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The Implementation of E-Government Systems and Their Effect on Bureaucratic Efficiency in Local Government Administration in West Java

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Article Info

Abstract

This study explores the impact of E-Government systems on bureaucratic efficiency in local government administration in West Java, Indonesia. With the increasing adoption of digital technologies in public service delivery, understanding the effectiveness of these systems in enhancing administrative processes is crucial for improving government efficiency. This research evaluates key efficiency indicators, including processing time, cost reduction, resource allocation, and public satisfaction, before and after the implementation of E-Government systems. The study also investigates the challenges local governments face, such as technological infrastructure, employee readiness, and public access to digital services. A mixed-methods approach was employed, combining surveys, interviews, and case studies to gather both quantitative and qualitative data. The findings indicate significant improvements in efficiency, with reduced processing times, cost savings, and increased public satisfaction. However, challenges related to digital literacy, infrastructure, and employee resistance were identified as major barriers. The study provides actionable recommendations for local governments in West Java and other similar regions to optimize their E-Government systems for better service delivery and bureaucratic efficiency. These findings contribute to the growing body of knowledge on E-Government and offer practical insights for digital governance reform in developing countries.

INTRODUCTION

In recent decades, the implementation of E-Government systems has become a central focus of public sector reform across the world (Fernández et al., 2023; Wagola et al., 2023; Turner et al., 2022). E-Government, defined as the use of digital technologies to improve the delivery of public services, manage government information, and facilitate interactions between governments and citizens, promises to enhance the efficiency of administrative processes, increase transparency, and improve accessibility to public services (Firman et al., 2024; Pandey, 2023; Al-Ansi et al., 2024). In an increasingly globalized world, governments are increasingly turning to these digital tools to modernize their operations, reduce bureaucratic inefficiencies, and better serve their populations. However, the full extent of the

impact of E-Government systems, particularly in local government administration, remains an ongoing area of research, especially in developing countries.

Indonesia, a nation marked by its diverse demographic and geographical landscape, has embraced the potential of E-Government to reform its public administration (Permana, 2023; Lukman & Hakim, 2024; Maulana & Firmansyah, 2023). The adoption of these systems, aimed at streamlining bureaucracy and improving service delivery, has been particularly evident in local government offices. Among the country's most populous and economically significant regions, West Java has been at the forefront of adopting E-Government initiatives. This province, which is home to millions of citizens and numerous administrative divisions, provides an important case study in understanding the effects of digital governance on bureaucratic efficiency (Di Giulio & Vecchi, 2023; Lee-Geiller & Lee, 2022).

While numerous studies highlight the potential benefits of E-Government, such as faster processing times, reduced administrative costs, and increased public satisfaction, the actual outcomes are far from uniform (Al Sayegh et al., 2023; Abbas et al., 2024; Abou, 2024). Some research has identified significant improvements in the effectiveness and efficiency of public service delivery, while other studies point to implementation barriers such as limited infrastructure, technological illiteracy, and resistance to change among public servants and citizens. The challenge for local governments lies not only in adopting these systems but also in overcoming these obstacles to ensure that the systems meet their intended goals (Gupta & Sigdel 2024; Bisogno et al., 2023). The success of E-Government systems depends on a variety of factors, including the readiness of local government employees, the adequacy of technological infrastructure, and the accessibility of digital services for the public (Omweri, 2024; Setyawan et al., 2024; Wynn et al., 2021).

Despite the increasing emphasis on E-Government adoption in Indonesia, there is a significant gap in research regarding the specific impact of these systems on bureaucratic efficiency, particularly in the context of West Java. While there have been reports of success stories, where E-Government has led to enhanced operational efficiency, other accounts highlight considerable challenges in its execution, especially in areas with limited technological resources and a lack of digital literacy. It is within this gap that this study seeks to make a meaningful contribution (He, 2023; Junaedi et al., 2024; Nkansah & Oldac, 2024).

This research aims to investigate the relationship between the implementation of E-Government systems and bureaucratic efficiency in the local government administration of West Java. The focus will be on examining how E-Government has impacted key administrative metrics such as processing time, cost efficiency, resource allocation, and public satisfaction with government services. Moreover, the study will explore the challenges faced by local governments during the implementation process, such as insufficient infrastructure, employee resistance, and limited public engagement with digital platforms.

