

Exploration of Barriers and Strategies for Implementing Green Information System at the Directorate of Information Technology Universitas Brawijaya

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Abstract

This study explores user perceptions of Green Information Systems (GIS) at the Directorate of Information Technology (DTI), Universitas Brawijaya, and identifies strategies for enhancing GIS adoption using the Persuasive System Design (PSD) framework. Data were collected through semi-structured interviews with four employees from various roles, including system administrators and managerial staff. Using thematic analysis and coding processes (open, axial, and selective), findings reveal positive perceptions of GIS, particularly in energy management through server virtualization, document digitalization, and e-waste management. However, challenges such as the absence of formal policies, central regulations hindering digitalization, and a lack of automated energy monitoring persist. Recommended strategies include automated sleep modes integrated with cybersecurity education, regulatory advocacy for digitalization, and campaigns on e-waste management. The integration of Green IS with cybersecurity offers an innovative approach to accelerate GIS adoption while improving data protection, supporting sustainable IT operations at DTI Universitas Brawijaya.

Keywords: Green information system, persuasive system design, power management, document digitization, electronic waste management

Introduction

Universitas Brawijaya has positioned itself as a “Green Campus,” with various initiatives focused on expanding green open spaces and conserving biodiversity. Studies indicate that Universitas Brawijaya’s

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open spaces meet the criteria for a Green Campus, contributing to CO₂ reduction and environmental sustainability (Selaniar, 2014). Additionally, Universitas Brawijaya has introduced several environmental policies, such as biodiversity conservation and the establishment of an environmental research laboratory (Universitas Brawijaya, 2024a). However, despite these physical sustainability efforts, Green Information Systems (GIS) adoption at Universitas Brawijaya remains underdeveloped. There are no specific policies addressing sustainable GIS practices, such as energy-efficient infrastructure, e-waste management, or paperless digitalization initiatives. This gap highlights the lack of a comprehensive GIS strategy, despite its potential to enhance environmental sustainability and institutional efficiency. The adoption of GIS often faces challenges such as user resistance, lack of supportive regulations, and the need for adequate infrastructure (Rahkonen & Dietrich, 2023).

Globally, many universities have begun integrating Green Information Systems (GIS) into their sustainability strategies. Research suggests that GIS involves the environmentally conscious use of information systems and has been widely implemented in leading institutions worldwide (Sukarman, 2018). However, in Indonesia, GIS adoption remains limited, facing challenges such as technological complexity, infrastructure constraints, and weak regulatory support (Murugesan, 2008). Previous research highlights several critical factors related to GIS implementation. Kirchner-Krath et al. (2024) observed that user resistance to GIS is triggered by a lack of understanding of its benefits, concerns about changes to work habits, and perceived incompatibility with existing systems. Pal (2023) emphasized the importance of staff training, investment in green infrastructure, and interdisciplinary approaches to support the success of green technology in higher education. Meanwhile, Shevchuk and Oinas-Kukkonen (2020) proposed using the Persuasive Systems Design (PSD) framework to enhance GIS adoption through persuasive and user behaviour-based system approaches.

This study aims to explore user perceptions of GIS at the Directorate of Information Technology (DTI) Universitas Brawijaya and identify PSD-based strategies to enhance GIS adoption. This approach is expected to address major barriers and make GIS implementation more effective in supporting sustainable IT operations in higher education institutions. Figure 1 illustrates the organizational structure of the DTI at Universitas Brawijaya.

