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Digitalization, Circular Economy, and BUMDes Sustainability: Evidence from the Bangka Belitung Islands Province

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Abstract

This study investigates the relationship between knowledge, attitude, perceived benefits, and support for the sustainability of digitalization in Village-Owned Enterprises (BUMDes) as a community empowerment mechanism within a circular economy framework in Bangka Belitung Islands Province, Indonesia. Motivated by environmental challenges—particularly waste management—and the need to enhance community empowerment through digital transformation, the study employed a convergent mixed-methods design. Quantitative data from 197 BUMDes managers were analyzed using multiple linear regression, while qualitative data from semi-structured interviews with 10 key informants were analyzed thematically. Knowledge and perceived benefits were positively and significantly associated with sustainability support, whereas attitude showed no significant association, reflecting an attitude–behavior gap linked to infrastructural, financial, and institutional barriers identified through qualitative analysis. Managerial knowledge and perceived advantages of digital technologies emerged as primary drivers of digital transformation, while inadequate infrastructure, limited digital competencies, financial constraints, and weak institutional support remained key barriers. These findings suggest that sustaining BUMDes digitalization as a community empowerment tool requires capacity building, institutional strengthening, collaborative governance, and supportive public policies. This study contributes empirical evidence on rural digital transformation, the circular economy, and community empowerment in an archipelagic region, offering practical implications for policymakers and community development practitioners.

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Introduction

Indonesia continues to face significant challenges in managing municipal and rural solid waste, particularly in archipelagic regions where geographic fragmentation, high

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transportation costs, and uneven infrastructure limit the efficiency of waste collection and recycling systems. In the Bangka Belitung Islands Province, the urgency of this issue is reflected in official waste data: in 2024, SIPSN recorded annual waste generation of 50,786.39 tons in Bangka Regency, 41,510.84 tons in Central Bangka Regency, 30,888.64 tons in West Bangka Regency, and 20,410.22 tons in East Belitung Regency (Ministry of Environment and Forestry, 2024). At the same time, digital readiness remains uneven. BPS reported that 76.06% of the population aged five years and above in Bangka Belitung accessed the internet in the last three months, with a gap between urban areas (80.08%) and rural areas (70.41%) (BPS-Statistics Indonesia, 2025a). These figures indicate that waste management and digital infrastructure remain interconnected local challenges, thereby underscoring the relevance of examining Village-Owned Enterprises (BUMDes) digitalization as a mechanism to support circular economy practices and village sustainability.

BUMDes play a central role in the framework of community empowerment in Indonesia. BUMDes function not only as village economic units but also as institutional vehicles through which rural communities gain collective control over local resources, income, and environmental management. Empirical studies have shown that BUMDes strengthen community empowerment when they effectively manage local resources and develop business units tailored to village needs (Puri and Khoirunurrofik, 2021; Ridhowati, 2024). In this context, the development of digital technology, which drives the digitalization of community life, increasingly supports the empowerment of BUMDes by integrating various digital tools into business management and community empowerment (Fatimah et al., 2026). According to Fatimah et al., BUMDes digitalization encompasses a range of empowerment-supporting technologies, including digital financial transaction systems, digital waste bank management, traceability platforms for recycling and by-product utilization, digital marketing of circular economy products, and applications that monitor community participation in waste management. These mechanisms are expected to enhance not only operational efficiency but also collective capacity, such as transparency, participation, and data-driven decision-making, which are fundamental to village community empowerment.

The circular economy is an economic system designed to minimize waste, extend product life cycles, and maintain materials in productive use through reuse, recycling, recovery, and regeneration. In a village context, circular economy practices can be implemented through composting organic waste, converting agricultural residues into value-added products, developing recycled handicrafts, utilizing biomass, and managing community-based waste banks. These practices are particularly relevant for BUMDes, as they integrate environmental management with local income generation and community empowerment. Digitalization enhances this process by enabling waste tracking, digital waste-bank transactions, product traceability, digital marketing of recycled products, and data-driven monitoring of community participation. International studies demonstrate that digital technologies—including digital platforms, IoT, blockchain, and data

analytics—support circular economy implementation by improving resource tracking, information flow, and circular business models (GACERE, 2025; Neri et al., 2023; United Nations Environment Programme, 2022). In Indonesia, research on waste-bank and BUMDes-based waste management shows that community-based circular practices can reduce waste while creating economic incentives for local communities (Helpiastuti et al., 2024; Rachman et al., 2021). Therefore, this study positions BUMDes digitalization as an enabling mechanism that links circular economy practices with village sustainability efforts. This approach aligns BUMDes digitalization with the global sustainable development agenda, particularly SDG 11 (Sustainable Cities and Communities) and SDG 12 (Responsible Consumption and Production), while grounding these global goals in a village-level empowerment framework. From a theoretical perspective, this study is grounded in the Theory of Planned Behavior (TPB) and the Diffusion of Innovations Theory. TPB explains that individual support for a behavior is shaped by beliefs, attitudes, perceived control, and expected outcomes (Ajzen, 1991). In this study, knowledge reflects BUMDes managers' cognitive understanding of digital technologies and circular economy practices, while attitude represents their evaluative orientation toward digitalization. Perceived benefits describe managers' beliefs that digitalization can generate economic, social, and environmental advantages for BUMDes and village communities. Meanwhile, the Diffusion of Innovations Theory explains how new ideas and technologies are adopted through perceived usefulness, compatibility, complexity, trialability, and observability (Rogers, 2003). Therefore, the adoption of BUMDes digitalization is not only a matter of technological availability, but also depends on managers' knowledge, attitudes, and perceptions of the benefits that digital innovation can provide for circular economy practices and village sustainability.

Attitude refers to BUMDes managers' favorable or unfavorable evaluation of digitalization as a means to support circular economy practices and village sustainability. According to the Theory of Planned Behavior, attitude is expected to encourage behavioral support when individuals believe that a particular action will yield desirable outcomes (Ajzen, 1991). However, a positive attitude does not always result in actual support or implementation. This phenomenon is known as the attitude–behavior gap, which describes the discrepancy between favorable evaluations and concrete behavior. Prior studies on sustainability behavior indicate that pro-environmental attitudes often fail to translate into action due to external barriers such as limited infrastructure, weak institutional support, financial constraints, and lack of operational capacity (Cherradi and Tetik, 2020; Wintschnig, 2021). In the context of BUMDes management, this gap may arise when managers support digitalization in principle but are unable to implement it because of limited internet access, insufficient funding, low digital skills, or weak organizational readiness. Therefore, attitude may play a different role than knowledge and perceived benefits in explaining support for sustainability.

