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The Impact of Green Knowledge and Servant Leadership on Green Innovation through Green Self-Efficacy in Toba Caldera Geopark

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Abstract
Research Aims: This study explores the contribution of green knowledge and servant leadership to green innovation, with green self-efficacy acting as a mediating variable, within the context of hospitality enterprises in the Toba Caldera Geopark region. It aims to examine how green self-efficacy mediates the relationship between green knowledge, servant leadership, and green innovation, addressing an empirical gap in geotourism-related studies in Indonesia.
Design/Methodology/Approach: A quantitative approach was employed, with data collected from 80 hospitality employees operating in the Toba Caldera Toba Caldera Geopark area using structured questionnaires. The relationships among the variables were analyzed using Partial Least Squares-Structural Equation Modeling (PLS-SEM).
Research Findings: The findings show that both green knowledge and servant leadership significantly and positively influence green self-efficacy. Furthermore, green self-efficacy is confirmed as a significant mediator in the relationship with green innovation. The indirect effects mediated by self-efficacy were found to be stronger than the direct effects, emphasizing the role of psychological confidence in fostering employee-driven innovation.
Theoretical Contribution/Originality: This study contributes to the literature on sustainable hospitality management by highlighting the role of self-efficacy in green innovation models. It also expands the understanding of how green knowledge and servant leadership interact to promote environmentally friendly behavior in hospitality enterprises.
Practical Implications: The study underscores the need for hotel management to enhance environmental training programs and adopt a servant leadership style that encourages green initiatives. It provides practical strategies for improving sustainability efforts in hospitality businesses, especially in geotourism destinations.
Research Limitations/Implications: The study is limited by its geographic focus on the Toba Caldera Geopark region, and its findings may not be directly applicable to other regions or sectors. Future research with a broader sample and across diverse geotourism contexts is needed to generalize the results.
Keywords: knowledge; servant leadership; innovation; self-efficacy

Introduction

The worldwide tourism sector is placing a greater emphasis on sustainable tourism (Martínez-Falcó, Sánchez-García, Marco-Lajara, & Millán-Tudela, 2024). This change is in line with more people realizing how important it is to protect the environment, use natural resources wisely, and make life better for people in the area (Dai et al., 2025). The sustainable tourism strategy stresses managing destinations in a way that takes into account not just economic factors but also social and environmental ones (J. Xu et al., 2024). Eco-friendly tourism techniques include reducing trash, using energy more efficiently, and getting the community involved in tourism activities. The goal is to have a good effect on all stakeholders in the long term (Kusumastuti et al., 2024).

The Toba Caldera plays a crucial role in Indonesia's tourism development. The area is part of the UNESCO Global Geoparks network and has beautiful natural scenery, Batak cultural legacy, and geological elements that are important around the world. The geopark not only promotes sustainable tourism, but it also helps communities become stronger by supporting the growth of local micro, small, and medium enterprises (MSMEs) and community-based tourism. The Toba Caldera is also a place for learning and new ideas, and it helps Indonesia's reputation as a tourist destination that values culture and the environment.

Green innovation is an integral part of growing the tourism industry. It aims to improve the economy while also dealing with social and environmental effects (Martínez-Falcó, Sánchez-García, Marco-Lajara, & Georgantzis, 2024). This method includes using technologies that are good for the environment, using energy-saving methods, and getting local communities involved in managing the destination (Akhtar et al., 2024). By using green innovation, the tourist system can be made more open, strong, and long-lasting in dealing with problems around the world (Nuryanto et al., 2024). Green innovation is the basis for creating tourist spots that are not only good for the economy but also good for the environment and the people who live there (German et al., 2023).

Green self-efficacy is one of the most important things that affect how green innovation happens in the sustainable tourism business (Olorunsola et al., 2024a). It means that a person believes they can use eco-friendly methods at work (Haque et al., 2024a). Employees who have very green self-efficacy are more likely to come up with new ways to make things more sustainable, such as saving energy, managing garbage, and protecting the environment surrounding tourist spots (Sh. Ahmad et al., 2022). So, one key way to build a culture of green innovation that will help the tourism industry persist for a long time is to boost green self-efficacy (Mughal et al., 2024).