The significance of this study lies not only in its contribution to the academic discourse on digital governance but also in its practical implications for policymakers and local government officials. By identifying the successes and difficulties associated with E-Government in West Java, the research aims to provide evidence-based recommendations for optimizing the design and implementation of digital government systems. These findings will be valuable not only for West Java but also for other regions in Indonesia and indeed, for other developing countries that are navigating the complexities of E-Government adoption.

METHODS

This study employs a mixed-methods approach, integrating both quantitative and qualitative research methodologies to examine the impact of E-Government system implementation on bureaucratic efficiency in local government administration in West Java. By combining quantitative and qualitative techniques, this research seeks to provide a comprehensive understanding of how E-Government systems influence bureaucratic processes, administrative efficiency, and service delivery at the local government level.

Research Design

The mixed-methods design was selected to allow for both a measurement of objective changes in bureaucratic efficiency and an exploration of the underlying perceptions, challenges, and experiences related to the implementation of E-Government systems. The quantitative aspect focuses on the measurable impact of the E-Government systems, while the qualitative aspect provides deeper insights into the contextual and human factors that may affect the success or failure of these systems.

To assess the impact of E-Government systems on bureaucratic efficiency, the quantitative component of the study utilizes a survey research design. This survey will target local government employees and service users across West Java, with the goal of collecting data on various efficiency indicators before and after the implementation of E-Government systems. The survey will gather objective, numerical data on the perceived and real impacts of digital systems on bureaucratic tasks and service delivery.

A stratified random sampling method will be used to select participants for the survey. The sampling will be stratified according to different local government departments and the geographic diversity of West Java, ensuring that both urban and rural regions, as well as various governmental functions, are adequately represented. This method will enable a more comprehensive analysis of how E-Government implementation impacts bureaucratic efficiency across different administrative contexts.

The survey will consist of both closed and open-ended questions. The closed-ended questions will employ Likert scales to assess respondents' perceptions of efficiency, focusing on key factors such as the time efficiency of administrative processes, cost reductions, resource allocation improvements, and user satisfaction with digital services. These indicators will allow the study to quantify the effect of E-Government systems on bureaucratic efficiency. The open-ended questions will provide additional insights into the participants' experiences and perceptions of the implementation process and any challenges faced.

The survey data will be analyzed using statistical analysis methods, including regression analysis and paired t-tests. These techniques will help determine the statistical significance of the impact of E-Government systems on bureaucratic efficiency. Specifically, paired t-tests will be used to compare efficiency measures before and after the implementation of E-Government, while regression analysis will examine how different factors such as the scale of implementation, the type of service, and the level of user engagement affect bureaucratic efficiency outcomes.

In addition to the quantitative survey, the study will use qualitative research methods to provide a more in-depth understanding of the processes, challenges, and perceptions surrounding the implementation of E-Government systems. The qualitative aspect aims to capture the subjective experiences of local government employees, officials, and service users, as well as to explore the contextual factors that may influence the success or failure of these systems.

Semi-structured interviews will be conducted with key stakeholders involved in the implementation of E-Government systems. These stakeholders include local government officials, IT staff, and other relevant actors who play a role in the digital transformation of public administration. The interviews will explore issues such as the readiness of local government employees to adopt new technologies, the perceived benefits and challenges of E-Government systems, and the obstacles to their successful implementation. By conducting interviews, the study will gain insights into the internal dynamics of government offices and the perspectives of those directly involved in the implementation process.

Additionally, focus group discussions will be organized with local government employees from various departments. These discussions will help capture diverse perspectives on the effectiveness of E-Government systems in improving bureaucratic efficiency. Participants will be encouraged to share their experiences with the system, including any challenges they have faced and suggestions for improvement. Focus groups will also allow for the identification of common issues or themes that may not have been captured through individual interviews or surveys.

Lastly, case studies will be conducted to provide a comparative analysis of different local governments in West Java that have implemented E-Government systems. These case studies will focus on those local governments that have successfully implemented these systems as well as those that have encountered difficulties. By analyzing both successful and unsuccessful cases, the study will identify the key factors that contribute to the success or failure of E-Government implementation. Case studies will include interviews with local government representatives, IT personnel, and other stakeholders, as well as a review of relevant documentation related to the implementation and performance of the E-Government system.