Previous studies have demonstrated that knowledge, attitude, and perceived benefits are crucial factors in explaining sustainability-oriented behavior and the adoption

of environmental innovations. Research on the Theory of Planned Behavior in environmental and organizational contexts indicates that knowledge enhances individuals' awareness of environmental issues and influences their intention to support green practices, while perceived benefits facilitate the acceptance of innovation by making expected outcomes more tangible and valuable (Bouarar and Mouloudj, 2021; Samputra et al., 2025). Studies on circular economy awareness in Indonesia also reveal that knowledge, attitude, and behavior are closely linked to the understanding and acceptance of circular economy practices, particularly when circular principles are translated into concrete activities such as reducing, reusing, repairing, refurbishing, and recycling (Dewi et al., 2022). Furthermore, international literature emphasizes that digital technologies can accelerate the adoption of circular economy practices by improving resource tracking, information flows, and circular business models (Ávila-García et al., 2025; GACERE, 2025). In the Indonesian context, research on waste banks and BUMDes-based waste management indicates that community-based circular practices can generate economic incentives and strengthen local sustainability when supported by managerial capacity and digital tools (Ashar and Yunus, 2025; Rachman et al., 2021). However, most existing studies examine technology adoption, circular economy awareness, or waste-bank management separately. Therefore, this study positions knowledge, attitude, and perceived benefits as direct explanatory variables associated with sustainability support for BUMDes digitalization within a circular economy framework.

Despite the growing body of research on digital transformation, the circular economy, and BUMDes, empirical understanding of how managerial knowledge, attitudes, and perceived benefits translate into sustained community empowerment outcomes remains limited. Existing studies have largely examined technology adoption, waste-bank management, or rural entrepreneurship as separate domains, with little attention to the cognitive and attitudinal foundations that sustain—or fail to sustain—BUMDes-led empowerment processes once digital and circular economy instruments are introduced. This gap is particularly significant in archipelagic and small-island provinces, where empowerment efforts face distinctive structural constraints: dispersed villages, unequal digital infrastructure, and environmental pressures associated with mining activities and increasing municipal waste generation (BPS-Statistics Indonesia, 2025; Ministry of Environment and Forestry, 2024). Because empirical evidence on Indonesian village empowerment has been concentrated in more developed regions on Java, it remains unclear whether the cognitive and attitudinal pathways identified in mainland contexts apply in geographically fragmented settings such as Bangka Belitung. Examining this province therefore extends the Theory of Planned Behavior and Diffusion of Innovations Theory beyond their conventional applications, while generating evidence directly relevant to community empowerment policy and the digital transformation of village institutions in archipelagic regions.

This study aims to examine the relationships between knowledge, attitude, perceived benefits, and sustainability support for the digitalization of BUMDes within a

circular economy framework in the Bangka Belitung Islands Province. Drawing on the Theory of Planned Behavior and the Diffusion of Innovations Theory, it is hypothesized that managers with higher levels of knowledge (H1), more positive attitudes toward digitalization (H2), and stronger perceived benefits (H3) will demonstrate greater sustainability support for BUMDes digitalization. These hypotheses are based on the premise that cognitive understanding, favorable evaluations, and anticipated benefits encourage the acceptance of digital innovations that facilitate circular economy practices. However, previous studies have suggested that positive attitudes may not always translate into supportive behavior because organizational, financial, and infrastructural constraints can limit implementation. Therefore, if the association between attitude and sustainability support is not statistically significant, such findings should not necessarily be interpreted as contradicting the Theory of Planned Behavior. Instead, they may indicate the presence of an attitude–behavior gap, whereby favorable evaluations alone are insufficient to generate practical support in the absence of enabling institutional and technological conditions. This interpretation provides an important theoretical foundation for the subsequent discussion of the empirical findings, while acknowledging that the cross-sectional design permits conclusions regarding associations rather than causation.

Literature Review

BUMDes are village economic institutions established to manage local assets, develop village-based business units, and enhance community welfare (Puri and Khoirunurrofik, 2021; Ridhowati, 2024). In the context of rural sustainability, BUMDes are expected not only to generate village income but also to promote community participation, environmental stewardship, and local economic resilience. BUMDes digitalization refers to the adoption of digital technologies to improve business operations, transaction recording, market access, community engagement, and environmental management. In this study, BUMDes digitalization is operationalized through digital financial transactions, digital waste-bank management, digital marketing platforms, traceability systems for recycled products and by-product utilization, and applications for monitoring community participation in waste management.

The circular economy offers a pertinent framework for enhancing the sustainability role of BUMDes by emphasizing waste reduction, extending product life cycles, reusing materials, recycling resources, and regenerating natural systems (GACERE, 2025; Neri et al., 2023). In the village context, circular economy practices can be implemented through concrete activities such as organic waste composting, waste-bank schemes, utilization of agricultural residues, production of recycled handicrafts, biomass-based energy initiatives, and the conversion of waste into value-added products. Community-based waste banks in Indonesia have demonstrated their ability to generate economic value from recyclable materials while reducing environmental impact and fostering local participation (Fatmawati et al., 2024; Rachman et al., 2021). Digital technologies enhance these circular practices by facilitating waste recording, resource

tracking, transparent transactions, product traceability, and digital market access. Consequently, the digitalization of BUMDes can be understood as an enabling mechanism that links village business management with circular economy outcomes and sustainability support.

Knowledge refers to BUMDes managers' understanding of digital technologies, circular economy principles, waste management practices, and the potential role of digital systems in supporting sustainable village enterprises. In this study, knowledge encompasses both digital literacy and circular economy literacy. From the perspective of the Theory of Planned Behavior, knowledge strengthens behavioral beliefs because individuals who understand a program or innovation are more likely to evaluate its relevance, feasibility, and expected outcomes (Ajzen, 1991). According to the Diffusion of Innovations Theory, knowledge is also an early stage in the innovation-decision process, as potential adopters must first become aware of and understand an innovation before forming attitudes or making adoption decisions (Rogers, 2003). Therefore, BUMDes managers with a stronger knowledge of digitalization and circular economy practices are more likely to recognize how digital waste-bank systems, digital marketing, and traceability platforms can improve resource management and village sustainability.