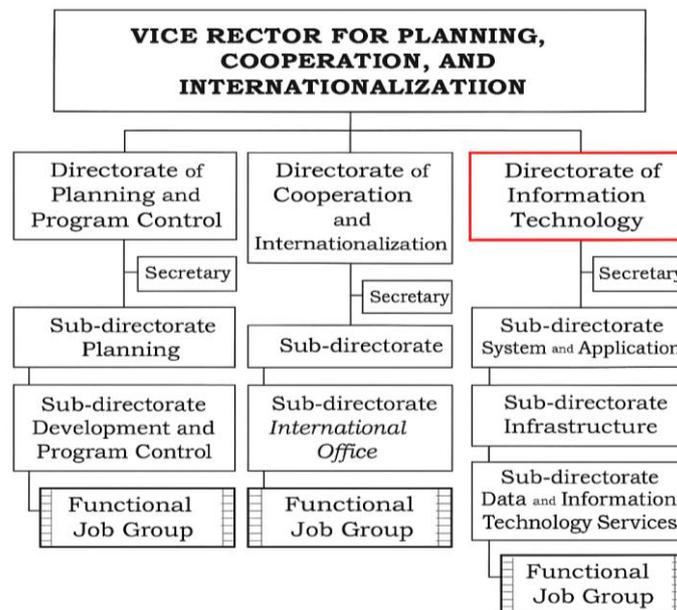


Figure 1. Organizational Structure of DTI Universitas Brawijaya (Universitas Brawijaya, 2024c)

The DTI at Universitas Brawijaya operates under the Vice Rector for Planning, Cooperation, and Internationalization. It comprises three key sub-directorates: Systems and Applications, Infrastructure, and Data and Information Technology Services. These divisions reflect the unit's organizational structure and focus areas in managing technology and information services. Beyond developing IT

infrastructure, DTI ensures optimal service delivery through its sub-directorates, emphasizing its strategic importance in supporting education and research at Universitas Brawijaya.

Literature Review

GIS focuses on the efficient and environmentally friendly use of information and communication technology. According to [Murugesan \(2008\)](#), GIS involves practices such as reducing energy consumption, using energy-efficient devices, and effectively managing electronic waste. In Indonesia, data from the Ministry of Environment and Forestry (KLHK) shows that electronic waste amounts to 1.3 million tons annually. The primary variables in this study are the level of awareness and adoption of Green Information Systems practices. This study will employ a qualitative thematic analysis to explore four aspects of GIS: power management, paper usage, data storage (server), and waste management.

[Kirchner-Krath et al. \(2024\)](#) focus on the challenges of GIS adoption within organizational contexts, employing theories such as Activity Theory, Innovation Diffusion Theory, and Technology Adoption Theory to explore adoption barriers at various stages. Their research highlights dilemmas such as social pressure, company regulations, and extrinsic environmental influences that impact GIS adaptation. This research intersects with the study of GIS in educational settings, offering insights into improving administrative efficiency in educational institutions.

[Pal \(2023\)](#) emphasizes the importance of staff training, investment in green infrastructure, and interdisciplinary approaches to integrating sustainable technology into higher education. Their findings point out challenges such as financial constraints, institutional resistance, and the need for digitalization to promote sustainability. This supports the relevance of continuous training and digitalization strategies in GIS adoption at Universitas Brawijaya.

[Shevchuk and Oinas-Kukkonen \(2020\)](#) explore Persuasive Systems Design (PSD) as a framework to enhance GIS adoption through user behavior-based design. They suggest that a well-structured PSD framework can assist in integrating regulations and solving daily challenges faced by employees in the education sector. This research highlights the potential for applying PSD principles to overcome resistance and regulatory obstacles in GIS implementation at DTI Universitas Brawijaya.

[Figure 2](#) illustrates that the Persuasive Systems Design (PSD) model offers a three-stage approach to system development: understanding fundamental issues influencing persuasive system design, analyzing the persuasion context, including intentions, events, and strategies, and designing or evaluating system quality and features to achieve persuasive goals. In this research, the problem formulation focuses on the context of persuasion (Analyzing the Persuasion Context), which aims to enhance GIS adoption at DTI Universitas Brawijaya. To achieve this, four main pillars are necessary: primary task support, dialogue support, system credibility support, and social support ([Oinas-Kukkonen & Harjumaa, 2009](#)).

Primary Task Support simplifies complex tasks into manageable steps with seven principles. Reduction simplifies tasks, Tunnelling guides users through processes, Tailoring ensures relevant information, and Personalization offers personalized content for better engagement. Self-monitoring allows users to track their progress, simulation demonstrates cause-and-effect relationships, and Rehearsal provides a practice environment. Dialogue Support enhances communication through seven principles, including Praise for positive behaviour, Rewards for achievements, Reminders for goal tracking, and Suggestions for relevant recommendations. Similarity and Liking create user engagement, while Social Role serves as a mentor figure for additional support.