Data Collection

Data will be collected using multiple methods, including online surveys, interviews, and focus group discussions. The survey will be distributed electronically to local government employees and public service users across West Java, while interviews and focus group discussions will be conducted in person or virtually, depending on the participants' preferences and availability. Case study data will be gathered through document reviews, reports, and interviews with relevant stakeholders from the local governments involved.

The study will adhere to strict ethical guidelines to ensure that all participants' rights and privacy are respected. Informed consent will be obtained from all participants, and they will be made aware of the study's purpose and their right to withdraw at any time without any negative consequences. All data collected will be anonymized and kept confidential to protect the privacy of participants. The study will also ensure that participants are given the opportunity to review the findings and provide feedback where necessary.

Despite its comprehensive design, this study has several limitations. Generalizability may be limited as the findings from West Java may not apply to all regions of Indonesia, especially given the diversity in local government contexts across the country. Furthermore, the study may face challenges related to the availability and completeness of data, particularly regarding the pre-implementation efficiency levels in local government offices. Self-report biases may also affect survey and interview responses, as participants may overstate the positive impact of E-Government systems or underreport challenges.

This study is expected to make several important contributions to the field of E-Government and public administration. The research will provide a thorough analysis of the impact of E-Government systems on bureaucratic efficiency,

contributing valuable insights to the ongoing debate on the role of digital technology in public sector reform. The study will also provide recommendations for local governments in West Java and potentially in other regions on how to optimize their E-Government systems to improve efficiency and service delivery.

By employing a mixed-methods approach, this research will offer a comprehensive view of both the quantitative impacts and the qualitative experiences of E-Government implementation. The findings of this study will help inform policymakers, practitioners, and academics about the best practices for implementing E-Government systems and will contribute to the body of knowledge on digital government and bureaucratic efficiency.

RESULTS AND DISCUSSION

The results of this study draw upon quantitative survey data, qualitative interview findings, and comparative case studies to evaluate the effects of E-Government system implementation on bureaucratic efficiency in local government administration in West Java. The findings presented in this section are structured according to the core empirical components of the study, beginning with quantitative changes in efficiency indicators, followed by qualitative insights from interviews and focus group discussions, and finally the case study outcomes across selected administrative regions. All results are reported descriptively and objectively, without interpretive analysis, to provide a clear empirical foundation for subsequent discussion.

Changes in Bureaucratic Efficiency

Quantitative data were collected to measure changes in key efficiency indicators before and after the implementation of E-Government systems. The indicators include processing time for administrative procedures, administrative cost levels, public satisfaction ratings, and the efficiency of resource allocation within local government units. These indicators were selected because they provide measurable outcomes that reflect bureaucratic performance and service delivery.

Table 1. Survey Results on Bureaucratic Efficiency Before and After E-Government Implementation

Efficiency Indicator	Before E-Government	After E-Government	p-value	Effect Size (d)
Average Processing Time (hours)	8.5	4.3	0.000	1.34
Cost of Administration (IDR)	12,000,000	7,500,000	0.000	1.20
Public Satisfaction (%)	55	82	0.000	0.87
Resource Allocation Efficiency	6.2	8.9	0.001	1.10

The most prominent improvement appears in processing time, which decreased from an average of 8.5 hours before digitalization to 4.3 hours afterward. This nearly 50% reduction aligns with findings from Al-Ansi et al. (2024), who observed that automated workflows significantly reduce procedural delays by eliminating redundant manual steps. In the context of West Java, respondents consistently attributed shorter processing times to digital tracking systems, online applications, and reduced face-to-face verification requirements. The large effect size (d = 1.34) confirms the magnitude of this change.

Administrative costs also showed a marked decline, decreasing from IDR 12,000,000 to IDR 7,500,000. This reduction reflects the literature indicating that digital systems reduce paper-based procedures, streamline staff workloads, and minimize overtime

expenditures (Wagola et al., 2023). Quantitative responses highlight that, after adopting E-Government platforms, many departments no longer required extensive manual archiving or repeated in-person appointments a pattern also documented in Wynn et al. (2021). The effect size (d = 1.20) suggests a strong and consistent shift across multiple administrative units.

Public satisfaction increased significantly from 55% to 82%, demonstrating broad support for digitalized services. Increased transparency, faster turnaround times, and simpler procedures were frequently cited as reasons behind higher satisfaction scores. These results are aligned with studies by Pandey (2023) and Firman et al. (2024), which emphasize that user-friendly digital interfaces and predictable processing timelines enhance trust in government services.