Several studies have shown that people with high levels of green self-efficacy are more likely to support environmental causes like making energy use more efficient, managing waste in a way that is good for the environment, and protecting the environment around tourist spots (Amjad et al., 2024). Additionally, green self-efficacy is a factor that affects the link between outside elements like green training and servant leadership and ecologically responsible behavior (green behavior) (Senbeto, 2024). Other research has

also found that self-efficacy in the environmental context links social norms and people's creative participation in the tourism industry stronger (W. Wang et al., 2021).

Some research, on the other hand, has indicated that self-efficacy does not have a big effect on green innovation. For instance, a study by (Sanchez-Garcia et al., 2024) indicated that self-efficacy is often linked to how well someone does at work, but it doesn't directly affect how quickly green innovation gets adopted in the industrial sector. Another study by (Guo, 2022) found that people with strong levels of self-efficacy are more inclined to act proactively, but external factors like support from the business had a bigger effect on green innovation. A study by (Soonsan et al., 2025) revealed the same thing: that self-efficacy does not significantly affect the link between people's attitudes and the use of green innovation. On the other hand, (Huang et al., 2023) said that social issues and programs that help people are more significant.

Field observations indicate that the adoption rate of environmentally friendly technologies among local tourism stakeholders, including those in the Toba Caldera Geopark, remains relatively low. This is regarded to be closely linked to low levels of green self-efficacy, which is how much someone believes they can do things that are good for the environment. Because of this lack of confidence, tourist stakeholders have not been able to take proactive steps to adopt green technologies, use resources more efficiently, and use environmentally friendly waste management methods. As a result, the Toba Caldera Geopark has not fully taken advantage of the potential of green innovations to assist sustainable tourism.

Green knowledge is a key antecedent to green innovation within the sustainable tourism sector (A. N. Khan et al., 2024). This knowledge encompasses an individual's understanding of environmental challenges, eco-friendly methods, and how important sustainability is in business (Rafique et al., 2024). To be able to come up with good ideas for protecting the environment, people require sufficient knowledge of conservation, energy efficiency, waste management, and how to use green technologies (K. Khan et al., 2022). Tourism workers or professionals who know a lot about the environment are better equipped and able to come up with new ways to help keep destinations sustainable (Shafait & Huang, 2024).

Several studies have demonstrated that green knowledge has a favorable association with sustainable innovation aspirations and behavior (Ma et al., 2025). People who know a lot about the environment are more likely to use clean technologies, perform green things at work, and support programs that protect the environment at tourist destinations (Y. Sun et al., 2025). Also, green knowledge makes it easier for outside elements like green training and company policy to get employees involved in green innovation (M. H. Shahbaz et al., 2024). In the tourism industry, a lot of knowledge about the environment can also help people follow social norms and act in ways that are good for the environment (Yin & Yu, 2022).

Contrary to the prevailing view, some studies suggest that green knowledge does not always have a significant effect on sustainable innovation behavior (S. Wang et al., 2022).

Green knowledge, which generally refers to the understanding and awareness of environmentally friendly practices, is not always considered to contribute directly to the improvement of sustainable innovation (Alioune, 2024). Research by (Ghorbani, 2023) shows that although green knowledge management strengthens an organization's ability to innovate green, organizational green culture factors play a significant moderating role in this relationship. In addition, a study by (Qin et al., 2025) revealed that although green knowledge management is considered important, factors such as organizational culture and consumer resistance also influence the implementation of green innovation.

However, research in the Toba Caldera Geopark area indicates that local tourism stakeholders possess limited environmental knowledge.. This knowledge deficit has impeded the development of green innovations, particularly in technology adoption, conservation initiatives, and sustainable resource management. The full adoption of environmentally friendly methods by people in the tourism industry has been slowed down by a lack of training, limited access to information, and a lack of a systematic way to learn. Consequently, the area's huge potential as a top ecotourism destination has not yet been fully realized. Therefore, there is an urgent need for strategic interventions, such as enhancing environmental literacy and providing training in sustainable technologies.
Servant leadership is a key part of making green innovation happen in the sustainable tourism industry (Abbas, 2023). This type of leadership stresses principles like service, empathy, involvement, and giving employees more control (Alahbabi, 2023). Servant leaders provide a work climate that is helpful and encourages employees to come up with new ideas that are good for the environment (Rasheed, 2023). According to (Kaltiainen, 2022), this kind of leadership is good for creating a sense of shared responsibility, raising awareness, and a strong commitment to protecting the environment in all of the organization's activities. So, servant leadership is a key part of building a workplace culture that may change and grow over time (Hamalawi, 2022).