Attitude refers to BUMDes managers' favorable or unfavorable evaluation of digitalization as a tool to support circular economy practices and village sustainability. In this study, attitude encompasses both cognitive and affective dimensions. The cognitive dimension pertains to managers' beliefs that BUMDes digitalization is important, useful, and relevant, while the affective dimension involves their acceptance, enthusiasm, and willingness to support digital transformation. According to the Theory of Planned Behavior, a positive attitude generally increases support for a behavior because individuals tend to endorse actions they evaluate favorably (Ajzen, 1991). However, attitude does not always translate into concrete support or implementation. This phenomenon, known as the attitude–behavior gap, refers to the discrepancy between favorable evaluation and actual behavior (Wintschnig, 2021). In organizational and rural governance contexts, this gap may occur because supportive attitudes are constrained by external factors such as limited internet access, inadequate funding, insufficient human resources, weak institutional support, or low organizational readiness. Therefore, attitude may have a weaker or different association with sustainability support compared to knowledge and perceived benefits.

Perceived benefits refer to BUMDes managers' beliefs regarding the tangible advantages of digitalization for business operations, environmental management, and village sustainability. In this study, perceived benefits encompass economic, social, and environmental dimensions. Economic benefits include improved transaction efficiency, expanded market access, increased income opportunities, and enhanced financial record-keeping. Social benefits involve stronger community participation, greater transparency, and improved accountability in BUMDes management. Environmental benefits consist of better waste monitoring, increased recycling, more effective waste-bank management,

and support for circular economy initiatives. Perceived benefits are central to innovation adoption because individuals and organizations are more likely to embrace an innovation when they believe it offers clear and observable advantages (Rogers, 2003). Therefore, BUMDes managers who perceive greater benefits from digitalization are expected to demonstrate stronger support for sustainability-oriented BUMDes development.

The relationship among knowledge, attitude, and perceived benefits should not be viewed solely as separate or additive factors. Prior studies on innovation adoption and sustainability behavior suggest that knowledge can serve as an antecedent that shapes attitudes and perceptions of benefits (Bouarar and Mouloudj, 2021; Dewi et al., 2022). Managers with greater knowledge of digital tools and circular economy practices are likely better equipped to evaluate the usefulness of digitalization and may develop more favorable attitudes toward its adoption. Conversely, limited knowledge may diminish perceived usefulness and undermine confidence in implementation. Nevertheless, this study employs a direct-effects model because its primary objective is to examine the independent associations of knowledge, attitude, and perceived benefits with sustainability support among BUMDes managers. This approach enables the identification of the factor most strongly associated with support for digitalizing BUMDes within a circular economy framework. More complex structural relationships involving mediation, moderation, or interaction effects among these constructs are recommended for future research.

The adoption of BUMDes digitalization in Bangka Belitung should be understood within the specific context of an archipelagic province. Small island and rural regions often face distinctive challenges, including dispersed settlements, unequal internet access, higher transportation costs, limited technical support, and fragmented waste management systems (BPS-Statistics Indonesia, 2025; Ministry of Environment and Forestry, 2024). These contextual factors may influence how BUMDes managers perceive digitalization and circular economy practices. For example, managers in areas with better internet infrastructure may be more capable of translating knowledge and perceived benefits into practical support, while managers in areas with limited connectivity may express positive attitudes but remain unable to implement digital systems effectively. Therefore, examining BUMDes digitalization in Bangka Belitung contributes to the literature by extending the discussion of digital innovation and circular economy adoption to small island rural governance contexts.

Based on the Theory of Planned Behavior and the Diffusion of Innovations Theory, knowledge is expected to be positively associated with support for sustainability. Managers with a stronger understanding of digital technologies and circular economy practices are more likely to support BUMDes digitalization because they recognize its relevance for waste management, market access, transparency, and village sustainability. Therefore, H1 is proposed: Knowledge is positively associated with sustainability support for BUMDes digitalization. Attitude is also expected to be positively associated with sustainability support because favorable evaluations of digitalization may increase managers' willingness to support digital transformation. Therefore, H2 is proposed:

Attitude is positively associated with sustainability support for BUMDes digitalization. Perceived benefits are expected to have a positive association with sustainability support because managers who perceive digitalization as economically, socially, and environmentally beneficial are more likely to support its adoption. Therefore, H3 is proposed: Perceived benefits are positively associated with sustainability support for BUMDes digitalization. If any of these hypotheses, particularly H2, is not supported, such a result should not necessarily be interpreted as inconsistent with the Theory of Planned Behavior. Instead, it may indicate that attitude alone is insufficient to generate support when enabling conditions, such as infrastructure, funding, digital skills, and institutional readiness—are not yet adequate.

Methods

This study employed a convergent mixed-methods design, integrating quantitative and qualitative approaches to achieve a comprehensive understanding of sustainability support for BUMDes digitalization within a circular economy framework. In a convergent design, quantitative and qualitative data are collected and analyzed separately but interpreted together to provide complementary explanations of the research problem (Creswell and Clark, 2018). The quantitative component examined the associations between knowledge, attitude, perceived benefits, and sustainability support using multiple regression analysis, while the qualitative component explored managers' experiences, perceived barriers, and contextual factors influencing the implementation of BUMDes digitalization. The study was conducted in the Bangka Belitung Islands Province, Indonesia, an archipelagic region consisting of six regencies and one municipality. This area was selected due to its growing emphasis on digital transformation, village economic development, and circular economy initiatives, while simultaneously facing challenges related to waste management and unequal digital infrastructure. The target population comprised active Village-Owned Enterprises (BUMDes) operating throughout the province. Eligible BUMDes were required to meet three criteria: (1) continuous operation for at least three years; (2) active management of one or more business units; and (3) implementation of environmental, waste management, or circular economy-related activities. A complete list of eligible BUMDes was obtained from the Provincial Office of Community and Village Empowerment and verified with district-level BUMDes databases prior to data collection.

A purposive sampling technique was employed because only BUMDes that met predefined operational criteria were considered capable of providing information relevant to the research objectives. Purposive sampling is appropriate when researchers intentionally select participants who possess specific experience or knowledge related to the phenomenon under study (Etikan, 2016). Invitations were distributed to eligible BUMDes across all districts and municipalities using both online questionnaires and onsite visits. Combining these two approaches helped reduce potential self-selection bias, particularly among BUMDes located in rural areas with limited internet access. After data

screening, a total of 197 valid questionnaires were retained for analysis. Respondents represented all districts and municipalities within Bangka Belitung Province. Their demographic characteristics included variations in age, educational background, managerial position, years of experience managing BUMDes, business sector, and organizational size, thereby providing sufficient diversity for statistical analysis.

