ISSN: 2723-9535

Available online at www.HighTechJournal.org

HighTech and Innovation Journal

Vol. 6, No. 2, June, 2025

Analysis of Success Factors for Green IT Implementation in Higher Education

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Received 27 December 2024; Revised 03 April 2025; Accepted 18 April 2025; Published 01 June 2025

Abstract

This study aims to identify success factors in the implementation of Green Information Technology (Green IT) in the higher education sector in Indonesia, which is increasingly challenged to implement sustainable practices. Using the Interpretive Structural Modeling (ISM) method, this study analyzes and maps the hierarchical relationships between key factors to provide a more structured understanding of the dynamics of Green IT implementation. The results show that external and social pressures are the main drivers in shaping sustainability policies in higher education. These policies then influence various important aspects such as management commitment, environmental awareness, infrastructure development, and budget allocation. In addition, this study highlights how the interaction between these factors creates an ecosystem that supports the sustainability of Green IT in the academic environment. The novelty of this study lies in the finding that external factors play a more dominant role than internal motivations in driving the implementation of Green IT in Indonesia, unlike the pattern common in developed countries. The practical implications of this study provide insights for policymakers in designing responsive sustainability strategies, strengthening institutional commitment, and increasing environmental awareness in higher education. However, this study also found several major obstacles in the implementation of Green IT, including lack of financial resources, resistance to change, lack of technical skills, and suboptimal coordination between stakeholders. Therefore, recommended improvement strategies include strengthening incentive-based policies, increasing environmental literacy through educational programs, optimizing investment in green infrastructure, and integrating Green IT into academic curricula. This study provides practical insights for policymakers to design more effective sustainability strategies, strengthen institutional commitment, and increase environmental awareness across higher education institutions.

Keywords: Green Information Technology; Higher Education; Success Factors; Interpretative Structural Modeling (ISM); Sustainability.

1. Introduction

In developed countries, universities have shown significant progress in implementing Green Information Technology (Green IT), especially through integrated strategic management [1, 2]. Research emphasizes the importance of strategic plans that support Green IT as part of campus sustainability policies [3, 4]. Universities that implement strategic policies in Green IT have been proven to be successful in reducing energy consumption and carbon emissions significantly [5, 6]. However, this strategy has not been widely implemented in developing countries such as Indonesia, which still face resource constraints [7].

One of the biggest obstacles to implementing Green IT is budget constraints, which limit the ability of higher education institutions to adopt more environmentally friendly technologies [3, 8, 9]. Many universities struggle to make

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http://dx.doi.org/10.28991/HIJ-2025-06-02-010

initial investments in energy-efficient technologies, which ultimately hinders the adoption of Green IT in higher education [10]. Educational institutions run by foundations, for example, often have limited funds to upgrade their technological devices and infrastructure to be more efficient and environmentally friendly [8, 11, 12]. In Indonesia, the implementation of Green IT in higher education is often hampered by the lack of adequate budget allocation [7, 13]. This financial constraint makes it difficult for many universities to make initial investments in green technologies that are more energy efficient [7]. As a result, many educational institutions prefer to maintain old infrastructure with higher energy consumption rather than switch to a more environmentally friendly system. Private universities run by foundations often struggle to allocate funds for technological upgrades due to limited budgets [9].

In addition to financial issues, the lack of concrete policy support is a significant obstacle to implementing Green IT in the higher education sector [14]. Many institutions do not have clear internal policies on adopting environmentally friendly technologies, so that Green IT implementation is not a top priority in campus operations [5, 8]. Higher education institutions in Indonesia need more mature strategic planning to ensure that Green IT can be properly integrated into academic policies and campus administration [5, 7]. A comparative study revealed that the challenges in implementing Green IT in developed and developing countries are very different [9, 15]. In developed countries, Green IT is supported by adequate policies and infrastructure, while in developing countries, universities still face budget constraints and limited technological support that hinder sustainability efforts [7]. However, research shows that with the right strategies and policies, Green IT has the potential to have a positive impact on the carbon footprint of educational institutions [7, 16, 17]. The implementation of Green IT in the higher education sector in Indonesia still faces many obstacles. One of the main challenges is that regulations and supporting policies have not been well integrated [3, 4, 18]. In many developing countries, Green IT policies have not been fully implemented, so many universities do not have clear guidelines for implementing environmentally friendly technologies [8]. The lack of strong regulations has led to various challenges in implementing sustainability policies on campus [15].

Low institutional commitment and lack of strategic planning for Green IT sustainability are other factors that hinder the adoption of this technology in Indonesian universities [1, 19, 20]. Most institutions are still more focused on conventional operational needs than investing in Green IT initiatives. As a result, Green IT has not been a top priority in campus management strategies [8]. In addition, awareness of Green IT among students and academic staff is still low [6, 7, 21]. Studies show that only 40% of respondents from universities in Southeast Asia understand the benefits of Green IT [14, 22, 23]. As a result, many universities in Indonesia do not yet have a structured and well-coordinated Green IT initiative [2, 5, 24]. Without clear policies and targeted strategies, Green IT implementation becomes less effective and challenging to run sustainably [7, 9, 25]. In the Southeast Asia region, including Indonesia, the level of awareness of students and academic staff towards Green IT is still relatively low [16, 24]. Studies found that around 60% of respondents from universities in Southeast Asia have limited [5] understanding of Green IT practices [7, 15]. This low awareness is a major obstacle in encouraging behavioral changes that support reduced energy consumption and the implementation of sustainable technologies in the campus environment [10, 19, 26]. Therefore, increasing awareness through educational programs and campaigns is an important step in encouraging environmentally friendly behavior in universities [8, 15].

The limited expertise and training of IT personnel in green technology management is a major obstacle to the implementation of Green IT in developing countries [5, 27]. The lack of training and education on Green IT limits the development of human resources capable of managing and optimizing sustainable technology [17]. The lack of expertise and training in green technology management among IT personnel in universities is also a major challenge. Most IT personnel in universities are still focused on conventional technical aspects and do not yet have specific skills in managing green technology effectively [5, 15]. This causes the implementation of Green IT to be less than optimal due to a lack of understanding of how to operate a more environmentally friendly system [28, 29].

Previous studies have shown significant growth in adopting Green Information Technology (Green IT) across sectors and geographical areas. One study identified three main factors influencing the adoption of green innovations by SMEs in Indonesia, namely technology, environment, and organization, with organizational factors as the main determinant [13]. However, this study still has limitations in terms of geographical coverage, narrow sector, sample homogeneity, and limited data collection period. Therefore, expanding the sector and region is recommended to increase the relevance of the findings. Meanwhile, another study examined the adoption of Green IT practices through a strategic cognition perspective, which showed that organizational identity orientation (individualistic or collectivistic), external pressures (coercive, normative, mimetic), and organizational focus (cost reduction or revenue expansion) together influence Green IT adoption. However, this study is still limited to a cross-sectional design, so its validity can be improved through a longitudinal design with a broader sample [20]. Another study contributed with an analysis of the literature on Green IT, highlighting how the focus of research has evolved from mere energy efficiency to integration in the concept of smart cities [14]. Some key clusters, such as green technology and socioeconomic impacts, have been identified, but research gaps are still found in the interdisciplinary approach. To support smarter and more sustainable living, a more holistic study that combines various disciplines is needed.

In the context of sustainable smart cities, other studies have highlighted the direct benefits of Green IT, including energy efficiency, reduced carbon footprint, and improved quality of public services [30]. This study asserts that the success of Green IT implementation is highly dependent on collaboration between stakeholders, such as government, industry, and the academic community. However, since this study is literature-based, empirical studies are still needed to test the generalizability and applicability of the findings in various actual conditions. In the creative industry sector, research on Green IT in the batik industry found that the adoption of green technology has a positive impact on green innovative behavior and green competitive advantage. However, it does not always directly contribute to increasing company competitiveness [7]. In addition, financial resources are proven to be a moderating factor in the relationship between competitive advantage and sustainable performance. Therefore, further research is recommended to expand the geographical scope and add other variables that may be influential in different industry contexts.

In developing countries, e-waste management is a major challenge in implementing Green IT. A study on electronic recycling practices in Bangladesh found that many recycling activities are still carried out informally in unsafe ways [31]. To address this challenge, the study recommends the development of formal recycling infrastructure, increased public awareness, and more precise supporting policies. However, to ensure the effectiveness of these recommendations, empirical studies with a more comprehensive approach are needed. Other studies have shown that strategic alignment between IT and business, as well as environmental motivation, strengthens the relationship between Green IT adoption and corporate environmental performance [1]. Intrinsic and extrinsic motivation are also important factors in the success of green technology implementation. However, to increase the validity of these findings, longitudinal designs and more objective data collection methods are still needed.

In the context of small and medium enterprises (SMEs), previous studies have explored the role of green creativity, business independence, and Green IT empowerment in improving sustainable business performance [32]. The findings suggest that business independence positively contributes to green competitive advantage and sustainable performance, while green creativity only affects competitive advantage. Green IT empowerment also moderates the relationship between business independence and green competitive advantage. However, this study is still limited in geographical coverage and cross-sectional design, so further studies with a broader scope and longitudinal approach are needed. In the context of large companies, research shows that implementing Green IT can improve financial performance through green innovation as a mediator [29]. However, this study was only conducted on public companies in Germany, so additional research in other countries is needed to increase the generalizability of the findings. In addition, research in the household sector in Denmark highlights how using of Green IT can help monitor energy consumption for efficiency and savings [33]. However, the main challenges in implementing this technology are the complexity of the system and the lack of understanding of energy data, so further research with quantitative methods and larger samples is needed.