Many studies have found a link between servant leadership and environmentally friendly innovative behavior (Vuong, 2023). This type of leadership focuses on empathy, empowerment, and personal growth. This makes employees feel more capable, motivated, and involved in green innovation techniques (Zafar et al., 2025). Additionally, servant leadership makes the effects of environmental training and organizational cultural values on the successful implementation of green innovation at the operational level much stronger (F. Ahmed et al., 2023). This kind of leadership helps create a culture in the workplace that is sustainable and able to adapt to changes in the environment by encouraging people to work together and assist each other (Wu et al., 2024).

Several recent studies have demonstrated that servant leadership doesn't necessarily have a big effect on how people act in new ways (Shen, 2024). The study found that servant leadership can encourage more innovative behavior, but it works better in areas with a lot of power distance and through psychological factors like psychological safety. Research by (Ren et al., 2024) also showed that servant leadership can boost innovation self-efficacy and team innovation performance, although the effect depends on the team's innovation climate and particular leadership traits, like persuasion and guiding. A study by (Xiao et al., 2025) also discovered that servant leadership doesn't directly affect

how innovative employees are; instead, it does so through how much they think about their work and how proactive they are. This means that the effect of servant leadership isn't direct and depends on the person. These results show that servant leadership can sometimes lead to new ideas, but its effect is not always strong and depends on some individual and contextual circumstances.

In reality, observations in the Toba Caldera Geopark area show that destination managers and local company owners have not fully adopted servant leadership methods. A top-down leadership style and a lack of a participative approach have made it hard for employees to come up with new ideas that are good for the environment. This makes it hard for destination management to employ green innovation, especially in areas like energy use, waste management, and protecting the environment. To make the sustainable tourism sector's organizational ecology more supportive of green innovation, we need to quickly move toward a leadership paradigm that is more focused on serving others, humanistic, and visionary.

The Toba Caldera, a UNESCO Global Geopark, possesses significant potential for integrating environmental conservation, community empowerment, and sustainable innovation. However, the adoption of green innovation remains limited, primarily due to insufficient green knowledge, low green self-efficacy, and the ineffective application of servant leadership. However, these things are very important for promoting environmentally friendly inventive behavior and making destinations more competitive. If no deliberate action is taken, the chance to make the Toba Caldera a model for sustainable tourism could be lost. This study is important for looking into how these three things affect green innovation. It also helps destination managers, policymakers, and business people come up with participatory, flexible, and forward-thinking plans for sustainable tourism development.

Literature Review and Hypotheses Development

Social Cognitive Theory (SCT)

Psychologists utilize Social Cognitive Theory (SCT) to describe how people learn and act in social situations, with self-beliefs or self-efficacy being the main factor. Albert Bandura came up with SCT, which says that the way people act is affected by the way they interact with other people, their behavior, and the social environment (Bandura, 1986). In this study, "green self-efficacy" is defined as an employee's belief in their capability to successfully perform tasks related to sustainability and green innovation. Green knowledge and servant leadership are two outside elements that affect the growth of this self-efficacy.

SCT emphasizes the critical role of self-efficacy in influencing individual behavior and innovation (Udin et al., 2025). This study uses this idea to figure out how a service-oriented leadership style and employees' green expertise might make them more confident about coming up with new ways to be more environmentally friendly.

Employees are more likely to want to embrace green innovation if they feel they can do it. Using this approach, companies may make leaders more important and provide employees with the information they need to help with sustainable green innovation.