Quantitative data were collected using a structured questionnaire that employed a ten-point Likert scale, ranging from 1 ("strongly disagree") to 10 ("strongly agree"). A ten-point scale was selected because it provides greater response variability and measurement sensitivity, allowing respondents to offer more nuanced evaluations compared to shorter scales (Preston and Colman, 2000). Prior to the main survey, the questionnaire underwent expert review and pilot testing to assess item clarity, content validity, and reliability. Pilot testing is essential for identifying ambiguous wording, enhancing item clarity, and ensuring that respondents interpret the items as intended (Dillman et al., 2014). Minor wording revisions were made to improve readability; however, no questionnaire items were removed, as all met the required validity and reliability criteria.

The questionnaire consisted of four constructs. Knowledge was assessed using six items that addressed digital literacy, understanding of the circular economy, waste management knowledge, digital applications, digital business processes, and environmental awareness. Attitude was measured with five items covering positive evaluation, acceptance of digitalization, willingness to adopt innovation, commitment to digital transformation, and confidence in digital implementation. Perceived benefits were evaluated using six items related to economic advantages, operational efficiency, transparency, environmental improvement, social participation, and market expansion. Sustainability support was measured through five items encompassing willingness to support digital transformation, participation in circular economy activities, promotion of digital innovation, long-term commitment, and institutional support.

Examples of questionnaire items include: "I understand how digital technologies can improve BUMDes operations" (Knowledge), "Digitalization is important for the future development of BUMDes" (Attitude), "Digitalization provides tangible economic and environmental benefits for BUMDes" (Perceived Benefits), and "I support the implementation of digital systems to enhance the sustainability of BUMDes" (Sustainability Support). To complement the quantitative findings, semi-structured interviews were conducted with ten purposively selected key informants, including BUMDes managers, village government representatives, and officials responsible for village empowerment. Semi-structured interviews are well suited for exploring participants' experiences while allowing flexibility to probe emerging themes (Kallio et al., 2016). Each interview lasted approximately 45 to 60 minutes, was audio-recorded with participants' consent, and transcribed verbatim for analysis.

Construct validity was assessed using corrected item-total correlations, while internal consistency reliability was evaluated using Cronbach's alpha. Cronbach's alpha

values of 0.70 or higher are generally considered acceptable in social science research (Nunnally & Bernstein, 1994). All constructs demonstrated Cronbach's alpha values exceeding this threshold, indicating satisfactory reliability. The pilot study confirmed that all questionnaire items adequately represented their intended constructs, and no items needed to be deleted.

The quantitative analysis employed descriptive statistics, Pearson correlations, classical assumption tests, and multiple linear regression. Multiple regression analysis was selected because it allows the researcher to estimate the relationships between several independent variables and a single dependent variable simultaneously (Hair et al., 2022). Classical assumption testing included assessments of normality, multicollinearity, heteroscedasticity, and outlier diagnostics. Normality was examined using residual distribution and probability plots. Multicollinearity was evaluated using Variance Inflation Factor (VIF) and tolerance values, with VIF values below 5 generally indicating that multicollinearity is not problematic (Hair et al., 2022). Heteroscedasticity was assessed through residual scatterplots. Potentially influential observations were examined using Cook's Distance and standardized residuals, as influential cases can distort regression estimates and reduce model robustness (Field, 2024). No substantial violations were identified; therefore, no corrective procedures such as variable transformation or robust estimation were necessary. Regression coefficients were reported using both unstandardized coefficients (B) and standardized beta coefficients (β), along with significance values, confidence intervals, and the coefficient of determination (R^2). Reporting confidence intervals is important because it provides information about the precision of regression estimates beyond statistical significance alone (Field, 2024).

Qualitative data were analyzed using thematic analysis, a systematic approach for identifying, analyzing, and reporting patterns or themes within qualitative data (Braun & Clarke, 2008). Interview transcripts were manually coded in three stages: open coding, axial coding, and selective coding. Emerging themes focused on digital infrastructure, managerial capability, institutional readiness, funding constraints, and perceptions of circular economy implementation. To enhance trustworthiness, the qualitative findings were validated through data triangulation, comparison with quantitative results, and member checking, wherein selected participants reviewed summaries of their interview responses. Triangulation and member checking are widely recognized strategies for strengthening the credibility of qualitative findings (Lincoln et al., 1985).

Participation was voluntary and based on informed consent. All respondents were informed about the purpose of the research, assured that their responses would remain confidential, and advised that they could withdraw from participation at any time without consequence. Personal identities were anonymized throughout data processing and reporting to ensure privacy and ethical compliance.

Result and Discussion

Respondent Characteristics

Age	Frequency	Percentage
20–30 years	78	39.6%
31–40 years	59	29.9%
>41 years	60	30.5%
Total	197	100%

Table 1. Distribution of Respondents by Age. *Source:* Primary data processed by the researchers, 2025.

Most respondents were in the 20–30 age group (39.6%), indicating that BUMDes managers are dominated by a productive-age generation that is relatively more adaptive to digital technology development. Meanwhile, respondents aged above 41 years accounted for 30.5%, reflecting strong institutional experience in BUMDes management. This composition is beneficial because the implementation of digitalization requires a combination of technological adaptability and organizational management experience.

Years of Operation	Frequency	Percentage
0–3 years	24	12.2
4–6 years	57	28.9
7–9 years	67	34.0
>10 years	49	24.9
Total	197	100.0

Table 2. Distribution of Respondents by Age. *Source:* Primary data processed by the researchers, 2025.

The majority of BUMDes have been operating for 7–9 years (34.0%), indicating that most organizations have reached a relatively stable institutional stage and are therefore better prepared to adopt digital innovations than newly established organizations. This finding is consistent with Khairina et al. (2025), who reported that organizational maturity enhances BUMDes' readiness for digital transformation through the establishment of organizational structures, standardized operational procedures, and accumulated managerial experience.