System Credibility Support builds trust through principles such as Trustworthiness for accurate information, Expertise for reliable knowledge, Surface Credibility for a professional impression, and Real-world Feel for human or organizational presence. Authority, Third-party Endorsements, and Verifiability are used to strengthen system credibility. Social support leverages social influence to encourage behaviour with seven principles, including Social Learning, Social Comparison, Normative Influence, and Cooperation, while Competition and Recognition motivate behaviour through comparison and public acknowledgment.

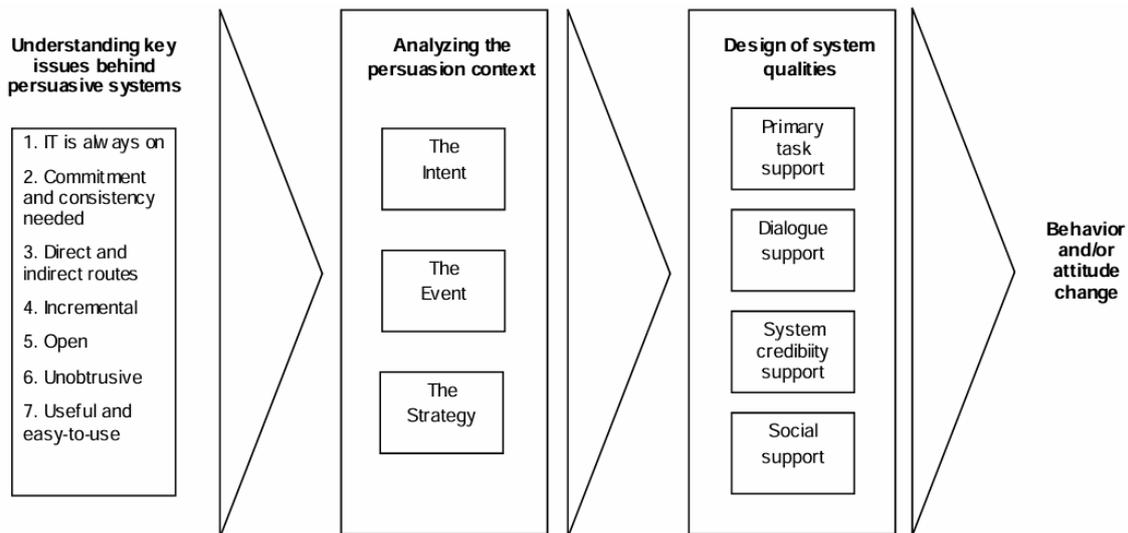


Figure 2. Persuasive Systems Design (PSD) Framework
([Oinas-Kukkonen & Harjumaa, 2009](#))

Methodology

This study employs a qualitative approach using a case study method, with data collection conducted through interviews to identify factors influencing perceptions and the adoption of GIS at the DTI at Universitas Brawijaya. Primary data was collected through semi-structured interviews with four respondents directly involved in GIS implementation. Respondents were selected from various levels, ranging from directors to sub-directorate staff, to ensure a comprehensive representation of work experiences related to the research topic. Respondent selection was conducted through purposive sampling to maximize the relevance of the obtained data.

Data processing will be carried out using Coding principles. Coding is a crucial step in the research process involving the organization of collected data by grouping or simplifying the data into more manageable categories ([Charmaz, 2006](#), in [Yukhymenko et al., 2014](#)). Coding consists of three main stages: open coding, axial coding, and selective coding, which are used to derive findings from the research ([Corbin & Strauss, 2008](#), in [Vollstedt & Rezat, 2019](#)).

The first stage in the coding process is open coding. Open coding involves breaking down, analyzing, comparing, conceptualizing, and categorizing data into specific groups ([Corbin & Strauss, 2008](#), in [Vollstedt & Rezat, 2019](#)). The second stage, axial coding, focuses on connecting main categories with subcategories and reorganizing categorized data to support the analysis being conducted ([Charmaz, 2006](#), in [Yukhymenko et al., 2014](#)). The final stage, selective coding, integrates the identified categories and organizes them into a systematic narrative or model ([Corbin & Strauss, 2008](#), in [Vollstedt & Rezat, 2019](#)).