In the agricultural sector, Green IT plays a role in improving energy efficiency and sustainability [33]. However, limited infrastructure, lack of technical knowledge, and resistance to change are still obstacles to its implementation. Further studies are needed to evaluate the effectiveness of Green IT solutions globally with a more in-depth and comprehensive approach. Meanwhile, a study on traditional IT infrastructure in Bangladesh revealed its negative impacts on the environment and proposed a Green IT framework for sustainability [33]. However, empirical studies are still needed to test the effectiveness of the framework across sectors. Another study developed a model linking Green IT to green brand image and competitive advantage, suggesting that green technology can improve firm competitiveness [34]. However, since this study used a cross-sectional design, the generalizability of the findings is still limited.

Based on previous studies, there are still a number of limitations in Green IT research that need to be explored further. Many studies have limited geographic and sectoral coverage, making them less generalizable. Most studies also use cross-sectional designs, which cannot capture long-term adoption trends. In addition, there is still a lack of empirical evidence because many studies rely more on literature reviews than real-world data. The role of external pressures, such as regulatory policies and economic incentives, is also under-explored regarding Green IT adoption. In the context of developing countries, financial, technical, and cultural challenges remain significant barriers that have not been studied in depth. In addition, many frameworks proposed in Green IT research do not have measurable performance indicators, making it difficult to assess the effectiveness of implementation. Therefore, a more comprehensive review of the success factors of Green IT implementation in the higher education sector, especially in Indonesia, is needed.

This study aims to identify key factors that can improve the effectiveness of Green IT implementation in higher education institutions, including aspects of policy, budget, human resources, and environmental awareness. Using the Interpretive Structural Modeling (ISM) method, this study will analyze and map the relationships between factors that influence each other in a complex system [35-37], especially in the context of Green IT sustainability in higher education. This approach allows the identification of hierarchical structures between success factors, so that it can support more strategic and effective decision making. Thus, this study will not only contribute to the academic understanding of Green IT in the higher education sector but also provide practical insights for policymakers and educational institutions in developing more structured and sustainable strategies.

The research questions that can be used as a reference for this research are:

- What are the main factors that influence the success of Green IT implementation in universities in Indonesia?
- How are these factors related, and which factors have the greatest influence on the success of Green IT implementation?
- How can ISM help in identifying the hierarchy and prioritization of Green IT success factors in the higher education sector?

- What factors should universities prioritize to optimize Green IT implementation based on the hierarchical structure resulting from the ISM analysis?

This study provides contributes significantly by mapping the success factors of Green IT in higher education more comprehensively and providing relevant strategic recommendations for higher education institutions in Indonesia, thus supporting the implementation of sustainable Green IT. This study is expected to provide important benefits for several parties, including for Higher Education in Indonesia, for Policymakers, and for Contribution to Global Literature. For Higher Education Institutions in Indonesia, namely by understanding the main success factors, educational institutions can take more appropriate and effective steps to support the sustainability of technology through Green IT. For Policy Makers: The results of this study can be a reference in formulating regulations or policies that support Green IT in a more structured manner in the higher education sector, as well as ensuring more effective budget allocation, while for the Contribution to Global Literature, namely as part of the global literature on Green IT, this study provides in-depth contextual insights into the success factors of Green IT in developing countries, which are still limited in previous studies. So, this study has significant value and outstanding contribution. With ISM, this study can create a model relevant to the Indonesian context, assist in formulating more sustainable policies and strategies, and support higher education in implementing Green IT with a broad impact. The ISM method provides an understanding of key factors and supports the formulation of priorities oriented towards sustainability and efficiency.

The structure of this study begins with an introduction highlighting the challenges in implementing Green IT in the higher education sector, such as budget constraints, low institutional commitment, unclear regulations, and limited awareness, while emphasizing the importance of analyzing success factors using the ISM method. This is followed by a literature review exploring the challenges, opportunities, and contextual differences in Green IT implementation, with a focus on Indonesia, while referring to global trends. The methodology section of the study discusses the use of ISM to analyze the relationships between factors and explains data collection through literature review, expert interviews, and FGDs. The results section identifies key factors, including policies, management commitment, awareness, infrastructure, and finance, which are mapped through ISM and MICMAC analysis. Practical implications provide recommendations for prioritizing sustainable policies, education, and investment. Finally, the conclusion emphasizes the dominant role of external pressures and proposes future research directions for broader application.

2. Literature Review

2.1. Green IT in Indonesia

The implementation of Green IT in Indonesia still faces various challenges and obstacles [13, 38], although awareness of the importance of sustainability and energy efficiency is increasing. Various factors, such as budget constraints, low awareness, and lack of regulatory and policy support, are the main obstacles to the implementation of Green IT in Indonesia, especially in the higher education and government sectors. Limited funding is one of the main obstacles that hinders the implementation of Green IT in many institutions in Indonesia. Othman et al. [10] noted that many universities in Indonesia have difficulty in making initial investments in energy-efficient devices and more efficient technological infrastructure. This situation is further exacerbated by the reliance on outdated technology, which tends to be more energy intensive and less supportive of sustainable practices [17, 39]. In the government sector, budget constraints also limit the implementation of Green IT. Nanath & Pillai [15] explained that Green IT projects in government institutions often cannot run optimally due to the lack of adequate funding allocation for environmentally friendly technology or efficient energy management systems. The implementation of Green IT in Indonesia is often hampered by the lack of specific and supportive regulations [10, 15]. Although the government has issued policies aimed at energy efficiency and sustainability, specific regulatory support for Green IT in the higher education and industrial sectors is still minimal. Aini & Subriadi [38] noted that the lack of clear regulations in Indonesia is a major obstacle to implementing consistent Green IT policies on campuses and universities. Overseas, many countries have adopted specific regulations for Green IT that enable sustainability practices at the operational and strategic levels. Aini & Subriadi [38] highlighted that developed countries, such as in Europe, have adopted stronger regulatory frameworks and support Green IT in various sectors, including higher education, resulting in faster and more effective adoption of green technology compared to Indonesia.

In Indonesia's higher education sector, low levels of awareness and support for Green IT among staff and students are a challenge. Hernandez [28], Lim et al. [40], and Leung [41] conducted research in various universities in Southeast Asia, including Indonesia, and found that less than half of students and staff have a deep understanding of Green IT practices and the importance of sustainability. This low awareness hinders behavioral changes that support energy efficiency in the campus environment. Research in Indonesia also shows that the lack of training in Green IT affects the ability of the workforce in higher education to manage and optimize green technologies. Othman et al. and Nanath & Pillai [10, 15] noted that many universities in Indonesia do not yet have adequately trained human resources to utilize sustainable technologies effectively, making the adoption of Green IT more challenging to implement. The implementation of Green IT in Indonesia is also hampered by uneven infrastructure and limited access to greener technologies. In some higher education institutions, limited access to modern technology hinders efforts to reduce energy consumption and increase efficiency. Kusuma et al. [7], Salles et al. [8], and Vakaliuk [17] noted that infrastructure supporting Green IT is more common in developed countries, while developing countries, such as Indonesia, still experience limitations in providing and maintaining energy-efficient technologies. Overall, the implementation of Green IT in Indonesia is still faced with various structural obstacles, ranging from budget constraints and lack of supporting regulations to low awareness of human resources [10, 13, 38]. With more precise policy support, increased awareness among staff and students, and better budget allocation, the implementation of Green IT in Indonesia is hoped to be more optimal. Further research on the success factors of Green IT is needed to provide more detailed insights and support the development of sustainable policies [11, 14, 42].

2.2. Green IT Higher Education Sector in Indonesia

The implementation of Green IT in the higher education sector in Indonesia faces various challenges that affect the progress of its implementation. The main influencing factors include budget constraints, lack of awareness and support from staff and students, unclear regulations, and limited energy-efficient technology infrastructure. Although some universities have started implementing Green IT, the results are still far from optimal compared to developed countries. Budget constraints are a major challenge that hinders universities in Indonesia from adopting Green IT. Many universities in Indonesia still rely on outdated equipment and infrastructure, which are less efficient in energy use. Pramanik et al. [43] noted that many universities in Indonesia have difficulty funding new equipment environmentally friendly and energy efficient. Limited education budgets are often allocated to more pressing priorities, so Green IT is not a primary focus. The lack of operational policies and guidelines that support Green IT in universities is also a constraint. Salles et al. [8], Othman et al. [10], and Nanath & Pillai [15] showed that the lack of clear regulations and policies related to Green IT means that many universities do not have structured guidelines to implement green technology effectively. As a result, most universities in Indonesia do not have integrated and measurable Green IT initiatives. Unlike developed countries where policies related to Green IT have been formally integrated, Indonesia still faces obstacles in providing strong regulatory support for green technology practices in higher education.

Awareness of the importance of Green IT and its impact on environmental sustainability among staff and students is still low. Marques et al. [16] and Dalvi-Esfahani et al. [24] found that in Southeast Asia, including Indonesia, most staff and students in higher education do not have a deep understanding of the concept and benefits of Green IT. Only about 40% of the campus population is aware of Green IT practices, such as reducing the use of electronic devices when not needed or using energy-efficient technology. This hampers campus efforts to reduce carbon footprints and improve campus sustainability. This low awareness also impacts low support for sustainability initiatives on campus. Nanath & Radhakrishna Pillai [5], Marques et al. [16], and Vakaliuk [17] emphasized that without effective education about Green IT, changing daily behaviors that support sustainability will be challenging. The lack of education and training programs that focus on Green IT in higher education is one of the leading causes of this low awareness. Limited infrastructure that supports Green IT, such as access to modern energy-efficient technology, is also a barrier. Kusuma et al. [7], Alamsyah et al. [23], and Sulistio & Sugarindra [27] showed that developing countries like Indonesia often lack access to technological infrastructure that supports sustainability, such as energy-efficient servers or integrated energy management systems. In many universities, these infrastructure limitations make it challenging to implement Green IT because existing technologies are not designed for optimal energy efficiency.