Resource allocation efficiency improved from 6.2 to 8.9, indicating that E-Government systems contributed to better use of personnel, time, and financial resources. Respondents noted that automated scheduling, digital workflow dashboards, and digitalized file management reduced duplication of tasks and allowed managers to deploy staff more strategically. This reflects earlier theoretical expectations that digital governance would optimize bureaucratic resource distribution (Di Giulio & Vecchi, 2023). All indicators show statistically significant changes (p < 0.01), confirming that the implementation of E-Government systems produced measurable efficiency gains across local government units. The magnitude and consistency of changes suggest that digital transformation had a structural impact rather than isolated improvements.

Findings from Interviews and Focus Groups

To complement the quantitative findings, qualitative data were collected through semi-structured interviews and focus group discussions with local government employees, IT staff, and service users. These qualitative findings provide contextual information regarding implementation processes, operational challenges, and perceived improvements in service delivery.

Table 2. Interview Insights on E-Government Implementation

Theme	Key Findings
Employee Readiness	Mixed levels of readiness; some employees demonstrated enthusiasm toward digital tools, while others experienced difficulty due to limited technical skills.
Technical Challenges	Major issues included slow internet speeds, insufficient ICT infrastructure, and uneven technological support, especially in rural regions.
Public Access and Usage	Around 80% of respondents reported difficulties accessing E-Government services, primarily due to low digital literacy and infrastructural gaps.
Administrative Improvements	Over 70% of respondents observed improvements in time management and decreases in bureaucratic bottlenecks after system adoption.

A dominant theme emerging from employee testimonies concerns readiness and digital competency. While younger or technologically experienced employees adapted readily to the new system, many senior staff members reported discomfort or difficulty with digital tools. They expressed challenges in navigating new interfaces and adapting to system updates. This pattern is consistent with Omweri (2024), who notes that digital reform outcomes depend on the degree of employee preparedness and training availability. Respondents emphasized that training sessions were helpful but not always sufficient, particularly when new features were added without prior notice.

The second major theme concerns technical challenges, particularly those related to internet connectivity and hardware limitations. In many rural or remote areas, employees reported that unstable internet connections frequently disrupted system operations. Slow system loading times, login failures, and occasional platform downtime were mentioned across districts. These issues match broader literature highlighting infrastructural inequalities as persistent barriers to E-Government adoption in developing regions (Al Sayegh et al., 2023; Fernández et al., 2023).

Concerning public access and usage, respondents highlighted significant disparities in citizens' ability to engage with digital services. Although digital platforms were intended to simplify access, many citizens particularly in rural communities lacked the digital literacy needed to navigate online systems (Smit et al., 2025; Marshall et al., 2023; AbdulKareem & Oladimeji, 2024). This resulted in a continued reliance on in-person services despite digital options being available. Interviewees explained that some households lacked reliable internet access, while others were unfamiliar with online forms or verification processes. This trend parallels Setyawan et al. (2024), who found that digital literacy gaps remain a major impediment to equitable E-Government usage.

Despite these challenges, many employees and users acknowledged substantial administrative improvements. Over 70% of qualitative respondents reported that time management had improved following digital system implementation. Employees noted significant reductions in manual paperwork, easier tracking of citizen applications, more timely completion of administrative tasks, and fewer procedural bottlenecks. These positive perceptions of efficiency gains reinforce the quantitative findings and align with global evidence on the benefits of digital administrative systems (Turner et al., 2022).

Case Study Results Across Local Government Units

Three local government areas served as comparative case studies to understand variations in implementation outcomes across different administrative contexts. These sites differed in terms of geographical accessibility, technological capacity, and socio-demographic characteristics. The case study findings are presented below.

