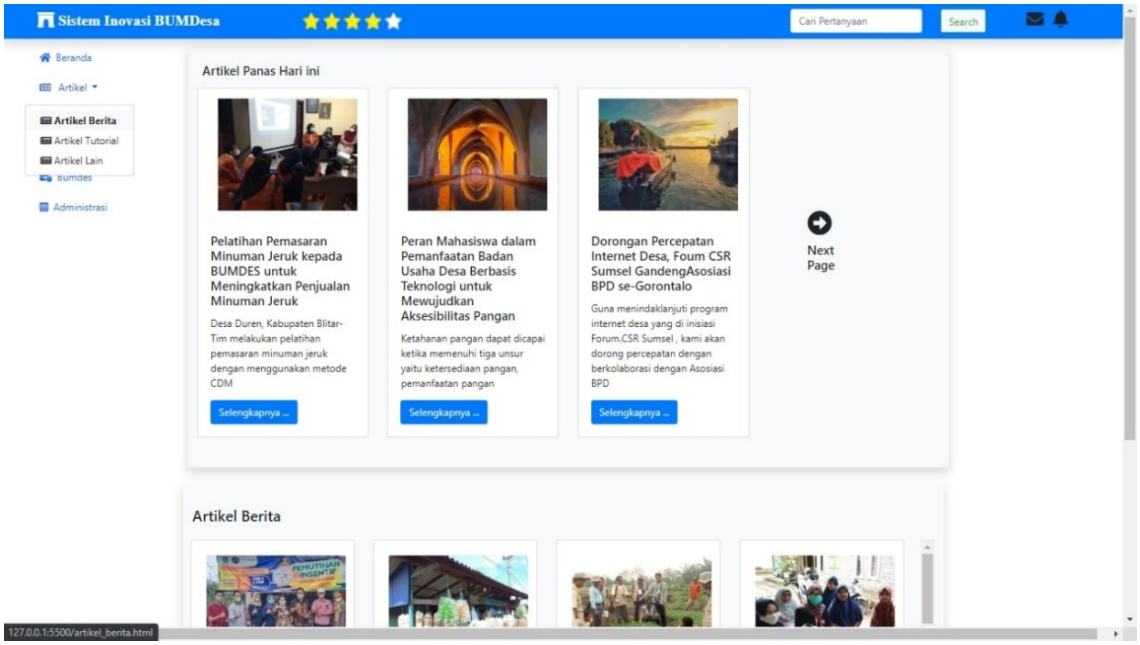

Figure 4. Article repository and knowledge-sharing interface

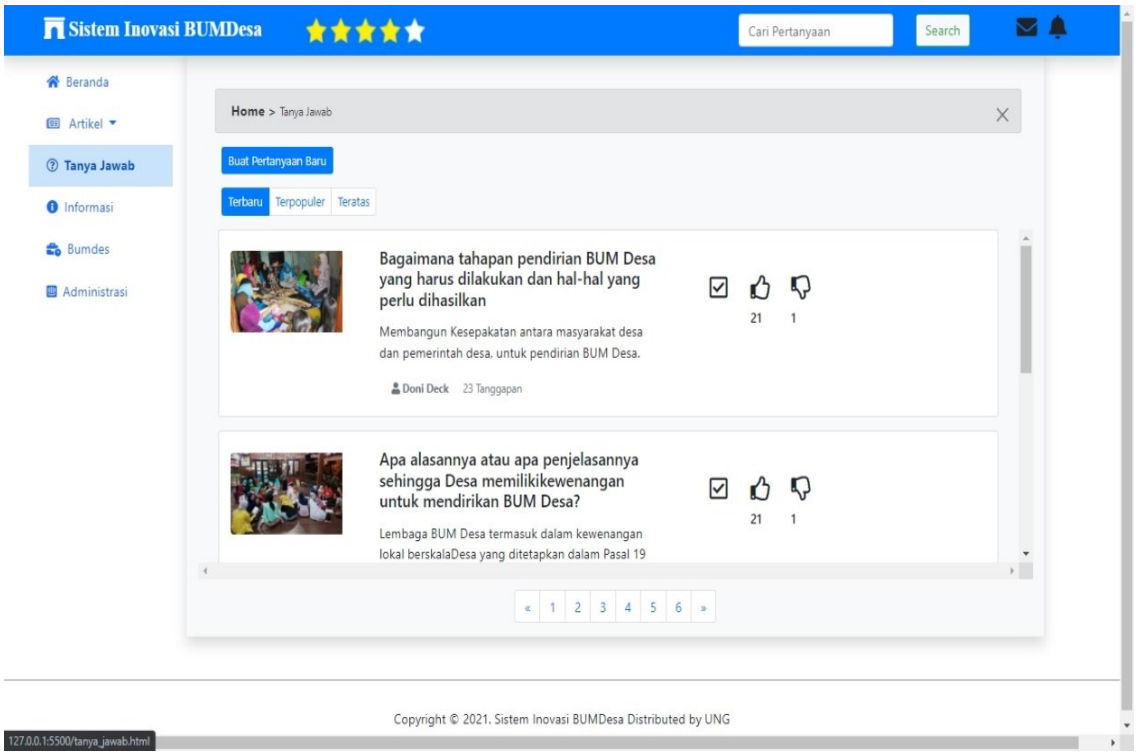

Figure 5. Q&A and administrative interaction interface

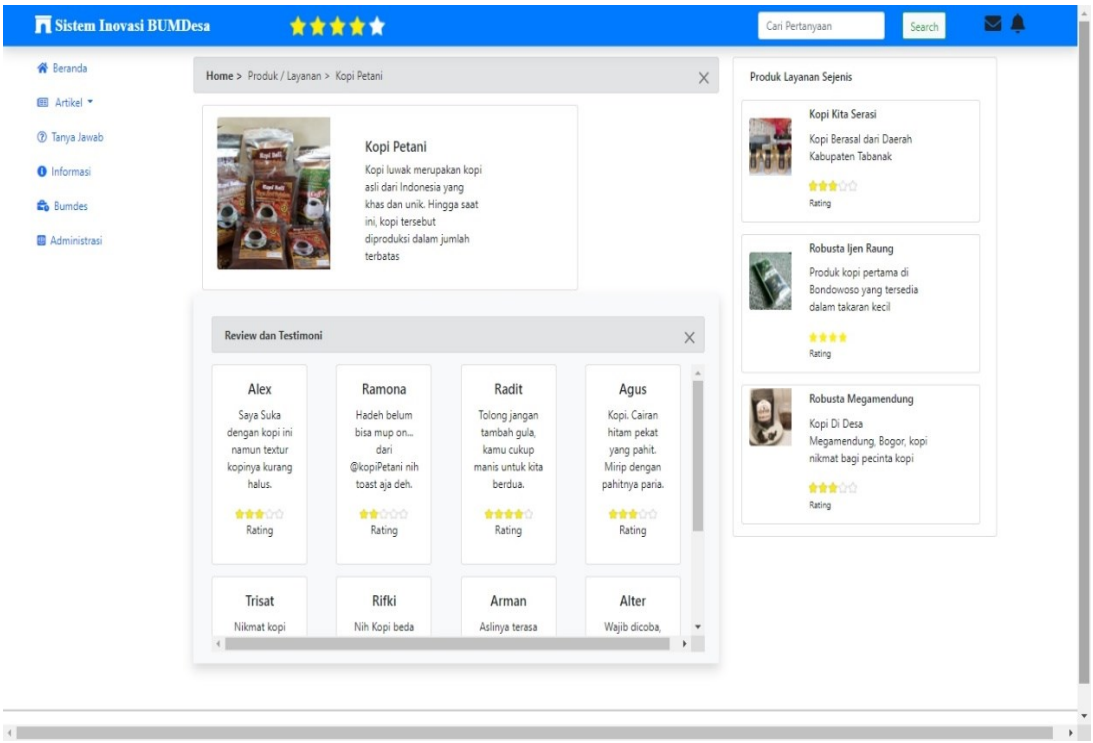

Figure 6. BUMDesa profile and product information interface

Repository Implementation and Knowledge Flow

At the core of SIBUDE is the knowledge repository, an integrated database that aggregates, stores, and organizes structured knowledge assets for BUMDesa management. The repository supports the storage, organization, and dissemination of knowledge assets in accordance with knowledge repository principles described by Dalkir & Liebowitz (2011).

All knowledge inputs, articles, discussion posts, training materials—are cataloged with metadata and linked to user profiles for accountability. The repository is updated in real-time as users interact with the system. For example, a BUMDesa facing issues with product marketing may pose a question, receive several community-based responses, and flag the most helpful answer for future users. The repository also supports machine readability via web services, enabling other systems to request data or push updates through API calls. This enhances interoperability and promotes integration with governmental data systems or academic research tools.

The development and implementation of SIBUDE represents a strategic response to the managerial and infrastructural challenges faced by BUMDesa. Prior studies suggest that digital platforms can function as knowledge, consensus, and innovation spaces that strengthen rural resilience and support a knowledge-based economy. In this context, the integration of a digital platform with a knowledge repository provides a knowledge-centric infrastructure for capacity building and adaptive learning (Singh et al., 2023; Kartikasari et al., 2024). This is particularly relevant for BUMDesa, where operational constraints are often linked to limited managerial capability, weak human capital, and restricted access to practical knowledge and external networks.

One of the major implications of this study is the operationalization of the Pentahelix collaboration model, which is increasingly recognized as a useful framework for cross-sector local development. By involving actors from academia, business, community, government, and media, SIBUDE moves beyond hierarchical knowledge dissemination and enables more horizontal forms of collaboration (Sjögren Forss et al., 2021; Pratiwi et al., 2025). In this sense, SIBUDE functions as a communication

and information bridge that facilitates the flow of practical and context-relevant knowledge across institutional boundaries.

From a technological standpoint, the integration of web services and knowledge repositories is consistent with research emphasizing the importance of interoperable digital systems capable of automated data exchange and near real-time access. Prior studies show that XML and web services are widely used to address heterogeneity, distribution, and interoperability across information systems, including integration with legacy applications (Salem et al., 2013). In this context, the use of XML and JSON in SIBUDE supports compatibility with external applications and facilitates broader interoperability with village information systems, government portals, and other digital platforms.