2.3. Analysis Using Interpretative Structural Modeling

Interpretative Structural Modeling (ISM) is an analytical method designed to identify and organize relationships between elements in a complex system [44, 45]. ISM categorizes elements based on their level of influence and dependency and builds a hierarchical structure that describes the relationships between these elements [45, 46]. This method is very suitable for analysis involving many interrelated factors, such as in implementing Green IT in the higher education sector, where factors such as policies, management support, human resource awareness, budget constraints, and technological infrastructure have important roles and influence each other. In the context of Green IT, ISM is used to analyze the success factors of Green IT implementation in universities in Indonesia. The use of ISM allows the identification of key drivers that need to be considered to achieve sustainability goals, such as energy efficiency, carbon emission reduction, and the use of environmentally friendly technologies. Zulkefli et al. [35] and Srivastava & Singh [47] noted that ISM is effective in grouping factors whose complexity is increased by multiple interdependent elements. ISM allows universities to focus on factors with the highest influence, such as policies and management support, which form the basis for other elements [48-50].

The ISM method in analyzing Green IT in the higher education sector begins with identifying key factors through literature studies and input from experts. Next, the relationships between factors are examined through the Structural Self-Interaction Matrix (SSIM), where the reciprocal influences between elements are recorded and arranged. In the context of Green IT, this includes, for example, how government policies can influence budget allocation for green technologies or how management support drives staff and student awareness. Once the SSIM is created, the next step is to construct a Coverage Matrix that produces a hierarchical structure of each factor. This structure clarifies which elements have a primary driving role (Driving Factors) and which are more dependent on other components (Dependent Factors). Xu & Zou [45] stated that ISM can map the complex interactions between various factors in sustainability efforts, resulting in a hierarchical model that helps strategic decision-making. ISM is very relevant for use in the Indonesian context, where implementing Green IT in the higher education sector still faces various challenges, such as budget constraints, low awareness, and lack of supporting regulations. With ISM, research can show that policies and management support are the main driving factors that can influence other factors. A study by Xu & Zou [45] highlighted that mapping the structure of relationships between elements with ISM helps universities to set clear strategic priorities, including in implementing Green IT, especially when policy support is still limited.

ISM analysis produces a hierarchical model that shows the key factors that should be prioritized for the success of Green IT. By highlighting the elements with the most significant influence, universities can focus resources on factors that genuinely support the implementation of sustainable Green IT. Farooq et al. [51] stated that ISM is useful in determining priority factors in developing environmentally friendly technologies, especially in developing countries that often have limited resources. ISM is an ideal method for analyzing the implementation of Green IT in the Indonesian higher education sector. With ISM, universities can understand the hierarchical structure of factors that influence the success of Green IT, set priorities based on the influence of each factor, and allocate resources effectively. In the Indonesian context, ISM allows universities to design strategies that are more focused and relevant to local conditions, ensuring that Green IT can be implemented sustainably.

3. Research Methodology

This study uses a quantitative approach with the Interpretive Structural Modeling (ISM) method, which is used to analyze the relationship between factors that influence the implementation of Green IT in the higher education sector. This methodology consists of several main stages from identifying factors to developing effective implementation strategies. Figure 1 shows the stages of this research methodology from the beginning to the end of the study.

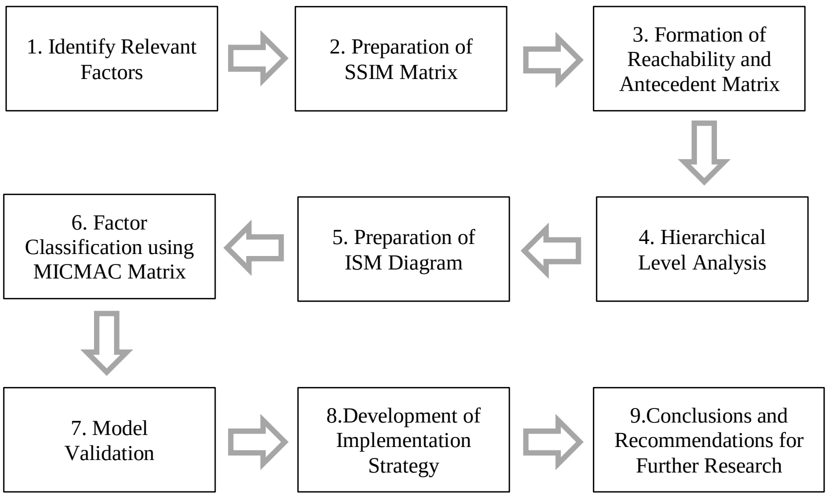

Figure 1. Analysis of Success Factors for Green Information Technology Research Stages Implementation in the Higher Education Sector in Indonesia

3.1. Identify Relevant Factors

The initial stage of this research is to identify relevant factors that can influence the implementation of Green IT in higher education. These factors are identified through two main sources:

- Literature Review: The researcher conducted a literature review from various sources such as scientific journals, books, research reports, and articles related to Green IT. Previous research is the main reference in identifying factors that have been widely discussed, such as technology selection, institutional policies, environmental awareness, and other managerial and technical factors.
- Expert Interviews: In-depth interviews were conducted with ten experts who have experience in information technology and environmental management in higher education. These experts provided additional insights into specific factors relevant to the context of higher education in Indonesia.
- Group Discussion Forum. The discussion involved 3 highly competent experts in the field of Green IT represented by 2 academics and 1 practitioner.

The results from these three sources are then verified and compiled into a list of factors to be analyzed using ISM.

3.2. Preparation of SSIM (Structural Self-Interaction Matrix)

Once the factors are identified, the next step is to construct the SSIM Matrix. SSIM is a matrix used to assess the relationship between the factors that have been identified. In this matrix, the relationship between each pair of factors is assessed based on four symbols:

- V (Leading to): Factor i contributes to the achievement of factor j.
- A (Led by): Factor j contributes to the achievement of factor i.
- X (Mutual): Factors i and j contribute to each other.
- O (No relationship): There is no direct relationship between factors i and j.

This assessment was conducted by distributing questionnaires to respondents consisting of 21 experts, including IT managers, academic staff, and environmental managers in universities. The SSIM questionnaire measures respondents' perceptions of the relationship between factors influencing Green IT implementation.

3.3. Formation of Range and Antecedent Matrix

From the SSIM results, the Reachability Matrix and Antecedent Set are compiled for each factor. The reachability matrix describes all factors that can be influenced by a particular factor (Reachability Set), while the antecedent set shows all factors that influence a specific factor.

- Range Set (R(i)): The set of factors influenced by factor i.
- Antecedent Set (A(i)): The set of factors that influence factor i.

The intersection set is then calculated to determine the hierarchical position of each factor. This process helps understand the level of dependency and influence of each factor in the system.

3.4. Hierarchical Level Analysis

Based on the affordances and antecedent matrix, a hierarchical-level analysis is performed to determine the relative position of each factor in the system. This process is carried out with the following steps:

- Factors with the same affordance set and antecedent set are placed at the top level.
- Factors that are only present in the affordance set are placed at the next level.
- This process is repeated until all factors are placed at their appropriate levels.

This hierarchical level analysis guides which factors need to be addressed early in a Green IT implementation.

3.5. ISM Diagram Preparation

Once the hierarchy levels are determined, the next step is to construct an ISM diagram, that is a hierarchical structure of factors. This diagram visualizes the relationship between factors by showing the key factors with a dominant influence and the most influenced factors. This diagram helps with higher education management in understanding the priorities and implementation strategies that need to be carried out.

Quantitative matrices are used to evaluate the relationships and weights of factors in the ISM model. The Structural Self-Interaction Matrix (SSIM) captures the relationships between factors using symbols (V, A, X, O) to indicate the type of influence, such as direct influence, reciprocal influence, or no relationship. This is then transformed into the Attainment Matrix, a binary representation where “1” indicates a direct or indirect relationship and “0” indicates no relationship, allowing for the calculation of affordances and antecedent sets.

In addition, MICMAC analysis is applied to classify factors based on their driving power (influence on others) and dependency (influence received). It classifies factors into autonomous, dependent, interrelated, or independent categories, providing a clear understanding of their role in the system. This metric offers a systematic quantitative approach to analyzing and prioritizing factors, ensuring the ISM model effectively identifies key driving and dependent elements for Green IT implementation.

3.6. Factor Classification using MICMAC Matrix

After preparing the ISM diagram, the analysis was continued by using the MICMAC Matrix (Matrice d'Impacts Croisés Multiplication Appliquée à un Classement) to classify factors based on driving power and dependence. This matrix groups factors into four categories:

- Autonomous Factors: Factors with low driving value and dependency, which stand alone and have little to do with other factors.

- Dependent Factors: Factors with high dependency and low driving value, which are highly influenced by other factors but do not have much influence.
- Relatedness Factors: Factors with high driving and dependency values, which are closely related to each other and can be unstable.
- Independent Factors: Factors with high driving value but low dependence, which have a strong influence on the system but are not significantly influenced by other factors.