District of Origin	Frequency	Percent (%)	Valid Percent (%)	Cumulative Percent (%)
Bangka Barat Regency	36	18.3	18.3	18.3
Bangka Regency	32	16.2	16.2	34.5
Central Bangka Regency	40	20.3	20.3	54.8
South Bangka Regency	42	21.3	21.3	76.1
Belitung Regency	27	13.7	13.7	89.8
East Belitung Regency	20	10.2	10.2	100.0
Total	197	100.0	100.0	—

Table 3. Distribution of Respondents by District of Origin. *Source:* Primary data processed by the researchers, 2025

Table 3 shows that the respondents were drawn from all regencies in the Bangka Belitung Islands Province, providing a representative overview of BUMDes across the study area. The largest proportion of respondents came from South Bangka Regency (42 BUMDes; 21.3%), followed by Central Bangka Regency (40 BUMDes; 20.3%), West Bangka Regency (36 BUMDes; 18.3%), Bangka Regency (32 BUMDes; 16.2%), Belitung Regency (27 BUMDes; 13.7%), and East Belitung Regency (20 BUMDes; 10.2%). The relatively balanced distribution of respondents indicates that the study was not concentrated in a single geographical area but rather reflects the characteristics of BUMDes throughout the Bangka Belitung Islands Province. Variations in the proportion of respondents across regencies may be attributed to differences in the number of active BUMDes, the level of institutional development, and the readiness of each region to implement digitalization and circular economy initiatives. Before further analysis, the research instrument was tested for validity to ensure that each questionnaire item accurately measured the intended construct. Validity was assessed using item–item correlations (Pearson Correlation), where an item was considered valid if the significance value was below 0.05. The validity test results for the Knowledge variable are presented in Table 4.

Item	r-calculated	r-table	Remark
X1.1	0.769**	0.138	Valid
X1.2	0.759**	0.138	Valid

Table 1. Validity Test Results for Knowledge Variable. *Source:* Primary data processed by researchers, 2025

The Knowledge variable (X1) validity test showed that both items (X1.1 and X1.2) had r-calculated values of 0.769 and 0.759, respectively, which are greater than the r-table value of 0.138. Thus, all indicators were declared valid and suitable for this study. The validity test results for the Attitude variable (X2) are presented in Table 5.

Item	**r-calculated**	**r-table**	**Remark**
X2.1	0.458**	0.138	Valid
X2.2	0.389**	0.138	Valid
X2.3	0.481**	0.138	Valid
X2.4	0.427**	0.138	Valid
X2.5	0.437**	0.138	Valid
X2.6	0.534**	0.138	Valid
X2.7	0.450**	0.138	Valid
X2.8	0.445**	0.138	Valid

Table 2.Validity Test Results for Attitude Variable. *Source:* Primary data processed by researchers, 2025

All eight items of the Attitude variable (X2.1–X2.8) recorded r-calculated values ranging from 0.389 to 0.534, exceeding the r-table threshold of 0.138. Therefore, every indicator was declared valid and could be used in the subsequent analysis.
The validity test results for the Perceived Benefits variable (X3) are presented in Table 6.

Item	r-calculated	r-table	Remark
X3.1	0.660**	0.138	Valid
X3.2	0.676**	0.138	Valid
X3.3	0.686**	0.138	Valid
X3.4	0.653**	0.138	Valid
X3.5	0.147**	0.138	Valid

Table 3. Validity Test Results for Perceived Benefits Variable. *Source:* Primary data processed by researchers, 2025

All five items of the Perceived Benefits variable (X3.1–X3.5) achieved r-calculated values above 0.138, indicating that every indicator was valid and appropriate for analysis, although item X3.5 showed the weakest correlation among them. The validity test results for the Sustainability Support variable (Y) are shown in Table 7.

Item	r-calculated	r-table	Remark
X3.1	0.715**	0.138	Valid
X3.2	0.692**	0.138	Valid
X3.3	0.695**	0.138	Valid
X3.4	0.712**	0.138	Valid
X3.5	0.739**	0.138	Valid
X3.6	0.603**	0.138	Valid

Table 4. Validity Test Results for Sustainability Support Variable. *Source:* Primary data processed by researchers, 2025

All six items of the Sustainability Support variable (Y1–Y6) recorded r-calculated values between 0.603 and 0.739, exceeding the r-table value of 0.138. Consequently, all indicators were declared valid and suitable for use in the subsequent analysis.

After the validity tests, a reliability test was conducted to determine the internal consistency of the research instruments. Reliability was measured using Cronbach's Alpha, where an instrument is considered reliable if the alpha (α) value is ≥ 0.600. The results are shown in Table 8.

Variable	Criterion (α)	Cronbach's Alpha	Remark
X1	0.600	0.804	Reliabel
X2	0.600	0.672	Reliabel
X3	0.600	0.709	Reliabel
Y	0.600	0.774	Reliabel

Table 5. Reliability Test Results. *Source:* Primary data processed by researchers, 2025

The reliability test shows that all variables achieved Cronbach's Alpha values above 0.600. The Knowledge variable (X1) recorded the highest value at 0.804, indicating very strong reliability. The Sustainability Support variable (Y) was also robust with a value of 0.774, while the Perceived Benefits (X3) and Attitude (X2) variables, with values of 0.709 and 0.672 respectively, also met the reliability criterion. Thus, all instruments used in this study were declared reliable and trustworthy for further analysis.

Before performing regression analysis, the research model was tested for classical assumptions, including a normality test to determine whether the residual data were normally distributed. The One-Sample Kolmogorov–Smirnov Test was used, with the criterion that data are normally distributed if the significance value (Asymp. Sig.) is greater than 0.05. The results are presented in Table 9.