SIBUDE's modular and role-based UI/UX design reflects an important consideration of the uneven levels of digital readiness and literacy in rural contexts. Prior studies show that rural digital platforms need to account for infrastructure constraints, users' operational capability, and willingness to adopt technology, while inclusive interface design should emphasize clarity, readability, intuitive navigation, and accessible onboarding (Van Calis et al., 2025; Mukti et al., 2022). In this sense, segmenting SIBUDE into functional modules and providing role-relevant access can improve accessibility, usability, and inclusiveness for different categories of BUMDesa users.

A key insight from the results is the importance of community-driven knowledge exchange. The Q&A module, in particular, illustrates how peer-to-peer learning can complement top-down policy or training programs. Prior studies show that professional Q&A communities function as important spaces for peer knowledge production, while user ratings, reputation mechanisms, and other participatory features can improve contribution quality and sustain user engagement (Chen et al., 2025). In this sense, the presence of voting mechanisms, content tagging, and contributor reputation metrics in SIBUDE is consistent with participatory approaches to knowledge sharing that support both content quality and community participation.

Moreover, SIBUDE's capacity to function as a centralized yet open-access knowledge repository directly addresses fragmentation and redundancy in rural development knowledge systems. Prior research suggests that the value of a knowledge repository lies not only in storing information but also in supporting searchability, actionability, and user contribution, so that knowledge can be effectively accessed, applied, and continuously enriched across diverse user groups (Durcikova & Fadel, 2016). In this sense, SIBUDE enables BUMDesa managers to document their experiences, access comparable case studies, and connect with relevant stakeholders through a more open and collaborative knowledge-sharing environment.

The study also highlights the growing need for automated knowledge extraction and content analysis, particularly in preparation for the next phase of development involving text mining and web scraping. Prior studies indicate that manual analysis of large text collections is often time- and resource-intensive, creating bottlenecks in conventional knowledge systems. In this regard, the integration of crawler agents, NLP-based text mining, and ontology-driven semantic indexing can enrich repository content, improve retrieval quality, and reduce reliance on manual data input (Huettemann, 2025). Such automation is consistent with current developments in knowledge engineering and supports the vision of a more dynamic and learning-oriented BUMDesa ecosystem.

Although the SIBUDE prototype demonstrates technical feasibility and conceptual clarity, challenges remain in sustainability, user adoption, and long-term integration. It is important to note that formal usability evaluation using the SUS instrument is designated for the subsequent large-scale deployment phase and will be reported in a follow-up study. User involvement has been shown to significantly influence system acceptance, as systems aligned with user needs are more likely to be adopted and continuously used (Leso et al., 2022; Teixeira et al., 2023). Therefore, sustained stakeholder engagement, regular content updates, and capacity-building efforts are essential to ensure SIBUDE becomes fully institutionalized within BUMDesa operations.

The research also reveals that digital transformation is not merely a technological undertaking but a socio-organizational shift. Many BUMDesa lack the institutional culture to support open knowledge exchange, often due to hierarchical leadership styles, weak accountability structures, or lack of incentives for innovation (Andaria et al., 2020; Imran et al., 2021; Leso et al., 2023). Therefore, future implementation must be accompanied by governance reforms, training programs, and performance indicators aligned with digital economy objectives.

In conclusion, this study provides empirical evidence and a functional prototype demonstrating that SIBUDE, as a web-based knowledge-sharing platform, can significantly enhance the management capacity of BUMDesa. By integrating digital tools with collaborative frameworks, SIBUDE embodies a scalable model for rural innovation systems. Its development affirms the necessity of blending technological innovation with participatory governance to achieve inclusive, sustainable digital transformation in Indonesia's rural economy.

CONCLUSION

The findings of this study demonstrate that enhancing the management capacity of BUMDesa can be effectively achieved by integrating knowledge management principles with collaborative digital platform technologies. The development of SIBUDE serves as a practical innovation by combining a knowledge repository and digital communication tools aligned with the Pentahelix model. Through SIBUDE, BUMDesa managers, government officials, academics, media representatives, and business actors are provided with a unified space for sharing, acquiring, and managing knowledge in support of local economic development. The system not only addresses issues related to low managerial capacity and fragmented information but also creates a scalable and interoperable infrastructure that enables automated data exchange and peer-driven learning. By embedding principles of knowledge sharing and collaboration aligned with the Knowledge-Based Economy (KBE), SIBUDE contributes to empowering rural communities with accessible digital knowledge. As such, it offers a replicable model for rural digital transformation that aligns with national priorities for inclusive economic growth and digital literacy. The current phase of this study focused on system design, development, and preliminary implementation; formal usability evaluation and full-scale deployment are planned for subsequent phases. Future enhancements such as automated content extraction, semantic tagging, and machine-readable APIs will further strengthen the repository's utility and support BUMDesa in becoming active nodes within Indonesia's digital economy.

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