This classification helps identify key factors that need special attention in a Green IT implementation strategy.

3.7. Model Validation

Factors for the ISM model were identified and validated using a combination of literature review, expert opinion, and Focus Group Discussions (FGDs). The literature review provided a theoretical foundation by analyzing previous studies, reports, and articles on Green IT implementation and sustainability challenges, ensuring that widely recognized factors were included. To adapt the model to the Indonesian context, expert interviews were conducted with IT and environmental management professionals in higher education, offering context-specific insights and identifying key challenges. In addition, FGDs were conducted with selected experts, including academics and practitioners, to cross-validate and refine the factors. This collaborative process ensured the relevance, accuracy, and completeness of the factors identified for the ISM model, allowing for the mapping of relationships and prioritization of key elements for Green IT implementation. The integration of these three methods provides a robust and systematic approach to identifying and validating factors.

3.8. Implementation Strategy Development

Based on the results of the analysis and validation of the model, this study develops a strategy for implementing Green IT in higher education. This strategy includes policy recommendations, resource allocation, and initiatives that need to be taken to support a more effective and sustainable implementation of Green IT.

3.9. Conclusion

The final stage of this study is to draw conclusions that summarize the main findings and provide recommendations for further research. These recommendations include suggestions for future research that can test the effectiveness of Green IT implementation strategies in other higher education contexts, as well as further exploration of the concrete impacts of Green IT implementation on operational efficiency and environmental sustainability in higher education. This methodology provides a comprehensive and systematic framework for analyzing Green IT implementation in higher education, as well as providing practical guidance for campus management in formulating more effective policies and strategies.

4. Results and Discussion

4.1. Identify Key Factors

The results of the FGD discussion are based on the results of the literature study and interview results, the following is an analysis of important factors that can be used as the basis for your research related to Green IT or IT sustainability initiatives in higher education. These factors are identified from the similarities and interrelationships of the three data sources, namely literature studies, expert interviews, and Discussion Group Forums, which can be summarized as:

a. Policies and Regulations

- Literature Study Results: Internal Policy [2]; Compliance with Regulations and Standards [3].
- Interview Results: Policy; Rule.
- FGD Results: Strong policies and clear internal regulations support effective Green IT implementation. Compliance with external regulations and internal policies is key to driving IT sustainability.

b. Management Commitment and Support

- Literature Study Results: Top Management Support [15]; Leadership and Management Commitment [52].
- Interview Results: Commitment; Institutional Support; Internal Support.
- FGD Results: Commitment and support from management and institutions are key drivers of the success of a Green IT program. Top management must lead by example and provide adequate resource support.

c. Awareness and Education

- Literature Study Results: Employee Education and Awareness [53]; Education and Awareness [24].
- Interview Results: Awareness; Education; Knowledge; Training.
- FGD Results: Environmental awareness, education, and training for employees or members of the institution are important aspects to advance the Green IT agenda. Awareness and knowledge of the importance of sustainability can influence behavior throughout the organization.

d. Infrastructure and Technology

- Literature Study Results: IT Technology and Infrastructure [38]; Technology Readiness [54].
- Interview Results: Infrastructure
- FGD Results: Infrastructure and technology readiness are important components in implementing Green IT, especially in terms of providing environmentally friendly technology and ensuring the readiness of IT systems in facing green initiatives.

e. Business and Operational Processes

- Literature Study Results: Aligned Business Processes [2].
- Interview Results: Business Process; Operational Procedures.
- FGD Results: Optimizing business processes and operational procedures in line with Green IT principles will impact resource efficiency and consistency in implementing sustainability initiatives.

f. External and Social Pressure

- Literature Study Results: External Environmental Pressure [5]; Pressure from Government, Corporate Social Responsibility [2].
- Interview Results: There are no explicitly related factors.
- FGD Results: Pressure from external parties, such as governments or the wider community, drives organizations to implement Green IT initiatives as part of social responsibility and compliance with regulatory standards.

g. Finance and Investment

- Literature Study Results: Availability of Financial Resources [5]; Investment in Resources [54].
- Interview Results: There are no explicitly related factors.
- FGD Results: The availability of financial resources and investment in green technologies plays a critical role in the successful implementation of Green IT programs.

From the results of the three sources above that have been analyzed, important factors were obtained, including:

1. Internal policies and regulations and compliance with external regulations
2. Management commitment and institutional support to support sustainability initiatives.
3. Employee awareness and education about sustainability and Green IT.
4. IT infrastructure and technology readiness to support green transformation.
5. Optimization of business processes and operational procedures that support resource efficiency.
6. External pressures, such as government or societal pressure for social responsibility.
7. Financial investments to support the implementation of green technologies

Table 1. Important Factors of Green IT in Higher Education

Factor	Code
Policies and Regulations	F1
Management Commitment and Support	F2
Awareness and Education	F3
Infrastructure and Technology	F4
Business Processes and Operations	F5
External and Social Pressure	F6
Finance and Investment	F7

Table 1 contains the key factors that have been identified as key elements influencing the success of Green IT implementation in higher education. The following is a detailed explanation of each of the possible elements listed in Table 1:

a. Policies and Regulations (F1)

This factor is often considered the main foundation of the ISM model because institutional policies and regulations determine the direction of Green IT implementation. Policies that support environmentally friendly practices can encourage the commitment of universities to implementing Green IT. In the ISM analysis, this factor usually has a high driving power value, indicating its significant influence on other factors.

b. Management Commitment and Support (F2)

Support from higher education management and leaders is a key factor in the success of Green IT initiatives. Without management commitment, implementation efforts often encounter obstacles. Management commitment also influences resource allocation and ensures that policies can be implemented in practice. This factor usually has a reciprocal relationship with policy and technical aspects, placing it in the MICMAC category of linkage factors.

c. Awareness and Education (F3)

Raising awareness among higher education faculty, students, and staff about the importance of Green IT contributes to organizational culture and behavioral change. Continuous education about environmental sustainability can increase compliance with Green IT policies. This factor is typically influenced by management policies and support but can also influence social acceptance, making it a dependent factor in the MICMAC analysis.

d. Infrastructure and Technology (F4)

This factor includes the provision of environmentally friendly and energy-efficient technology and infrastructure. This component is the technical aspect of Green IT, where energy-efficient technology and technology management systems play a major role. Adequate infrastructure and technology require policy support and financial investment, and this factor often directly affects campus operational processes.

e. Business Processes and Operations (F5)

Integrating Green IT principles into campus business processes and operations can improve resource efficiency. Optimizing business processes with environmentally friendly standards, such as reducing energy consumption and utilizing energy-efficient devices, can reduce environmental impact. These business processes are interrelated with technology and policy factors, making them often dependent on factors that are influenced by other factors.

f. External and Social Pressure (F6)

External pressures, such as government regulations, industry standards, or demands from the wider community, can drive higher education to adopt Green IT. These factors often act as triggers that accelerate the adoption of Green IT. In MICMAC, this factor can be placed in the category of linkage factors because external pressures can drive policy support and environmental awareness on campus.

g. Finance and Investment (F7)

Procurement of Green IT infrastructure requires significant investment, so financial support is a critical factor in Green IT implementation. Financial resources enable the procurement of environmentally friendly technologies and the development of efficient operational systems. This factor often has a high dependence on policy and management support and is key in supporting other operational factors.

4.2. Structural Self-Interaction Matrix (SSIM)

To build a Structural Self-Interaction Matrix (SSIM), the most important thing is to determine the relationship between each pair of factors that have been identified. Each pair of factors will be evaluated to determine the direction of its influence using the following symbols:

V: Row factors affect column factors.

A: Column factors affect row factors.

X: Both factors influence each other.

O: There is no direct relationship between the two factors.

In determining the relationship between each pair of factors, we created a questionnaire that we distributed involving 21 respondents. The results are shown in Table 2.

Table 2. Results of the VAXO determination survey

Respondents	Relationship between Factors	Percentage (%)				Results
		V	A	X	O	V
1st	(Policies and Regulations) VS (Management Commitment and Support)	71.4	14.3	14.3	0	**V**
2nd	(Policies and Regulations) VS (Awareness and Education)	42.9	21.4	28.6	7.1	**V**
3rd	(Policy and Regulation) VS (Infrastructure and Technology)	50	7.1	42.9	0	**V**
4th	(Policies and Regulations) VS (External and Social Pressures)	42.9	21.4	35.7	0	**V**
5th	(Policy and Regulation) VS (Finance and Investment)	0	50	42.9	7.1	**A**
6th	(Policies and Regulations) VS (Business Processes and Operations)	42.9	21.4	35.7	0	**V**
7th	(Management Commitment and Support) VS (Awareness and Education)	42.9	14.3	35.7	7.1	**V**
8th	(Management Commitment and Support) VS (Infrastructure and Technology)	42.9	57.1	0	0	**A**
9th	(Management Commitment and Support) VS (External and Social Pressure)	57.1	14.3	28.6	0	**V**
10th	(Management Commitment and Support) VS (Finance and Investment)	7.1	57.1	35.7	0	**A**
11th	(Management Commitment and Support) VS (Business Processes and Operations)	50	7.1	42.9	0	**V**
12th	(Awareness and Education) VS (Infrastructure and Technology)	50	7	35.7	7.1	**V**
13th	(Awareness and Education) VS (External and Social Pressure)	42.9	21.4	21.4	14	**V**
14th	(Awareness and Education) VS (Finance and Investment)	0	57.1	42.9	0	**A**
15th	(Awareness and Education) VS (Business Process and Operations)	7.1	21.4	64.3	7.1	**X**
16th	(Infrastructure and Technology) VS (External and Social Pressures)	35.7	28.6	35.7	0	**V**
17th	(Infrastructure and Technology) VS (Finance and Investment)	7.1	50	42.9	0	**A**
18th	(Infrastructure and Technology) VS (Business Processes and Operations)	21.4	28.6	50	0	**X**
19th	(External and Social Pressure) VS (Finance and Investment)	14.3	42.9	35.7	7.1	**A**
20th	(External and Social Pressure) VS (Business Processes and Operations)	42.9	21.4	35.7	0	**V**
21st	(Finance and Investment) VS (Business Processes and Operations)	57.1	0	42.9	0	**V**

The survey results in Table 2 show the relationship between various factors that influence the implementation of Green Information Technology (Green IT) through the VAXO determination survey approach. The VAXO method is used to classify the relationship between factors into dependent (V), antecedent (A), cross (X), and no relation (O), which provides an understanding of how one factor influences other factors in the Green IT system.