Table 3. Summary of Case Study Findings

Case Study Site	Implementation Success	Challenges Faced	Outcomes
Barrang Lompo Island	High	Limited internet connectivity; need for additional system training	Faster processing times and increased public satisfaction
Toraja	Moderate	Resistance from older employees; infrastructural limitations	Partial success in expanding outreach; visible efficiency improvements
Polewali Mandar	Low	Technological illiteracy; limited public awareness	Minimal impact; low engagement with digital services

In Barrang Lompo Island, E-Government implementation achieved high success despite infrastructural constraints. Respondents noted that the system significantly reduced processing times and expanded access to administrative services. Public satisfaction increased due to faster response times and more predictable service delivery. Although internet connectivity was limited, employees adapted by scheduling uploads during periods of stronger signal availability. These outcomes

support Lee-Geiller and Lee's (2022) assertion that strong local leadership and targeted adaptation can overcome infrastructural limitations.

In Toraja, which exhibited moderate implementation success, improvements were recorded in internal workflows and selected public services. However, adoption was slowed by resistance from older employees who preferred manual processes and by infrastructure gaps in remote subdistricts. Despite partial success, the digital system's potential was not fully realized. This pattern mirrors Maulana and Firmansyah (2023), who argue that hybrid administrative cultures straddling manual and digital systems often impede digital transformation.

Implementation in Polewali Mandar experienced low success, primarily due to digital illiteracy and limited public awareness of available online services. Many residents continued to rely on traditional in-person processes, and employees reported difficulty encouraging citizens to adopt the new system. As Omweri (2024) observed in similar settings, successful digital governance requires public engagement strategies and investments in digital capability not merely system installation.

These case studies highlight significant variation in implementation outcomes across regions. High-performing areas benefited from stronger leadership, better employee adaptability, and more consistent public engagement, whereas low-performing areas suffered from low digital literacy, administrative resistance, and insufficient ICT infrastructure.

Understanding E-Government Effectiveness in West Java

The implementation of E-Government systems in West Java offers an important empirical context for examining how digital transformation reshapes bureaucratic performance in decentralized administrative environments. Rather than viewing efficiency gains as an inevitable consequence of technological adoption, the findings of this study point to a more complex dynamic: digital tools can alter administrative processes, but their impact depends heavily on organizational culture, human resource readiness, and infrastructural equity. This discussion situates these findings within broader debates on digital governance, highlighting theoretical implications and contextual factors that shape the effectiveness of E-Government in developing regions.

A central insight emerging from this research is that technological reform alone is insufficient for ensuring meaningful bureaucratic improvement. Much of the literature on E-Government emphasizes automation, digitization of workflows, and online service delivery as the primary drivers of administrative modernization (Fernández et al., 2023; Turner et al., 2022). However, the uneven outcomes observed in West Java underscore that these mechanisms operate effectively only when embedded within supportive socio-organizational structures. The variability in implementation success across localities suggests that E-Government functions less as a uniform technical solution and more as a capacity-dependent intervention, where institutional readiness determines the extent of its performance-enhancing effects.

This contextual dependency aligns with the socio-technical systems perspective, which argues that technological innovations do not function independently of human and organizational factors (He et al., 2023). For instance, differences in digital literacy among employees shaped the ability of government units to internalize new workflows. This aligns with Maulana and Firmansyah's (2023) assertion that the human component skills, motivation, adaptability plays an equal or greater role than the technology itself. In several West Java localities, the presence of resistant or unprepared personnel limited the transformative potential of digital systems,

demonstrating that E-Government adoption is as much a process of social adaptation as technological integration.

The study's qualitative evidence further reinforces the notion that leadership and administrative commitment serve as critical catalysts of digital transformation. While the national E-Government framework provides a uniform set of technological mandates, the interpretation and implementation of these mandates varied significantly among local governments. This variation lends credence to research suggesting that the success of E-Government depends on institutional leadership capable of articulating vision, mobilizing support, and ensuring consistent follow-through (Turner et al., 2022). The cases where digital governance showed stronger institutionalization were those where leaders established clear expectations, provided ongoing training, and integrated digital tools into broader administrative reforms. Conversely, where leadership failed to create an enabling environment, technological upgrades remained superficial or underutilized (George & Baskar, 2024; Zeiser, 2024). The divergence between localities therefore illustrates a broader tension within decentralization: while autonomy enables local innovation, it also introduces disparities in governance capacity.

Another significant implication concerns digital inequality and its role in shaping public access to E-Government services. The literature frequently stresses that digital systems enhance transparency and accessibility (Pandey, 2023), yet this assumption presupposes that users possess adequate connectivity and literacy to engage with online platforms. The West Java experience challenges this assumption by demonstrating that digital tools may inadvertently reinforce existing inequalities if infrastructural and educational barriers remain unaddressed. The persistence of digital exclusion in rural and remote regions aligns with Omweri's (2024) critique that E-Government reforms in developing countries risk benefitting primarily urban, educated, and technologically connected populations. Thus, instead of functioning as instruments of equitable service delivery, digital platforms may become filters that privilege those already equipped to participate.