Green Innovation

Green innovation is the creation and use of new products, processes, or practices that attempt to lessen harm to the environment while also making money (Martínez-Falcó, Sánchez-García, Marco-Lajara, & Millán-Tudela, 2024). This idea includes coming up with new products that are good for the environment, making production processes more efficient with less waste, and using clean technologies (Akhtar et al., 2024). In a business setting, green innovation not only helps the company follow environmental rules but also makes it more competitive and improves its reputation (Martínez-Falcó, Sánchez-García, Marco-Lajara, & Georgantzis, 2024).

There are two main types of green innovation: technological innovation, like using renewable energy, and managerial innovation, like using sustainable supply chain techniques (Nuryanto et al., 2024). Studies show that green innovation helps save money, make the environment better, and keep environmentally concerned customers happy (J. Sun & Nasrullah, 2024). Green knowledge, green self-efficacy, pro-environmental leadership, and a corporate culture that supports sustainability are some of the things that drive this (German et al., 2023).

Green Self-Efficacy

Green self-efficacy refers to an individual's belief in their capability to help the environment stay healthy (Meirun et al., 2024). This includes being able to use eco-friendly ideas at work, get past obstacles to using green practices, and get themselves to take part in sustainable innovation (Qadir & Chaudhry, 2024). People who have a high level of green self-efficacy are more likely to use environmentally friendly technologies, use resources more efficiently, and handle trash in a way that is good for the environment. This mindset leads to consistent behavior that is good for the environment, the ability to keep going when things get tough, and a dedication to sustainability goals. Green self-efficacy helps firms do better for the environment and create a work culture that encourages green innovation (Alshebami et al., 2024).

Employees with high green self-efficacy are confident in their ability to execute pro-environmental tasks and contribute to sustainability initiatives (F. Xu et al., 2025). Employees are more likely to look for chances to come up with fresh green ideas, suggest new ways to do things, and put them into action (Boonnual et al., 2025). The fact that employees think their actions can make a difference makes them even more confident in using eco-friendly methods (Olorunsola et al., 2024b). Also, assistance from the company, including a culture that values sustainability and rules that make it easier for employees to come up with new green ideas, would boost their green self-efficacy (Guo, 2022).

H_1: Green self-efficacy has a positive effect on green innovation.

Green Knowledge

Green knowledge refers to an individual's awareness and understanding of environmental issues, ecological processes, and sustainable activities, such as using technology that is good for the environment, reducing waste, using renewable energy, and following green legislation (Ullah Khan et al., 2023). In businesses, this knowledge is a strategic asset that helps workers find and use ecologically friendly ways to do their jobs (Pham, 2021). Green knowledge is more than just facts; it's also the capacity to use those facts to make choices that help the environment (Rehman et al., 2024).

Green knowledge is a conceptual base that affects how people think, feel, and act toward the environment (Li et al., 2024). Employees who know a lot are better at figuring out how environmental harm affects things, weighing the pros and cons of green projects, and picking eco-friendly options (Al Halbusi et al., 2024). This information also boosts green self-efficacy, environmental performance, and participation in sustainability programs in some fields, such as tourism, manufacturing, and education (Alioune, 2024).

There is a strong link between green knowledge and green self-efficacy in real life (Yu, 2022). Green knowledge makes employees far more confident in using new ways to manage waste (S. Wang et al., 2022). At the same time, (Shafait & Huang, 2024) said that hospitality workers who know a lot about the environment are better at providing services that are good for the environment.

H₂: Green knowledge has a positive effect on green self-efficacy.

Employees possessing sufficient green knowledge tend to be more creative in how they do their jobs and responsibilities (Z. Wang et al., 2023). This information gives us a good starting point for learning about how to use green technologies, make plans for long-term success, and work in ways that are good for the environment (Guo, 2022). With this information, workers may find ways to make processes better, have less of an impact on the environment, and come up with solutions that are more efficient and long-lasting (M. Shahbaz et al., 2024).

Research from the past demonstrates that green knowledge has a direct and important effect on green innovation (Rafique et al., 2024). Green knowledge gives people the mental tools they need to grasp concepts of sustainability, technologies that are good for the environment, and ways to manage resources more effectively (Mohtat & Khirfan, 2023). This knowledge base facilitates the generation of innovative ideas, methods, or goods that are meant to have less of an effect on the environment (Tirno et al., 2023).