One of the main findings of this survey is the role of Policies and Regulations in shaping other factors. The majority of respondents, 71.4%, stated that Management Commitment and Support are highly dependent on Policies and Regulations, meaning that clear policies and regulations can encourage management commitment and support in implementing Green IT. In addition, the relationship between Policies and Regulations and Infrastructure and Technology is also quite strong, with 50% of respondents considering this relationship dependent (V), while 42.9% see it as a cross relationship (X), indicating a reciprocal relationship between the two.

In addition to policy factors, Awareness and Education also have a significant impact, especially in relation to Finance and Investment. As many as 57.1% of respondents stated that better awareness and education can increase budget allocation and investment in green technology. However, in some cases, this awareness does not always have a direct impact on financial decision-making, as seen in Finance and Investment vs Infrastructure and Technology, where only 21.4% of respondents consider this relationship dependent (V), while 64.3% see it as a cross relationship (X).

In addition, the survey highlights the role of External and Social Pressures, which often influence various aspects of Green IT implementation. For example, in the relationship between External and Social Pressures and Business Processes and Operations, 42.9% of respondents consider external pressure as a factor that plays a direct role in determining business processes, while 35.7% see it as a cross (X) relationship, indicating that business processes can also shape perceptions and reactions to external pressures.

Finance and Investment factors also have a significant influence on the sustainability of business processes in higher education. As many as 57.1% of respondents stated that financial and investment decisions directly impact on Business Processes and Operations, which means that without adequate budget allocation, it is difficult for educational institutions to implement Green IT-based sustainability strategies.

Overall, the survey results show that Policies and Regulations and Finance and Investment have a dominant role in the implementation of Green IT. Clear policies drive management commitment, while financial decisions determine how green technology can be implemented in operational business processes. In addition, Awareness and Education and

External and Social Pressures also play a role in shaping organizational behavior, although they often show a cross-influencing relationship (X) rather than a direct cause-and-effect relationship.

Once the SSIM is formed, the next step is to organize it into a range matrix showing the direct relationship between factors in binary form (0 and 1). The SSIM (Structural Self-Interaction Matrix) matrix in Table 3 shows the relationship between factors that have been identified in the implementation of Green IT using the Interpretive Structural Modeling (ISM) approach. SSIM is used to understand how factors interact and determine the hierarchical relationship between them. In Table 3, there are seven main factors denoted as F1 to F7, with each factor compared to find out the type of relationship that occurs.

Each cell in the matrix is filled with a symbol that represents the type of relationship between two factors. The symbol V (Leads to) indicates that the factor in the row has an influence on the factor in the column, while A (Is led by) indicates that the factor in the column has more influence on the factor in the row. The symbol X (Mutual relationship) indicates that the two factors influence each other, and the sign - (No direct relationship) means there is no direct relationship between the factors.

From Table 3, it can be seen that F1 has an influence on F2, F3, F4, and F7, indicating that this factor plays a dominant role in influencing other elements in the system. However, F1 itself is influenced by F6, indicating that its success depends on the conditions set by the factor. Meanwhile, F3 and F6 have a reciprocal relationship indicated by the symbol X, indicating that these two factors influence each other in the implementation of Green IT.

In addition, F4 also has a reciprocal relationship with F7, which means that although F4 can influence F7, F7 also has an impact back on F4. Factor F5 is influenced by F6, but directly influences F4. Meanwhile, F6 has a direct influence on F7, which shows that this factor plays a role in shaping decisions or implementations related to this factor.

Overall, this matrix provides insight into how the key factors are interrelated in the system, with F1 and F6 being the factors with a strong influence on the other factors, while F7 is more of a factor that receives influence without having a direct impact back. With this understanding, the next step in the ISM method is to convert the SSIM matrix into a Binary Interrelationship Matrix (Reachability Matrix) and construct a hierarchy of factors, which will help in identifying the key factors that are drivers in the system and the factors dependent on other elements.

Table 3. SSIM for identified factors

	F1	F2	F3	F4	F5	F6	F7
F1	-	V	V	V	V	A	V
F2		-	V	A	V	A	V
F3			-	V	V	A	X
F4				-	V	A	X
F5					-	A	V
F6						-	V
F7							-

4.3. Structural Self-Interaction Matrix (SSIM)

Based on the previously created SSIM, here is the Reachability Matrix.

Table 4. Matrix Range

	F1	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**
F1	1	1	1	1	1	0	1
F2	0	1	1	0	1	0	1
F3	0	0	1	1	1	0	1
F4	0	1	0	1	1	0	1
F5	0	0	0	0	1	0	1
F6	1	1	1	1	1	1	1
F7	0	0	1	1	0	0	1

The matrix shown in Table 4, the Range Matrix, functions as a Reachability Matrix in the Interpretive Structural Modeling (ISM) approach. This matrix converts the relationship between factors previously analyzed in the Structural

Self-Interaction Matrix (SSIM) into a numerical form that shows the direct relationship between factors in the system. In this matrix, the number 1 indicates that there is a direct relationship between two factors, while the number 0 indicates that there is no direct relationship.

From Table 4, it can be seen that F1 has a direct relationship with almost all factors (F2, F3, F4, F5, and F7) except for F6, which is indicated by the number 0 in column F6. This shows that F1 has a broad influence in the system but is not directly related to F6. In contrast, F6 has a relationship with all other factors, indicating that this factor plays a central role in the system and can affect the implementation of Green IT.

Factor F2 has limitations in its influence on F1, because the value of 0 is found at the position of F2-F1. This indicates that F2 does not have a direct relationship with F1 but still has connections with other factors. F3 and F5 have limitations in their relationships with other factors, as seen from the presence of several 0 values in their rows, especially in the relationship with F2 and F4. Factor F7 also shows a more limited relationship than the other factors because it does not have a direct relationship with F2 and F5.

In general, this matrix illustrates how the identified factors are interrelated in the system studied. Factors F1 and F6 appear to have a dominant role because they are related to almost all factors in the system, indicating that they act as key elements in the implementation of Green IT. Meanwhile, F3, F5, and F7 are more dependent on other elements because their direct relationship is more limited. This matrix is an important basis for further analysis to determine the hierarchy of factors, identify the main driving elements, and understand how these factors can be controlled and optimized to support the success of Green IT implementation in the higher education system or other sectors.

After the range matrix is formed, the next step is to conduct a partition-level analysis to determine the hierarchy and relationships between factors in the ISM. The matrix shown in Table 5: Final Range Matrix is the final result of the Interpretive Structural Modelling (ISM) analysis, which aims to understand the hierarchical relationships between factors in the system being studied. This matrix shows the relationship between factors by using the number 1 to indicate a direct relationship and the number 0 to indicate no direct relationship. In addition, the symbol *1 indicates the relationship obtained after transposition in the finalization stage of the matrix, clarifying the interconnection between factors.

From Table 5, it can be seen that factor F6 has the most dominant role in the system, with a Driving Power value of 7. This places F6 at Level 3, indicating that this factor is the main driving element that influences other factors in the system. In addition, F1 also has a fairly large influence, with a Driving Power

of 6, placing it at Level 2. The existence of F1 at this level indicates that although not as strong as F6, this factor still has a significant role in shaping the dynamics of the system. Meanwhile, factors F2, F3, F4, F5, and F7 have a Driving Power of 5 and are at Level 1. These factors tend to be more dependent, meaning that they are more influenced by other factors than they are influencing the system as a whole. This can be seen from the Dependencies column, where these factors have a value of 7, indicating that they have a high dependence on other factors to be able to function effectively in the system.

In addition, in the Power analysis, which measures the extent to which a factor influences other factors, it is seen that F6 has the highest value, which is 7, indicating that this factor not only has a broad relationship with other factors but also plays a major role in driving the sustainability of the system. In contrast, factors such as F2, F3, F4, F5, and F7 are more dependent than influencing because their Power values are only 5. Based on this hierarchy, F6 can be considered as the main factor that drives the system towards more effective implementation, while F1 acts as a link between the main driving factors and the more dependent factors. Factors at Level 1 (F2, F3, F4, F5, and F7) are more elements that need support from other factors to run well.