Data validation was carried out through source triangulation and expert triangulation. First, interview results were consistently compared among respondents to ensure no bias or information inconsistencies. Second, validity sheets were sent back to respondents for direct verification with signatures. This layered triangulation ensures that the research findings are highly accurate and credible, providing deep insights into the implementation of GIS at DTI Universitas Brawijaya.

Thematic analysis results were aligned with the PSD framework, consisting of four main pillars: Primary Task Support, Dialogue Support, System Credibility Support, and Social Support. Each finding in this study was categorized under the principles of the PSD framework to generate relevant practical recommendations.

Results

The results of this study are derived from a thematic analysis of interviews conducted at the DTI, Universitas Brawijaya, following the coding process (open coding, axial coding, and selective coding) and aligned with the PSD framework. This section presents the analysis based on four key aspects: power management, paper usage, data storage, and electronic waste management. Interviews were conducted with four (4) employees at DTI Universitas Brawijaya, consisting of system administrators and managerial staff. After transcription, the data were analyzed to identify recurring themes, allowing for a structured exploration of the challenges and opportunities in GIS adoption at DTI Universitas Brawijaya. The following subsections detail these findings, supported by direct quotes from respondents for authenticity.

Regarding power management, DTI Universitas Brawijaya does not have a formal policy on energy efficiency. Instead, power-saving measures, such as turning off devices (lights, air conditioning, and monitors) after working hours, are only practiced as informal habits rather than enforced regulations. This results in inconsistent implementation across different units. One respondent stated, *“There is no written regulation; everything is based on habit.”* (Respondent 4). While server virtualization has reduced the number of physical devices and improved energy efficiency, capacity adjustments are still managed manually due to the unreliability of past automation attempts. As one respondent noted, *“So far, it has been done manually because when we tried automation, it did not meet expectations.”* (Respondent 1). Additionally, certain servers must remain operational 24/7 to support university services, creating a challenge in optimizing power consumption. *“Some PCs must remain on continuously because they are connected to university services.”* (Respondent 3). Another major issue is the absence of external energy audits, meaning there is no standardized benchmark for energy consumption efficiency.

In terms of paper usage, digitization efforts through *Pendapa*, an application for document processing and e-signatures, have significantly reduced paper consumption in administrative processes. *“We try to digitize as much as possible. The Pendapa application allows us to create and send documents without needing to print them.”* (Respondent 2). However, central regulations still mandate the physical printing of financial documents and certain certificates, limiting the full transition to paperless operations. *“The central office in Jakarta requires printed documents with physical signatures and stamps.”* (Respondent 1). Another challenge is the lack of standardized policies for digital documents across external organizations, making electronic certificates and documents less widely accepted. *“We anticipate that many companies still prefer conventional certificates instead of digital ones.”* (Respondent 2). Despite these obstacles, DTI UB continues to promote paperless workflows, aiming to cut costs, minimize paper waste, and improve bureaucratic efficiency. *“Going paperless helps reduce costs and improve productivity by eliminating bureaucratic delays.”* (Respondent 2).

For data storage, DTI Universitas Brawijaya primarily uses on-premise storage due to security concerns, cost efficiency, and improved access speeds. Storing large volumes of data on the cloud is considered expensive and raises security risks. One respondent highlighted, *“Since our data is already very large, moving it to the cloud would be more costly.”* (Respondent 1). Additionally, *“For security reasons, we prefer to store data in our own data center.”* (Respondent 1). Cloud services, such as Google Drive, are only used for specific purposes, while most university services remain on-premises to ensure better control over data. *“Some services, like Google Drive, are available for all users, but other major services remain on-premise.”* (Respondent 3). Furthermore, energy monitoring at the data center helps optimize operations and bandwidth allocation, reducing latency and improving performance. *“Because data is stored locally, bandwidth usage is more optimized, and latency is reduced.”* (Respondent 1).