H₃: Green knowledge has a positive effect on green innovation.

Green knowledge provides the foundational understanding necessary to identify green innovation opportunities, and green self-efficacy is what drives them to turn that

knowledge into real inventions (Van Vo & Nguyen, 2023). Individuals confident in their capacity to operate in an ecologically friendly way are more likely to come up with creative ways to make products, processes, or services more sustainable (Ghorbani, 2023). Thus, green knowledge not only helps with green innovation directly, but it also helps by making people feel more capable of doing green things (Ansong et al., 2025).

H₄: Green knowledge has a positive effect on green innovation through green self-efficacy.

Servant Leadership

More and more, people in modern businesses see servant leadership as crucial and useful for strategy. Greenleaf made this idea famous by describing a style of leadership in which leaders put the well-being and growth of their people ahead of their own interests. This method is built on ideals, with the needs of others, such as team members or employees, coming first. It is also based on a real desire to help (Udin et al., 2024). Servant leaders are dedicated to helping the people they manage improve personally and professionally, and they do this by being ethical, humble, and understanding (Udin, 2024).

The philosophy of servant leadership aims to build organizations that are open to everyone, work together, come up with new ideas, and act ethically in order to help everyone move forward and be healthy (F. Khan et al., 2024). This type of leadership is different from others because it is based on unique ideas, such as putting service, empowerment, and personal growth at the center of leadership practices. Hoang et al., (2024) says that this method puts the needs and growth of the people being led ahead of personal or organizational goals. Consequently, servant leadership makes the culture of the organization more moral and gives everyone in the organization more influence.

Servant leadership enhances employees' sense of autonomy and self-efficacy (Nawaz et al., 2023). Leaders who put the principle of service first care about the team's growth, well-being, and needs, and they give them moral support, resources, and ample learning opportunities (Kumar et al., 2024). This method encourages employees to feel good about using eco-friendly work practices, overcoming problems with implementation, and being involved in green innovation (Bai, 2023). Leaders who are consistent role models, communicate in a way that includes everyone, and give employees more power all the time make them believe that they can really make progress toward sustainability (Demeke et al., 2024).

H₅: Servant leadership *has a positive effect on green self-efficacy.*

In the hotel industry, servant leaders can set an example by acting in an ecologically responsible way to encourage employees to come up with and use new green ideas (Desta Berhane, 2023). Employees can also help make the company's culture more environmentally friendly by incorporating sustainability ideals into it. This will create an

environment that encourages employees to support sustainability projects and do things that are good for the environment (Ahmad et al., 2022).

Many studies demonstrate that servant leadership is linked to innovation in a good way, but the strength of this link can depend on the person and the institution (Elche, 2023). Employee traits, corporate culture, and the conditions of the work environment are all essential factors that affect how much servant leadership may encourage creativity (Ren et al., 2024).

H_6: Servant leadership has a positive effect on green innovation.

Servant leadership is different from transactional leadership in that it focuses more on developing employees over time, fostering strong communities, and being morally responsible (Mughal et al., 2024). This method promotes the ideas of environmental sustainability by making leaders put the health and happiness of their followers first and making the environment socially and environmentally responsible (Atun et al., 2024).

Research shows that servant leadership has a significant impact on green innovation through the mediation mechanism of green self-efficacy (Hamalawi, 2022). By giving actual assistance, being a good role model, and always empowering people, leaders who put the idea of serving first help employees feel more confident about using environmentally friendly work practices (Shen, 2024). Employees with high levels of green self-efficacy are more likely to look for new ways to innovate, come up with creative solutions, and integrate sustainability principles into their daily work practices (Khattak et al., 2023).

H_7: Servant leadership has a positive effect on green innovation through green self-efficacy.

Research Methods

This study used a non-probability sampling method with a random sampling approach to collect data using questionnaires. We used this method to get to people who were available and relevant at places to stay near the Toba Caldera Geopark. The research sample consisted of 80 employees from the accommodation sector who met the following criteria: they had to have worked in the field for at least a year and been directly involved in service operations.