Table 5. Final Range Matrix

	F1	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**	Driving Power	
F1	1	1	1	1	1	0	1	6	Level 2
F2	0	1	1	*1	1	0	1	5	Level 1
F3	0	*1	1	1	1	0	1	5	Level 1
F4	0	1	*1	1	1	0	1	5	Level 1
F5	0	*1	*1	*1	1	0	1	5	Level 1
F6	1	1	1	1	1	1	1	7	Level 3
F7	0	*1	1	1	*1	0	1	5	Level 1
Dependencies Power	2	7	7	7	7	1	7		

4.4. Partition Level Analysis

Partition Level is used to determine the hierarchy between factors in ISM. This process helps identify which factors are the main drivers and which factors are more influenced. Table 6, literacy 1 illustrates the relationship between various factors based on Affordability Set (factors that can be influenced by a particular factor), Antecedent Set (factors that influence a specific factor), and Intersection Set (factors with reciprocal relationships with other factors). In addition, Table 6 also groups factors into hierarchical levels, which provides a deeper understanding of the role and interrelationship of each factor in the system.

From Table 6, it can be seen that F1 has an Affordability Set that includes factors 1, 2, 3, 4, 5, and 7, which means that this factor has an influence on various other factors. However, when viewed from the Antecedent Set, F1 is only influenced by F6, which shows that the existence of F1 in this system depends on this factor. The Intersection Set of F1, which only contains one element, shows that the reciprocal relationship owned by F1 is quite limited compared to other factors. Meanwhile, F2, F3, F4, and F5 have a similar pattern of relationships, with an Affordability Set that includes factors 2, 3, 4, 5, and 7. This shows that these factors can influence each other. On the other hand, the Antecedent Set of these factors is quite broad, covering almost all factors in the system (1, 2, 3, 4, 5, 6, and 7), which means that they depend on many factors to function optimally. The Intersection Set for these factors shows that reciprocal relationships occur between the same factors, namely 2, 3, 4, 5, and 7. Thus, these factors have a high level of interaction and are at Level I, indicating that they have equal standing in the system hierarchy.

Unlike other factors, F6 has unique characteristics. This factor has an Affordability Set that includes all factors (1, 2, 3, 4, 5, 6, and 7), which means that F6 has a wide potential influence on the system. However, when viewed from the Antecedent Set, F6 is only influenced by itself. The Intersection Set for F6 also contains only 6, indicating that this factor has a limited reciprocal relationship with itself. This suggests that F6 is likely an independent factor or a major driving factor in the system, which plays a central role in determining how the system operates.

From the structure of Table 6, it can be interpreted that F6 has a very dominant role and is a key element in the system. Meanwhile, F1 has a fairly large role but is still influenced by external factors (F6). Meanwhile, F2, F3, F4, and F5 are closely connected and are at the same level, indicating that these factors are interdependent in carrying out their roles in the system.

Table 6. Literacy 1 (F2, F3, F4, F5, F7)

Factor	Affordability is set	Antecedent set	Intersection Set	Level
F1	1,2,3,4,5,7	1.6	1	
F2	2,3,4,5,7	1,2,3,4,5,6,7	2,3,4,5,7	I
F3	2,3,4,5,7	1,2,3,4,5,6,7	2,3,4,5,7	I
F4	2,3,4,5,7	1,2,3,4,5,6,7	2,3,4,5,7	I
F5	2,3,4,5,7	1,2,3,4,5,6,7	2,3,4,5,7	I
F6	1,2,3,4,5,6,7	6	6	
F7	2,3,4,5,7	1,2,3,4,5,6,7	2,3,4,5,7	I

b. Level 2:

Table 7, literacy 2 shows the results of the literacy factor analysis after removing several factors from the system, namely F2, F3, F4, F5, and F7. Thus, only F1 and F6 remain in the analysis. Table 7 provides an overview of the relationship between the two factors through the Affordability Set (factors that can be influenced), Antecedent Set (factors that influence), Intersection Set (reciprocal relationships), and the hierarchical Level of each factor.

Based on the data presented, F1 has an Affordability Set that includes factors 1, 2, 3, 4, 5, and 7, which means that in the initial system, this factor has an influence on various other factors. However, after factors F2, F3, F4, F5, and F7 are removed, F1 only has a relationship with itself and F6 in the Antecedent Set. The Intersection Set of F1 only contains the number 1, indicating that its reciprocal relationship is limited to itself. Thus, F1 is categorized as a Level II factor, meaning that this factor still has a significant role in the system but is under the influence of other factors. Meanwhile, F6 has a more limited Affordability Set, only including factors 1 and 6. After several factors are removed from the system, F6 only maintains a relationship with itself and F1. The Antecedent Set of F6 only contains the number 6, indicating that this factor is independent of other factors in the system. In addition, the Intersection Set of F6 only contains number 6, confirming that F6 is an independent factor that remains dominant in the system.

From the results of this analysis, it can be concluded that after the elimination of several factors, F6 remains the main factor that stands alone and does not depend on other elements in the system, while F1 still has a relationship with other factors that previously existed but now only depends on itself and F6. With F1's position at Level II, this factor still plays an important role but is under the influence of other factors in the remaining system. On the contrary, F6 remains the most influential factor, which shows that in the implementation of this system, F6 has the main control over the running of the system, while F1 still has an impact on several aspects, but to a more limited extent than before.

Table 7. Literacy 2 (F1) without F2, F3, F4, F5, F7

Factor	Affordability is set	Antecedent set	Intersection Set	Level
F1	1,2,3,4,5,7	1.6	1	II
F6	1.6	6	6	

c. Level 3:

Table 8, literacy 3 (F6) without F1 illustrates how the system evolves after factor F1 is removed, leaving F6 as the only major factor in the analysis. Table 8 highlights the relationships between factors through the Affordability Set, Antecedent Set, and Intersection Set and determines the remaining hierarchical levels in the system.

Based on Table 8, F1 only has affordability on its own (Affordability Set = 1), which means that after F6 becomes the only major factor in the system, F1 loses its ability to influence other factors. The Antecedent Set of F1 includes 1.6, indicating that before F1 is eliminated, this factor is still influenced by F6. However, with no other factors remaining in the system, this relationship becomes insignificant. In addition, the Intersection Set of F1 only contains number 1, indicating that after the system structure changes, F1 no longer has a reciprocal relationship with other factors and stands alone without a broader role.

Meanwhile, F6 remains the dominant factor with an Affordability Set of 1.6, indicating that despite its reduced scope of affordability, this factor still has an influence on the system. The Antecedent Set of F6 only contains the number 6, confirming that F6 is not dependent on other factors and remains independent. In addition, the Intersection Set of F6 also has a value of 6, indicating that the only relationship that still persists in the system is F6 with itself. In the system hierarchy, F6 is at Level III, indicating that this factor is the only remaining element with a significant influence.

Table 8 shows that after F1 is eliminated, F6 becomes the only factor with full control over the system. On the other hand, F1 loses its relevance because it no longer has any relationship with other factors and only has a relationship with itself. Thus, the remaining system is now completely dependent on the existence of F6 as the main driving factor.

Table 8. Literacy 3 (F6) without F1

Factor	Affordability is set	Antecedent set	Intersection Set	Level
F1	1	1.6	1	
F6	1.6	6	6	III

4.5. ISM Diagram

In Figure 2, the ISM Diagram illustrates the hierarchical relationship between factors in the implementation of Green IT in the higher education sector using the Interpretive Structural Modeling (ISM) approach. This structure shows how various factors are interrelated and influence each other in supporting the sustainability of green information technology. These factors are grouped into three main levels, reflecting their role and level of influence in the system.

At the lowest level (Level 3) in the hierarchy, F6 (External and Social Pressure) acts as the main driving element in the system. This factor reflects how government regulations, societal expectations, and market and environmental demands influence higher education institutions' decisions to adopt Green IT practices. The existence of this external pressure then directly influences F1 (Policies and Regulations), which is at the level above it.

As a connecting element (Level 2) in the system, F1 (Policies and Regulations) plays a very crucial role in bridging external pressures with the implementation of Green IT in higher education institutions. This factor determines how universities respond to external demands through the policies and regulations implemented. Decisions in formulating this policy will have an impact on various operational and strategic aspects in the implementation of Green IT.

At the highest level (Level 1) in the hierarchy, there are five main factors that are highly dependent on policies and regulations. These factors are F2 (Management Commitment and Support), which reflects the support and commitment of higher education leaders in encouraging the implementation of Green IT; F3 (Awareness and Education), which refers to the level of understanding, awareness, and education about Green IT practices among academics, students, and education personnel; F4 (Infrastructure and Technology), which relates to the readiness of technology and infrastructure supporting environmental sustainability; F5 (Business Processes and Operations), which shows how Green IT policies can be integrated into the management and operational systems of higher education; and F7 (Finance and Investment), which describes how budgets, investments, and financial resources can be allocated to support sustainability initiatives.

Factors at level 1 are highly influenced by policies and regulations, meaning that decisions made in Green IT policies will determine how management supports implementation, how environmental awareness is increased, how infrastructure is prepared, how business processes are adapted, and how funding is allocated. In addition, a reciprocal relationship is seen between several factors at this level, such as F2 and F3, indicating that strong management support will increase awareness and education related to Green IT, and vice versa, the higher the level of awareness and education will encourage management commitment to further support the initiative. The same thing also happens between F5 and F7, where sufficient investment will determine the extent to which business processes can be adapted to support the implementation of Green IT, and the effectiveness of Green IT implementation in business operations will determine the need for more significant investment for system sustainability.