In the case of electronic waste management, DTI Universitas Brawijaya manages e-waste using SIMASTER, an asset management application that tracks and stores damaged electronic equipment before disposal. *“For disposal, we follow internal regulations. We also have a storage facility for damaged items.”* (Respondent 2). Devices that are still functional but outdated are often redirected to other units, such as the university library. *“Instead of immediate disposal, we transfer old but usable devices to other units, like the library.”* (Respondent 1). The most frequently upgraded devices are access points, as they need to support an increasing number of users and evolving technological

demands. “Access points are frequently replaced to improve capacity and serve more users.” (Respondent 2). Additionally, the procurement of new equipment is managed through SIREKA, an application that ensures that technical specifications meet operational requirements. “We use SIREKA, an information system for procurement planning, to ensure that technical specifications are clearly defined and prevent mismatches.” (Respondent 2).

Thematic analysis findings were then mapped onto the Persuasive Systems Design (PSD) framework. In the Primary Task Support category, DTI Universitas Brawijaya has implemented the principle of Reduction through the *Pendapa* application, which simplifies paper management and improves administrative efficiency. However, Tunneling has not been systematically applied, as there is no structured step-by-step guide for users to adopt environmentally friendly behaviors. Tailoring is evident through server virtualization based on service needs, but Personalization remains minimal since the system does not offer customized experiences for users. Moreover, Self-monitoring is absent, as there are no tools to track individual energy consumption or carbon footprints.

In the Dialogue Support category, Reminders exist through verbal instructions to turn off electronic devices, but Praise and Rewards are not integrated into the system, meaning users do not receive recognition for environmentally friendly actions. Suggestions are also lacking, as the system does not proactively offer energy-saving recommendations. Similarly, Social Role elements, such as mentoring features, are absent, reducing opportunities for guided sustainability efforts.

Regarding System Credibility Support, DTI Universitas Brawijaya demonstrates Trustworthiness through accurate and transparent monitoring systems and SIMASTER, which enhance trust in IT management. Expertise is evident in the implementation of server virtualization, reflecting the institution’s technical capabilities. However, Surface Credibility and Real-world Feel are underdeveloped, particularly in the professional representation and visibility of GIS initiatives. Third-party Endorsements and Verifiability are also lacking, as there is no external validation or certification supporting DTI Universitas Brawijaya’s sustainability efforts.

In the Social Support category, GIS adoption at DTI Universitas Brawijaya remains limited. Social Learning and Social Comparison are not yet implemented, meaning users cannot compare their sustainability efforts with peers. Normative influence is weak, as no institutionalized social norms promote sustainable IT practices. Social Facilitation and Cooperation exist informally, particularly in shared efforts to turn off unused devices, but these initiatives are not embedded in the GIS system. Competition and Recognition mechanisms are absent, despite their potential to encourage participation through incentives and awards for energy-saving efforts.

Therefore, DTI Universitas Brawijaya has adopted some GIS principles, particularly in Reduction (paperless workflows), Reminders (verbal energy-saving habits), and Trustworthiness (accurate system monitoring). However, most PSD principles remain underdeveloped, particularly in Self-monitoring, Rewards, Social Learning, and Competition. To enhance GIS adoption, DTI Universitas Brawijaya should establish formal energy policies, introduce automated energy monitoring tools, develop incentive programs, and integrate PSD-based feedback mechanisms to encourage sustainable behavior. These improvements will help create a more persuasive and effective system to support environmentally responsible IT practices at Universitas Brawijaya.

The findings of this study align with existing literature in several areas. For instance, the challenge of inconsistent user behavior in energy-saving practices due to the absence of formal policies at DTI Universitas Brawijaya mirrors findings by Kirchner-Krath et al. (2024), who emphasized that user resistance often stems from unclear internal regulations and a lack of structured incentives. The server virtualization efforts at DTI Universitas Brawijaya resemble the strategies proposed by Meenakshi et al. (2020), which highlight the effectiveness of local data storage optimizations in reducing energy consumption. Similarly, DTI Universitas Brawijaya’s difficulty in achieving a fully paperless environment due to external regulations is consistent with Ahmad et al. (2013), who identified the need for a uniform policy and organizational awareness for successful digital transformation. Moreover, the integration of document digitization at DTI Universitas Brawijaya echoes the approach outlined by Anuradha (2024), who stressed the importance of internal digitization practices in fostering sustainability. However, DTI Universitas Brawijaya has yet to implement comprehensive Persuasive

Systems Design (PSD) mechanisms such as simulation, competition, and rewards—an area where Shevchuk and Oinas-Kukkonen (2020) argue significant improvements can be made to increase user engagement and behavioral change.