		Unstandardized Residual
N		197
Normal Parameters[a,b]	Mean	.0000000
	Std. Deviation	9.10316726
Most Extreme Differences	Absolute	.039
	Positive	.029
	Negative	-.039
Test Statistic		.039
Asymp. Sig. (2-tailed)		.200[c.d]

Table 6. Kolmogorov–Smirnov Normality Test. *Source:* Primary data processed by researchers, 2025

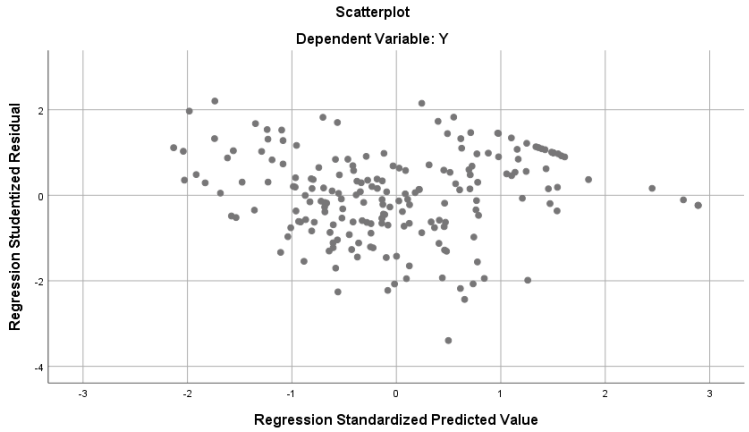
Based on the results, the sample size (N) was 197 with an Asymp. Sig. (2-tailed) of 0.200, which is greater than 0.05. This indicates that the residual data are typically distributed, meaning that the normality assumption is satisfied and the regression model is appropriate for further analysis.

A multicollinearity test was performed to ensure that the independent variables in the regression model were not highly correlated with each other. The test used Tolerance and Variance Inflation Factor (VIF) values, with the criteria of Tolerance > 0.10 and VIF < 10 as indicators of no multicollinearity. The results are presented in Table 10.

Model		Collinearity Statistics	
		Tolerance	VIF
1	X1	.812	1.231
	X2	.823	1.215
	X3	.730	1.370

Table 7. Multicollinearity Test Results. *Source:* Primary data processed by researchers, 2025

All independent variables recorded Tolerance values between 0.730 and 0.823 and VIF values between 1.215 and 1.370, meeting the required criteria. These results confirm that the regression model is free from multicollinearity, allowing each variable to be analyzed independently in explaining the dependent variable. A heteroskedasticity test was then conducted to determine whether the residual variance remained constant across predicted values in the regression model. A good model should be free of heteroskedasticity, which is indicated by a random scatter of residual points without any clear pattern. The results of this test are illustrated in Figure 2.



The scatterplot shows a random distribution of residuals with no visible pattern, indicating that the model satisfies the assumption of homoskedasticity and is therefore suitable for further regression analysis.

Based on the scatterplot, the residual points are randomly distributed above and below the zero line without forming any discernible pattern. This indicates that the residual variance is constant (homoskedasticity) and that the regression model is free from heteroskedasticity problems. Therefore, the classical assumption of homoskedasticity is fulfilled, allowing the regression results to be interpreted more accurately.

The hypothesis testing was then carried out using t-tests (partial tests) for each independent variable, and the results of these tests are presented in Table 11. Table 11 presents the results of the t-test (partial test) for the independent variables of Knowledge (X1), Attitude (X2), and Perceived Benefits (X3) on Sustainability Support (Y).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	**Std. Error**	**Beta**	**t**	**Sig.**
1	(Constant)	4.195	3.221		1.302	.194
	X1	.566	.171	.199	3.310	.001
	X2	.125	.068	.110	1.850	.066
	X3	.732	.094	.495	7.810	.000

Table 8. t-Test (Partial) Results. *Source:* Primary data processed by researchers, 2025

The t-test results show that Knowledge (X1) and Perceived Benefits (X3) have positive and significant effects on Sustainability Support ($p < 0.05$). In contrast, Attitude (X2) has no significant effect ($p = 0.066 > 0.05$). This indicates that support for sustainability is primarily determined by respondents' knowledge and perceived benefits

rather than by their attitudes alone. To evaluate the joint effect of the three independent variables on Sustainability Support, an F-test (simultaneous test) was conducted to assess the overall significance of the regression model. The results are presented in Table 12.

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	12506,935	3	4168,978	49,539	,000[b]
	Residual	16242,060	193	84,156		
	Total	28748,995	196			

Dependent Variable: Y; Predictors: (Constant), X3, X2, X1

Table 9. F-Test (Simultaneous) Results. *Source:* Primary data processed by researchers, 2025

The F-test results indicate an F value of 49.539 with a significance level of 0.000, which is well below 0.05. This confirms that the regression model is highly significant, meaning that Knowledge, Attitude, and Perceived Benefits collectively explain a significant portion of the variance in Sustainability Support.

The F-test confirmed that Knowledge (X1), Attitude (X2), and Perceived Benefits (X3) jointly have a significant effect on Sustainability Support (Y), with a significance value below 0.05. This finding demonstrates that the regression model is valid and capable of explaining the relationships among the variables. Thus, sustainability support is shaped not only by the individual influence of each variable but also by their combined contribution.

To determine the magnitude of this combined contribution, the coefficient of determination was examined using both R^2 and Adjusted R^2 values, which indicate the proportion of variance in the dependent variable explained by the independent variables. The results are presented in Table 13.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,660[a]	,435	,426	9,174

a. Predictors: (Constant), X3, X2, X1

Table 10. Coefficient of Determination (Model Summary).*Source:* Primary data processed by researchers, 2025

The results show an R value of 0.660, indicating a strong positive relationship between the independent variables (Knowledge, Attitude, and Perceived Benefits) and the dependent variable (Sustainability Support). The R Square value of 0.435 means that 43.5% of the variation in Sustainability Support can be explained by the three independent variables in the model, while the remaining 56.5% is influenced by factors outside this study. The Adjusted R Square value of 0.426 supports this finding by accounting for the number of independent variables, confirming that the model provides a reasonably good explanation of the dependent variable.

Qualitative Analysis

Qualitative findings were obtained through semi-structured interviews with selected BUMDes managers using purposive sampling to gain a deeper understanding of the factors influencing support for BUMDes digitalization within the context of the circular economy. The interview data were analyzed using thematic analysis, involving data reduction, coding, theme categorization, and interpretation to identify recurring patterns and key insights. The analysis revealed four major themes: (1) understanding of digitalization, (2) perceived benefits of digitalization, (3) barriers to digitalization implementation, and (4) institutional support needs.

Theme 1. Understanding of BUMDes Digitalization

Most informants perceived digitalization as a strategic approach to utilizing information technology to improve the effectiveness of BUMDes management, encompassing transaction recording, waste bank management, village product marketing, and financial reporting. They emphasized that digitalization not only streamlines administrative processes but also enhances transparency and accountability in organizational governance. These qualitative findings corroborate the quantitative results, demonstrating that knowledge positively and significantly influences sustainability support. This suggests that a higher level of managerial understanding regarding the functions and benefits of digitalization strengthens support for the digital transformation of BUMDes.