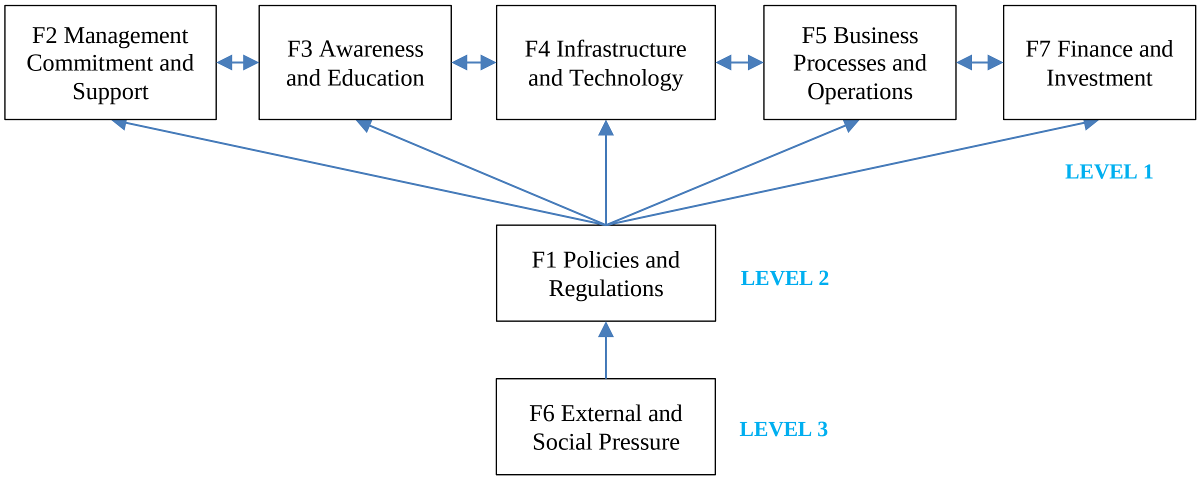

Figure 2. ISM Diagram

From Figure 2, it can be interpreted that the implementation of Green IT in the higher education sector is highly dependent on external forces, which then lead to the formulation of policies and regulations as the main factors in the system. Strong regulations will ensure that all elements in the system run in line with the principles of sustainability. Therefore, an effective strategy in implementing Green IT must start with strengthening policies and regulations, which will then have a broad impact on various aspects of implementation.

Furthermore, the reciprocal relationship between several factors in the system shows that the success of Green IT implementation depends not only on good policies but also on the synergy between management, academic awareness, infrastructure readiness, business process efficiency, and proper funding allocation. Universities that want to be successful in adopting Green IT practices must consider that sustainability cannot be achieved with just one factor but must involve all factors in this hierarchy in an integrated and mutually supportive manner.

4.6. MICMAS Analysis

This MICMAC (Matrice d'Impacts Croisés Multiplication Appliquée à un Classement) diagram illustrates the relationship between factors in the system based on driving power and dependency power. This diagram serves to group the main factors that play a role in the implementation of Green IT in the higher education sector and understand how these factors influence each other in the system.

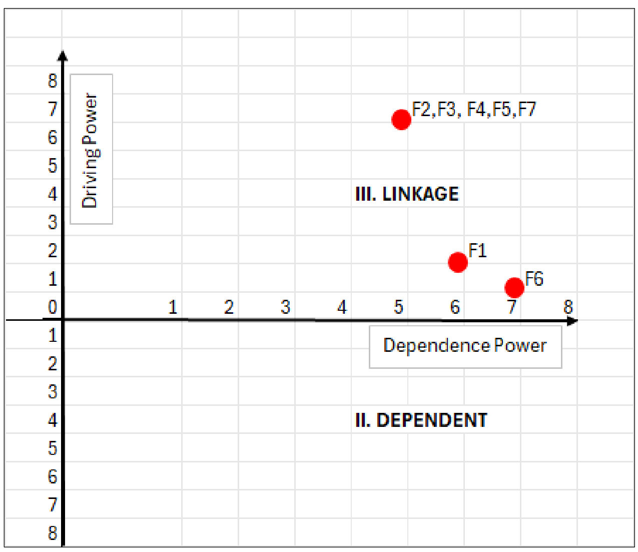

Figure 3. MICMAC diagram

In Figure 3, two main axes represent the characteristics of each factor. The vertical axis (Driving Power) measures how much influence a factor has on other factors in the system. The higher a factor is positioned on this axis, the more significant its role as a driving element. The horizontal axis (Dependence Power) measures the extent to which a factor is dependent on other factors. Factors further to the right indicate a higher dependence on other elements.

Based on the position of the factors in the diagram, three main groups can be identified:

- Factors F2, F3, F4, F5, and F7 are in quadrant III (Linkage), with high Driving Power values (around 7-8) and high Dependence Power (around 6-7). These factors have the characteristics of influencing and being influenced by each other, meaning that changes in one factor will impact other factors in the system. The existence of these factors in the Linkage category indicates that they are very dynamic elements in the implementation of Green IT. Therefore, any changes in policy or strategy related to these factors must be carried out carefully because an imbalance in one element can disrupt the stability of the system as a whole.
- Factor F1 is between quadrant III (Linkage) and quadrant II (Dependent), with a Dependence Power value of around 6 and Driving Power of around 5. The position of F1 in the middle indicates that F1 (Policies and Regulations) has a fairly high dependence on other factors but also plays an important role in regulating the balance of the system. This factor is a link between external pressures and internal factors that play a role in the implementation of Green IT. Thus, the sustainability of the system is highly dependent on the effectiveness of the policies and regulations implemented.
- Factor F6 is in quadrant II (Dependent), with a high Dependence Power value (around 7) but a lower Driving Power value (around 3-4). This position indicates that F6 (External and Social Pressure) is more influenced by other factors than having a major influence on the system. In other words, external and social pressures in the implementation of Green IT are more reactive to policies, management support, infrastructure readiness, and environmental awareness. Therefore, although external pressures play a role in driving the adoption of Green IT, this factor depends on the regulations and internal strategies developed by higher education institutions.

Based on Figure 3, it can be interpreted that the implementation of Green IT in the higher education sector is highly dependent on policies and regulations (F1) because this factor acts as the main link in the system. In addition, factors in the Linkage category (F2, F3, F4, F5, and F7) have very complex and mutually influencing relationships, so an integrated approach is needed to manage these factors effectively. Meanwhile, F6, as an external factor, is more influenced by policies and internal conditions, so its success in driving Green IT depends on the readiness and strategy implemented by the institution. The overall results of the MICMAC Diagram show that in implementing Green IT, higher education institutions need to focus on policies and regulations as the main driving elements, while other factors need to be managed strategically to ensure balance in the system.

4.7. Discussion

The discussion in this article highlights the importance of success factors in implementing Green IT in the higher education sector in Indonesia. Using Interpretive Structural Modeling (ISM) and MICMAC Analysis, this study finds that external and social pressures are the main drivers, encouraging universities to adopt strong sustainability policies (F1), which then influence management commitment (F2), awareness (F3), infrastructure (F4), and financial investment (F7).

Interpretation of Results and Comparison with Previous Research

The results of this study indicate that External and Social Pressure (F6) is the main driving factor in the implementation of Green IT in Indonesian universities. This factor reflects the influence of government regulations, industry pressure, stakeholder demands, and global awareness of sustainability issues. This external pressure then drives Policy and Regulation (F1) as a core element in supporting the implementation of Green IT in the academic environment. With strong regulations, this policy plays a role in regulating, directing, and facilitating strategic steps in implementing environmentally friendly technology.

In addition, this study also found that Management Commitment (F2) and Awareness and Education (F3) have important roles at the operational level. Management commitment is a major factor in providing resources, strategic planning, and monitoring the implementation of Green IT policies. Meanwhile, awareness and education serve to increase the understanding and involvement of academics, students, and education personnel in supporting Green IT practices more actively and sustainably.

The results of this study show fundamental differences with several previous studies. For example, Indrawati et al. [13] examined the factors influencing the adoption of green innovation by SMEs in Indonesia. This study found that three main factors, namely technology, environment, and organization, play a role in the adoption of green innovation, with organizational factors as the main determinant. However, this study was limited in geographical and sector coverage, so the results are less generalizable to the context of higher education. In contrast to this study, which highlights that external and social pressures (F6), and policies (F1) are the main factors in the implementation of Green IT, Indrawati et al. [13] focused more on the internal aspects of the organization in the adoption of green innovation.

Furthermore, Chen & Roberts [20] emphasized the strategic cognition perspective in the implementation of Green IT/IS. Chen's main findings indicate that identity orientation (individualistic vs. collectivistic), external pressures (coercive, normative, mimetic), and organizational focus (cost efficiency or revenue expansion) are factors that contribute to the implementation of Green IT. In this case, Chen's research results are similar to this study regarding the role of external pressure as an important factor, but Chen's research focuses more on internal factors within the organization compared to policy and regulatory factors, which are the main findings in this study.

Meanwhile, Chiang [14] highlighted the evolution of Green IT from energy efficiency to smart city integration, identifying various clusters such as green technology and socio-economic impacts. This research relies more on a literature review and lacks specific empirical data related to Green IT implementation in the higher education sector. Therefore, this study fills the gap in the literature by providing a more specific empirical data-based model for higher education.

Similarly, Thomas et al. [30] emphasized the role of Green IT in smart cities, highlighting energy efficiency, carbon footprint reduction, and quality of public services. However, this research is conceptual and literature-based, so it still requires more concrete empirical studies. This study contributes by providing an empirical analysis of how external factors and regulations play a role in the implementation of Green IT in Indonesian universities.

In other studies, such as Setyaningrum et al. [32], it was found that the adoption of Green IT in MSMEs is influenced by green competitive advantages, innovation, and financial resources. Although these findings are relevant in the industrial context, this study emphasizes the aspects of external pressure and regulation as the main drivers, which have not been widely studied in the context of MSMEs.