Discussion

Users at DTI Universitas Brawijaya recognize the importance of power efficiency, particularly through server virtualization, which has significantly reduced energy consumption. However, the absence of formal energy policies has resulted in inconsistent implementation of power-saving practices, such as sleep time automation and unused device management. While some staff members turn off devices after working hours, these efforts remain informal and unregulated. According to [Wen & Hung \(2007\)](#), implementing dynamic sleep time intervals through measured power management can improve efficiency. Similarly, [Fan et al. \(2017\)](#) highlight that integrating multi-level sleep modes via GreenSleep can further optimize power savings. Unlike previous studies that emphasize energy-saving automation, DTI Universitas Brawijaya still relies on manual interventions, which may lead to inefficiencies. Thus, adopting a measurement-based sleep time mechanism, combined with formalized internal energy policies, could help standardize power-saving behaviors. Additionally, Self-monitoring features should be integrated to allow users to track energy consumption in real-time, aligning with findings from [Kirchner-Krath et al. \(2024\)](#), which suggest that monitoring tools enhance user engagement with sustainability initiatives.

Beyond energy efficiency, the integration of cybersecurity measures into automated sleep modes could provide dual benefits: reducing power consumption while safeguarding sensitive data. Research by [Shevchuk & Oinas-Kukkonen \(2020\)](#) suggests that PSD can improve adoption by incorporating elements like Reminders and Self-monitoring. For instance, a notification system that alerts users about prolonged device inactivity could serve as a gentle reminder while also reinforcing cybersecurity measures. To further incentivize energy-saving behavior, DTI Universitas Brawijaya could implement a Rewards system, where teams that consistently reduce energy consumption receive institutional recognition or benefits. The digitalization of administrative systems at DTI Universitas Brawijaya, including electronic document management and digital signatures, has led to significant reductions in paper usage and improved process efficiency. However, regulatory barriers remain, particularly the requirement for physical signatures on certain financial documents, which hinders a full transition to paperless operations. Research by [Anuradha \(2024\)](#) highlights that digital transformation is a key component of environmentally friendly practices, yet [Ahmad \(2013\)](#) argues that successful adoption depends on collective awareness and uniform policies. DTI Universitas Brawijaya's experience aligns with these findings, as inconsistent national regulations on digital documents have limited its ability to implement a fully paperless system.

To strengthen Dialogue Support, DTI Universitas Brawijaya could introduce institutionalized education campaigns that highlight the security and efficiency benefits of digitalization. Additionally, System Credibility Support can be improved by securing third-party endorsements, such as ISO certification for digital document security, to build greater trust and legitimacy in the institution's paperless initiatives. Expanding Social Support mechanisms—such as creating a knowledge-sharing platform where staff members can exchange best practices on digitalization—could further facilitate acceptance of digital transformation efforts. While DTI Universitas Brawijaya has made significant strides in implementing Green IS principles, critical gaps remain in Self-monitoring, Competition, and Rewards. Introducing real-time monitoring dashboards for power usage, institution-wide sustainability competitions, and incentive programs can enhance user engagement and accelerate adoption. By integrating these Persuasive System Design elements, DTI Universitas Brawijaya can move beyond informal sustainability efforts toward a structured, long-term Green IS strategy that is both effective and scalable.

On-premise data storage at DTI Universitas Brawijaya is valued for its cost efficiency and enhanced security, especially for large-scale data. Despite the global shift toward cloud services for lower carbon footprints, on-premise solutions remain crucial due to data characteristics and security concerns. [Arya et al. \(2020\)](#) propose strategies like proxy and power management to enhance local data storage

efficiency. [Rahkonen & Dietrich \(2023\)](#) suggest hybrid storage models combining on-premise and cloud to balance security and carbon reduction. Implementing automated energy monitoring systems could further optimize DTI Universitas Brawijaya's data center operations. Primary Task Support has been implemented by DTI Universitas Brawijaya, proven by opting for on-premise storage solutions tailored to specific needs. However, the lack of Self-monitoring for energy consumption management limits efficiency. Introducing a hybrid approach with automated energy monitoring, supported by System Credibility Support through Verifiability, will help maintain data security while improving sustainability. Furthermore, educating users on data security and energy efficiency is crucial to enhancing the effectiveness of these storage solutions.