Theme 2. Perceived Benefits of Digitalization

Informants consistently perceived digitalization as delivering substantial benefits to BUMDes operations. These benefits include improved efficiency in transaction recording, enhanced financial transparency, more effective business management, wider market access through digital marketing platforms, and greater opportunities to create added value from circular economy-based waste management. Several informants further highlighted that digital systems strengthen public trust by improving the transparency and accessibility of information related to BUMDes activities. In addition, digitalization was viewed as an important mechanism for expanding the market reach of recycled products

beyond local markets, thereby supporting the long-term sustainability and competitiveness of BUMDes.

Theme 3. Barriers to Digitalization Implementation

Although the informants generally demonstrated positive attitudes toward digitalization, nearly all acknowledged the existence of significant barriers to its effective implementation. The most reported challenges included limited internet connectivity in rural areas, inadequate digital competencies among BUMDes managers, budget constraints for technological investments, the lack of user-friendly digital applications specifically designed for BUMDes operations, and insufficient technical support from local governments. As a result, many BUMDes have not yet been able to fully implement digitalization despite their willingness to embrace technological innovation. Consequently, support for digitalization remains largely at the conceptual level rather than being translated into effective organizational practices.

Theme 4. Institutional Support Needs

The final theme identified from the interviews underscores the critical need for stronger institutional support to facilitate the digital transformation of BUMDes. Most informants highlighted the importance of continuous digital capacity-building programs, ongoing technical assistance for the implementation of digital applications, improved information and communication technology (ICT) infrastructure, and government policies that provide incentives for BUMDes adopting circular economy-based waste management practices. The informants consistently emphasized that the success of digitalization depends not only on the competencies of individual BUMDes managers but also on sustained support from local governments, higher education institutions, and other development stakeholders. Accordingly, the digital transformation of BUMDes is perceived as a collaborative and multi-stakeholder process requiring coordinated efforts to strengthen institutional capacity, promote sustainable rural economic development, and enhance environmental sustainability.

Discussion

Influence of Knowledge on Sustainability Support

The findings indicate that knowledge has a positive and significant effect on sustainability support, suggesting that the greater the knowledge of BUMDes managers regarding digitalization and the circular economy, the stronger their support for the sustainability of BUMDes digital transformation. This finding suggests that BUMDes managers in the Bangka Belitung Islands Province who possess a better understanding of digitalization are more prepared to support its implementation in BUMDes management. Such knowledge includes the use of digital technologies for transaction recording, waste bank management, marketing recycled products, and preparing more transparent and accountable financial reports. Considering the characteristics of the Bangka Belitung

Islands Province as an archipelagic region facing waste management challenges, uneven digital infrastructure across rural areas, and geographically dispersed communities, managerial knowledge plays a critical role in enhancing readiness for digital transformation. A comprehensive understanding of the functions, benefits, and application of digital technologies enables BUMDes managers to utilize digitalization as a strategic instrument for improving operational efficiency while promoting the implementation of circular economy practices and sustainable rural development. These findings are consistent with the Theory of Planned Behavior (Ajzen, 1991), which posits that knowledge shapes individuals' behavioral beliefs, thereby influencing their intention to support and engage in a particular behavior. When BUMDes managers recognize that digitalization can enhance organizational performance and contribute to sustainable village development, they are more likely to support its implementation. The findings also support the Diffusion of Innovations Theory (Rogers, 2003), which identifies knowledge as the initial stage in the innovation adoption process. Before an innovation is adopted and implemented, individuals or organizations must first become aware of it, understand its functions, and evaluate its relevance. In the context of this study, BUMDes managers with greater knowledge of digital technologies and circular economy principles demonstrate stronger support for digitalization as a means of promoting sustainability. The findings are further supported by previous studies highlighting knowledge as a key determinant of environmental innovation adoption and sustainable behavior. Bouarar et al. (2021), Dewi et al. (2022), and Samputra et al. (2025) reported that higher levels of knowledge enhance individuals' awareness, readiness, and willingness to support environmentally oriented practices. Therefore, the first hypothesis, which proposed that knowledge positively and significantly influences sustainability support, is supported.

Influence of Attitude on Sustainability Support

The findings indicate that attitude does not have a positive and significant effect on sustainability support, indicating that the second hypothesis is not supported. Empirically, the results suggest that most BUMDes managers in the Bangka Belitung Islands Province hold positive attitudes toward the adoption of digitalization to support circular economy-based BUMDes management. They recognize that digitalization has the potential to improve administrative efficiency, enhance transparency in organizational management, and expand market access for village products. However, these positive attitudes have not been fully translated into actual support for digitalization initiatives. This situation is influenced by several constraints, including limited internet access in rural areas, inadequate digital competencies among BUMDes managers, budget limitations, and insufficient technical assistance from local governments. Consequently, positive attitudes alone are insufficient to foster sustainability support in the absence of adequate resources and an enabling environment.

These findings are not entirely consistent with the Theory of Planned Behavior (Ajzen, 1991), which suggests that positive attitudes toward a particular behavior generally

increase individuals' intentions and willingness to perform that behavior. In the context of this study, however, the positive attitudes of BUMDes managers have not been translated into tangible support for digitalization because they are constrained by external factors beyond individual control. Therefore, the relationship between attitude and support for digitalization appears to be indirect and contingent upon environmental conditions and organizational readiness.

The findings also support the concept of the attitude–behavior gap, which refers to situations in which individuals express positive attitudes toward an innovation but fail to translate those attitudes into actual behavior. This phenomenon has been widely documented in sustainability research, demonstrating that limitations in resources, infrastructure, and institutional support can hinder behavioral change despite favorable attitudes toward sustainable practices.

The present findings are consistent with those of Wintschnig (2021) and Cherradi (2020), who reported that positive attitudes toward sustainable behavior do not necessarily result in actual behavioral implementation due to various external barriers. In contrast, these findings differ from those reported by Bouarar et al. (2021), who found that attitude positively influences the adoption of environmentally friendly organizational practices. This discrepancy may be attributed to differences in the research context. Bouarar et al. conducted their study in organizations with more advanced digital infrastructure and higher levels of organizational readiness, whereas the present study focuses on BUMDes in the Bangka Belitung Islands Province, where digital infrastructure and human resource capacity remain relatively limited. Consequently, the second hypothesis, which proposed that attitude positively influences sustainability support, is not supported.