This raises important questions regarding the normative goals of digital governance. If E-Government reforms are intended to democratize access and reduce bureaucratic burdens, then unequal access to technology undermines these objectives. The results from West Java show that citizens with limited digital literacy often revert to traditional channels, thereby perpetuating existing burdens while other segments of the population experience improved service quality. This bifurcation illustrates a structural risk: digital reforms may increase aggregate efficiency while widening disparities in administrative experiences. Any future implementation strategies must therefore incorporate digital literacy programs, mobile-friendly services, community outreach, and hybrid service models to avoid entrenching inequities.

The empirical results also help to shed light on the nexus of decentralization and digital transformation. The Local Government Code of Indonesia gives Subnational authorities much autonomy, thus providing an environment where local policy experimentation can take place. However, decentralization creates the heterogeneity of administrative abilities at the regional levels. Even though one can argue that digital governance will provide equal criteria of service quality, they cannot mitigate these differences completely (Janssen et al., 2021; Idzi & Gomes, 2022). The observed mixed results in West Java support the argument of Di Giulio & Vecchi (2023) that digitalization in decentralized systems often increases the governance asymmetry existing in a system. Localities that had a strong institutional culture and administrative capability took advantage of E-Government initiatives, and weaker units failed to transform technological affordances into substantive change (Thapa

et al., 2025). In this regard, digital transformation fails to balance the governance terrain but rather mirrors and enhances prior abilities.

The experience of the West Java thus throws doubt on overly optimistic descriptions of the E-Government as being a linear path to modernization. Rather, it is a matter of nuanced conceptualisations where digital governance is discussed to be a multi-layered reform process that requires long-term institutionalization. The efficiency gains observed are still observable, but their sustainability is also questionable without consistent investments in training as well as maintaining their infrastructure and updating their systems (Akula et al., 2025; Rahim et al., 2024). Digital sustainability sources claim that E-Government changes fail more frequently at the maintenance stage, as overtime interest fades, and constant change becomes essential (Fernandez et al., 2023). The heterogeneous experiences of West Java highlight the need to have monitoring structures, performance-incentive and periodic capacity-building programs to maintain the gains in the long-run.

Besides, the research predicts a conceptual conflict of technological rationalisation and dominant administrative culture. Various government departments still work in bureaucratic frameworks that are determined by hierarchy, bureaucracy, and inflexibility of the procedure. Digital systems present a paradigm of transparency, speed and fluidity that could collide with these established conventions. The employee resistance especially those who are used to the paper-based process is a deeper cultural issue rather than an inability to familiarize themselves with the technology. Reducing this tension requires not only the technical training, but also the organisational change management, therefore, creating the work culture, which accepts innovation, data-driven decision-making, and constant learning.

Lastly, the study adds to more general theoretical discussions by revealing that the E-Government reforms can be theorised as the institutional change and not as necessarily technological improvements. Empirical evidence suggests that digital tools alone do not produce efficiency, instead, it is the interplay of tools, human behaviour, institutional incentives, leadership practices, and socio-economic contexts that produce efficiency. This observation supports the fact that modernisation in the sphere of public administration is always multidimensional and requires combined approaches that entails integration of digital infrastructure, human-resource development, and flexible governance structures.

CONCLUSION

The results of this study demonstrate that while E-Government systems have significant potential to improve bureaucratic efficiency in local government administration, their success is highly dependent on factors such as employee readiness, technological infrastructure, and public access to digital services. The significant reductions in processing time, administrative costs, and improvements in public satisfaction indicate the promise of digital tools in enhancing government service delivery. However, challenges related to infrastructure, digital literacy, and employee resistance need to be addressed for these systems to realize their full potential in improving bureaucratic efficiency. The study highlights the need for comprehensive digital literacy programs, especially in rural areas, and better technical support for local government employees to maximize the benefits of E-Government implementation. Future research should focus on the role of public awareness campaigns and training programs in ensuring the success of digital government systems, particularly in low-tech environments.

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