Waste management at DTI Universitas Brawijaya is regarded as effective through the use of SIMASTER, which provides systematic tracking and reuse of electronic equipment. However, increasing awareness of sustainable waste management remains a challenge. [Anuradha \(2024\)](#) emphasizes the importance of circular economy approaches, where reuse and recycling are prioritized. [Ahmad et al. \(2013\)](#) highlight that social awareness and education can drive better waste management practices. DTI Universitas Brawijaya can further enhance these efforts by launching internal campaigns and providing incentives for sustainable electronic waste management. This analysis highlights that DTI Universitas Brawijaya utilizes Primary Task Support through the SIMASTER application for electronic waste management, adhering to the Reduction principle. Yet, the absence of Simulation features to visualize the impact of recycling limits the effectiveness. Enhancing Dialogue Support with rewards for units excelling in waste management can promote better adoption. Integrating education on electronic waste management with cybersecurity awareness ensures a more comprehensive approach to Green IS, aligning with both Security and Normative Influence principles.

Implications

This study contributes to the growing body of knowledge on GIS implementation by demonstrating how user perceptions and institutional practices interact within a higher education setting in Indonesia. Unlike many previous studies that focus on Western or corporate contexts, this research offers insights from a public university environment where regulatory, infrastructural, and cultural limitations shape sustainability efforts. From a theoretical perspective, this study reinforces the relevance of the PSD framework in analyzing GIS adoption. It expands upon the framework by applying it not only to individual user behavior but also to institutional policy gaps, offering a broader lens for interpreting persuasive design elements in organizational settings.

Practically, this study informs university policymakers and IT directors about critical areas for intervention, such as the need for formal energy efficiency policies, reward systems, and digital document standardization. By connecting GIS practices with cybersecurity and digital administration, this research advocates for an integrated sustainability strategy. These findings can serve as a roadmap for similar institutions seeking to transition toward sustainable IT practices without significant infrastructural overhaul. This study also points to a promising direction for future research exploring the relationship between cybersecurity and Green IS, particularly in the context of automated energy-saving features such as sleep modes. Investigating how these two domains can complement each other, ensuring both operational sustainability and data security, may lead to the development of more holistic system designs tailored for educational and public sector institutions.

Conclusion

This study reveals that user perceptions of the benefits and challenges of Green IS practices at the DTI Universitas Brawijaya are generally positive, despite notable obstacles. Power management has demonstrated efficiency through server virtualization, yet the lack of formal policies, such as automated sleep mode mechanisms, remains a challenge. Paper usage has been minimized through digitalization, but central regulations mandating the use of physical documents continue to be a hindrance. On-premise data storage is deemed suitable for DTI Universitas Brawijaya's needs, although energy monitoring audits and cloud integration require further development. Electronic waste management has been

systematically conducted using the SIMASTER application, but increasing user awareness of sustainability still needs enhancement.

Strategies to enhance the adoption of Green IS practices at DTI Universitas Brawijaya can leverage PSD principles. These include educating users about power management through posters, reminders, and formalizing internal policies (Social Support and Normative Influence) related to sleep mode procedures for idle computers or laptops (System Credibility Support). Continuous advocacy for paperless practices across all units interacting with DTI, including central financial policymakers (Dialogue Support), is essential. Conducting specific internal audits to evaluate Green IS behavior, covering both user habits and server performance (System Credibility Support), should be prioritized. Additionally, implementing education and reward systems for sub-directorates that successfully maximize the use of tools before replacement (Third-party Endorsements, Rewards) is recommended to foster sustainable practices.

To further promote Green IS adoption, DTI Universitas Brawijaya should establish formal policies related to power management, including education and formal regulations for implementing automatic sleep mode integrated with cybersecurity measures. Continued advocacy with central financial authorities is necessary to support the adoption of digital document standards and address regulatory barriers. User education on electronic waste management needs to be reinforced through targeted educational campaigns and reward programs. This study is limited by its small sample size and focus on a single institution. Future research should explore larger-scale implementations and the intersection between GIS and cybersecurity.

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