Influence of Perceived Benefits on Sustainability Support

The findings indicate that perceived benefits represent the strongest determinant of sustainability support for BUMDes digitalization in the Bangka Belitung Islands Province. BUMDes managers who perceive tangible benefits from digitalization are more likely to support the adoption of digital technologies in managing village-owned enterprises within a circular economy framework. These perceived benefits include improved administrative efficiency, simplified transaction recording, enhanced financial transparency, more structured waste bank management, expanded market access for recycled products, and increased community participation in waste management activities. For most managers, the tangible benefits derived from digitalization constitute the primary motivation for supporting digital transformation, exceeding the influence of knowledge or positive attitudes alone.

These findings are consistent with the Diffusion of Innovations Theory (Rogers, 2003), which identifies relative advantage as one of the most influential determinants of innovation adoption. According to this theory, individuals and organizations are more likely to adopt an innovation when they perceive that it offers substantial advantages over existing practices. In the present study, BUMDes managers who believed that

digitalization could improve organizational performance while generating economic, social, and environmental benefits demonstrated stronger support for sustainable digital transformation.

The findings also support the Theory of Planned Behavior (Ajzen, 1991), which argues that behavioral beliefs regarding the expected outcomes of an action significantly influence behavioral intentions. When BUMDes managers perceive digitalization as beneficial for village enterprise development and environmental management, they become more willing to support its implementation as part of sustainable rural development. These findings are consistent with Neri et al. (2023), who reported that digital technologies enhance the effectiveness of circular economy implementation through improved information management, resource efficiency, and business process transparency. Similarly, the UNIDO (2025) report highlights digitalization as a key enabler of the circular economy by improving operational efficiency, expanding market opportunities, and strengthening data-driven decision-making. In the Indonesian context, Ashar and Yunus (2025) demonstrated that the digitalization of waste bank management generates economic benefits for local communities while improving the effectiveness of community-based waste management systems.

The qualitative findings further strengthen these quantitative results. Interviews revealed that most BUMDes managers possess a clear understanding of the strategic importance of digitalization in improving organizational performance, including transaction recording, waste bank management, product marketing, and transparent financial reporting. This suggests that knowledge serves as the initial foundation for managers to recognize and accept digital innovation. Such findings reinforce the Diffusion of Innovations Theory, which emphasizes that innovation adoption begins with the knowledge stage, where individuals first become aware of, understand, and evaluate an innovation before deciding whether to adopt it (Rogers, 2003). These qualitative findings are also consistent with the studies of Bouarar et al. (2021), Dewi et al. (2022), and Samputra et al. (2025), which identified knowledge as a fundamental driver of awareness, readiness, and support for sustainability-oriented innovations.

Beyond knowledge, interview participants consistently emphasized that the perceived benefits of digitalization constituted the primary reason for supporting digital transformation. Managers reported that digital technologies improve operational efficiency, accelerate administrative processes, enhance financial transparency, expand market access for village products, and strengthen waste bank management as part of circular economy implementation. These findings further confirm Rogers' (2003) proposition that relative advantage is a key determinant of innovation adoption. The more tangible the benefits perceived by managers, the greater their willingness to adopt and support digital innovation. This interpretation is supported by Neri et al. (2023) and UNIDO (2025), who identified digitalization as an essential catalyst for accelerating circular economy implementation through improved resource management and operational efficiency. Likewise, Ashar and Yunus (2025) found that digital waste bank

management enhances both operational effectiveness and economic value creation within local communities.

Despite these positive perceptions, the qualitative findings reveal several barriers to BUMDes digitalization in the Bangka Belitung Islands Province, including limited internet access, inadequate digital skills, budget constraints, the lack of BUMDes-specific digital applications, and insufficient government technical assistance. These obstacles explain why positive attitudes have not consistently translated into implementation. This finding partially challenges the Theory of Planned Behavior (Ajzen, 1991), which suggests that favorable attitudes encourage behavior. In this study, however, external organizational and environmental constraints created an attitude–behavior gap, where positive attitudes did not necessarily lead to digital transformation. This phenomenon is consistent with the findings of Wintschnig (2021) and Cherradi (2020), who argued that sustainable behavior is often constrained by limited infrastructure, resource availability, and institutional support. Finally, the qualitative findings indicate that BUMDes managers expect stronger institutional support to accelerate digital transformation. Informants emphasized the importance of continuous digital capacity-building programs, ongoing technical assistance, improved digital infrastructure, and supportive government policies capable of facilitating digital innovation. These findings suggest that successful BUMDes digitalization depends not only on individual readiness but also on the availability of a supportive institutional ecosystem. This interpretation is consistent with Wahid, M. (2024) who argued that successful digital transformation in community-based organizations requires the integration of human resource capacity, digital infrastructure, and supportive public policies. Similarly, Khairina et al. (2025) concluded that the sustainability of BUMDes digitalization is strongly influenced by institutional governance quality and collaboration among multiple stakeholders. Overall, the integration of quantitative and qualitative findings demonstrates that successful BUMDes digitalization extends beyond technological adoption. It requires a combination of managerial knowledge, perceived organizational benefits, adequate infrastructure, institutional capacity, and collaborative governance. These factors collectively strengthen sustainability support and contribute to the effective implementation of circular economy practices in rural communities.

Conclusion

This study demonstrates that knowledge and perceived benefits have positive and significant effects on sustainability support for the digitalization of Village-Owned Enterprises (BUMDes) within a circular economy framework in the Bangka Belitung Islands Province, whereas attitude does not have a significant effect. The qualitative findings complement the quantitative results by revealing that managerial knowledge and the tangible benefits of digitalization are the primary drivers of sustainability support. At

the same time, limited digital infrastructure, inadequate digital competencies among BUMDes managers, and insufficient institutional support remain major barriers to effective implementation. Therefore, strengthening managerial capacity, improving digital infrastructure, and providing sustained policy and institutional support are essential to accelerate BUMDes digital transformation and promote the implementation of circular economy practices for sustainable rural development.

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Author's declaration

The authors collectively contributed to the conception and design of the study, data collection and analysis, interpretation of the findings, and preparation and critical revision of the manuscript. All authors read and approved the final manuscript and agree to be accountable for the integrity of the work.

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Availability of data and materials

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request, subject to participant confidentiality and applicable ethical considerations.

Competing interests

The authors declare no competing interest.

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