From the results of this study, it can be concluded that External and Social Pressure (F6) and Policy and Regulation (F1) are the main factors in the implementation of Green IT in higher education, in contrast to previous studies that have focused more on internal factors, innovation, or technological efficiency. In addition, this study uses Interpretive Structural Modeling (ISM) to map the relationships between factors and determine strategic priorities in the implementation of Green IT, providing advantages in analyzing the complex interrelationships between elements in the higher education system.

Theoretical Implications

The results of this study contribute to Green IT theory and technology management in educational institutions in several ways:

Mapping Factors in a Structured Hierarchy: This study uses Interpretive Structural Modeling (ISM) to map the relationships between key Green IT factors in a structured hierarchy, which has not been widely done in the context of Indonesian higher education. This approach contributes to Green IT theory by developing an ISM-based framework to understand the interactions between factors and reinforces the theory that successful Green IT requires a multi-level and multi-layer approach.

The Role of External Pressure as a Dominant Driving Factor: The finding that external pressure (F6) is a key driver of Green IT policy provides new theoretical insights, especially in the context of developing countries. In more general Green IT theory, external pressure tends to be viewed as a complementary factor, but in this study, external pressure is positioned as the primary factor shaping internal policy. This suggests that theoretical models of Green IT may need to consider the economic and social contexts of different institutions.

The Influence of Management Commitment and Environmental Awareness in the Higher Education Sector: This study also supports the theory of technology management, especially in the context of management commitment (F2) and environmental awareness education (F3), which are interrelated. In the context of higher education, the importance of management commitment to Green IT has been strengthened, and this study contributes to the theory by placing awareness and commitment as connecting factors that can connect policies to operational practices.

Practical Implications

The results of this study have several important practical implications for university policymakers and other decision makers in encouraging the implementation of Green IT:

External Pressure-Based Policies and Regulations: The findings highlight that external pressures such as government regulations and social demands can be key drivers of Green IT policies. Therefore, policymakers in higher education institutions should ensure that their internal policies are not only aligned with external standards but also flexible to respond to changing regulations and societal expectations. Universities can work with regulators to identify relevant sustainability standards and ensure they are implemented in their operations.

The Role of Management Commitment in Driving Awareness and Infrastructure: With management commitment identified as a connecting factor, university leaders need to be actively involved in Green IT initiatives. Management should provide support in the form of budget allocations, strategic policies, and programs that raise awareness of the importance of Green IT among staff and students. Management can also initiate training programs to increase understanding of Green IT on campus.

The Importance of Education and Awareness Among Students and Staff: Awareness and education (F3) are key elements in developing a culture of sustainability on campus. Universities should integrate Green IT into their curriculum and student activities to ensure that all stakeholders understand and support sustainability goals. Through awareness campaigns and training, universities can encourage staff and students to participate in environmentally friendly practices, which not only create positive effects on campus but also impact the community.

Funding Allocation for Green Infrastructure and Technology: Infrastructure and Technology (F4) and Finance and Investment (F7) need to be supported with adequate budgets. These practical implications suggest that universities should prioritize investment in green infrastructure, such as the use of renewable energy, reduced electricity consumption, and hardware recycling. With sustainable investment, universities can reduce long-term costs while increasing operational efficiency.

The findings of this study are quite transferable to other sectors or countries with similar socio-economic and environmental conditions, especially in developing regions. Key factors such as external pressures, budget constraints, limited institutional commitment, and the need for a strong policy foundation are common challenges faced in resource-limited and developing countries.

The use of the Interpretive Structural Modeling (ISM) method in this study provides a structured framework that can be adapted to various sectors, such as health care, manufacturing, or public administration, where sustainability practices are also influenced by external pressures and resource constraints. The hierarchical structure of factors, including an emphasis on management commitment, awareness, infrastructure, and financial investment, is widely applicable across contexts that require strategic alignment for sustainability.

However, transferability depends on contextual similarities. Factors such as regulatory environments, cultural attitudes toward sustainability, and availability of green technologies may differ across sectors or countries. While the framework and findings offer valuable insights, they must be tailored to specific conditions to account for local priorities, policy landscapes, and resource availability. Comparative studies and contextual modifications are recommended to increase the relevance of the findings when applied to other settings.

5. Conclusion

The implementation of Green IT in universities in Indonesia is influenced by various interrelated factors in a complex system. Based on the results of the Interpretive Structural Modeling (ISM) analysis, there are seven main factors that determine the success of Green IT implementation. External and social pressures (F6) are the main driving factors, including government regulations, community demands, and industry encouragement in implementing environmentally friendly technologies. These factors directly influence policies and regulations (F1), which function as the main link in the system. Strong regulations will be the foundation for various other aspects, such as management commitment (F2), academic awareness (F3), infrastructure readiness (F4), business and operational processes (F5), and financial support and investment (F7). With a targeted strategy, including improving education, management support, budget optimization, and digitizing campus operations, Green IT can be implemented effectively in the academic environment, supporting sustainability goals and providing broader benefits to the institution and the environment.

This study has several limitations that can be opportunities for future research. First, this study focuses on factor analysis based on ISM, which is qualitative and expert-based, so further research is needed with a quantitative approach and statistical models to empirically test the relationship between factors. Second, this study has not considered specific aspects of each university, such as differences in institutional scale, geographic location, and academic characteristics, which can affect the success of Green IT implementation. Therefore, future studies can expand the scope of the analysis by conducting comparative studies between universities in various regions. Third, this study is still limited to internal factors of universities, while external aspects such as government support, industry partnerships, and financial incentive policies can be the focus of further research. By considering these factors, future research can provide a more comprehensive picture of the optimal strategy for implementing Green IT in the higher education sector.

5.1. Recommendations for Further Research

Based on the findings and discussion above, some recommendations for further research are as follows:

The study's focus on Indonesia reveals several region-specific factors that may not be fully applicable elsewhere. Budget constraints are a significant barrier, as many Indonesian universities lack funding for energy-efficient technologies. Weak institutional commitment and low awareness among students and staff further hamper the adoption of Green IT, in contrast to countries where sustainability is prioritized. In addition, Indonesia's limited regulatory framework creates a gap in guidance for universities, unlike developed countries with comprehensive environmental policies. The study also found that external pressures, such as government mandates and societal expectations, are the primary drivers of Green IT, whereas institutions in developed countries often act on internal motivations. While these challenges are specific to Indonesia, they offer insights for other developing countries facing similar conditions.

Longitudinal Approach to Monitor Changes in Factors: Longitudinal research is needed to see how these factors evolve and how policy changes or external pressures affect Green IT implementation. This approach will provide insight into the resilience and sustainability of Green IT policies in the face of change.

Integrating New Technologies into a Green IT Framework: Further research could explore how new technologies such as the Internet of Things (IoT) and Big Data can be integrated into a Green IT framework to improve energy efficiency and sustainability. These technologies could provide further insights into energy consumption patterns and potential savings in university operations.

Higher education can address external pressures through targeted strategies, including aligning policies with government regulations, collaborating with industry and communities, and raising awareness about sustainability. For example, higher education can adopt national sustainability frameworks, as seen in China's green campus program, or collaborate with local institutions, such as the National University of Singapore, to implement energy-efficient systems. Enhancing sustainability education, as Monash University has done through dedicated courses and zero-waste initiatives, can better meet societal demands.

Investing in green infrastructure, such as Stanford University's adoption of renewable energy systems, is another effective approach. Additionally, participating in global sustainability rankings, such as the GreenMetric World University Rankings, encourages the adoption of best practices and responds to environmental expectations. These strategies demonstrate how higher education can align with external demands while promoting long-term sustainability.

Thus, this study makes a significant contribution to understanding the success factors of Green IT implementation in Indonesian higher education institutions, focusing on external pressure as the main driver. With the ISM and MICMAC approaches, this study not only strengthens the theory of Green IT but also provides practical guidance for higher education institutions in implementing sustainability initiatives. Theoretical implications include new understandings of the role of socio-economic context in Green IT, while practical implications offer recommendations for policymakers to prioritize supportive policies, management commitment, and awareness education. Further research is needed to deepen this understanding and ensure sustainable Green IT implementation in the higher education sector in Indonesia and other developing countries.

6. Declarations

6.1. Author Contributions

Conceptualization, U.Y.; methodology, U.Y.; validation, U.Y. and P.S.; formal analysis, U.Y. and A.S.; investigation, U.Y., A.S., and P.S.; resources, A.S.; data curation, A.S.; writing—original draft preparation, U.Y. and A.S.; writing—review and editing, U.Y., A.S., and P.S.; visualization, A.S.; supervision, U.Y. and P.S. All authors have read and agreed to the published version of the manuscript.

6.2. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

6.3. Funding and Acknowledgments

We would like to express our sincere gratitude to the Ministry of Research, Technology, and Higher Education of the Republic of Indonesia (Contract Number: 0459/E5/PG.02.00/2024) for awarding us the *Direktorat Riset, Teknologi, dan Pengabdian kepada Masyarakat (DRTPM)* grant under the Fundamental Research Scheme. We also extend our heartfelt thanks to the Institute for Research and Community Service, *Universitas Muhammadiyah Magelang*, for their continuous moral support throughout this study. Finally, we are deeply grateful to the respondents who generously took the time to participate in this research.

6.4. Institutional Review Board Statement

Not applicable.

6.5. Informed Consent Statement

Not applicable.

6.6. Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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