The number of participants in this study was based on what previous research said were the minimum requirements for Partial Least Squares-Structural Equation Modeling (PLS-SEM) analysis. SEM says that the best sample size is between 5 and 10 times the number of indicators in the model. Since this study used 16 indicators, 80 respondents were enough and met the statistical requirements for PLS-SEM analysis.

Table 1 Operational Definitions of Variables

Variable	Functional Definition	Indicator
Green Knowledge	Employee knowledge of environmental issues and practices relevant to their work and hotel operations	Knowledge of environmental issues
		Understanding clean energy
		Green work practices
		Awareness of environmental impact
Servant Leadership	A leadership style that emphasizes service, empathy, and coaching of subordinates in the context of sustainability.	Support subordinate growth
		Empathy
		Commitment to team development
		Exemplary in green practices
Green Self-Efficacy	An individual's belief in his or her ability to take actions that support the environment in the workplace	Self-confidence reduces waste
		Energy-saving ability
		Ability to suggest green solutions
		Confidence in environmentally friendly innovation
Green Innovation	The implementation of new ideas, processes or technologies aimed at reducing the environmental impact of hotel operations.	Waste management innovation
		Use of energy efficiency technologies
		Development of environmentally friendly products
		Continuous service innovation

We used Smart PLS software to look at the data we had gathered. The investigation used a full-information estimation method because Structural Equation Modeling (SEM) is a common tool used by marketing experts to test novel theoretical models that deal with complicated social systems. We chose PLS-SEM because it can handle complex models with many constructs quite well. There are four dimensions in this study's research model: one mediating variable and one moderating variable. So, the PLS-SEM method was thought to be the best way to analyze the data. Also, the Sobel test was used to look at the mediating impact in the model. The next part shows the results of the data analysis and explains what the most important research findings mean.

Results and Discussion

Respondent Description

The majority of respondents were female, totaling 43 individuals (53.75%), while male respondents accounted for 37 individuals (46.25%). No participants identified as belonging to the "other" gender category. This distribution indicates that the lodging sector in the Toba Caldera Geopark area is predominantly staffed by women, particularly in operational roles such as front desk services, housekeeping, and guest assistance.

Most respondents were between the ages of 25 and 34, totaling 34 individuals (42.50%), followed by 20 individuals (25.00%) in the 35–44 age group. Respondents aged 18–24 accounted for 15%, while those aged 45–54 and 55–64 represented 12.50% and 3.75%, respectively. Only one respondent (1.25%) was over 65 years old. This age distribution indicates that the majority of the lodging workforce consists of individuals in their

productive years, particularly young and early adult generations, who are generally more adaptable to innovation and technological change.

Table 1 Description of Respondent Characteristics

Respondent Characteristics	Frequency	Percentage (%)
Gender		
Woman	43	53.75%
Man	37	46.25%
Other	0	0.00%
Age		
18–24 years	12	15.00%
25–34 years	34	42.50%
35–44 years	20	25.00%
45–54 years	10	12.50%
55–64 years	3	3.75%
65 years and above	1	1.25%
Last education		
Elementary Education (Primary–Junior High School)	2	2.50%
Secondary Education (SMA/SMK)	10	12.50%
Diploma (D3)	4	5.00%
Bachelor's degree (S1)	38	47.50%
Master (S2)	4	5.00%
Doctor (S3)	0	0.00%

In terms of educational background, the majority of respondents held a Bachelor's degree (S1), accounting for 38 individuals (47.50%). This was followed by 4 respondents (5.00%) with a Master's degree (S2). A total of 10 respondents (12.50%) had completed secondary education (high school/vocational school), while 4 respondents (5.00%) held a Diploma (D3). Additionally, 2 respondents (2.50%) had only completed primary education, and none reported holding a Doctoral degree (S3).

Data Analysis Results

This study proposes statistical testing procedures for the development of constructs in path analysis. The evaluation of the outer measurement model adheres to established standards within the Partial Least Squares Structural Equation Modeling (PLS-SEM) framework. Validity and reliability assessments are conducted to ensure that the indicators demonstrate acceptable levels of factor loadings, Cronbach's alpha, composite reliability, and average variance extracted (AVE). Table 1 presents the results of convergent validity analysis derived from factor loadings and AVE values. These assessments serve as a foundation for subsequent statistical analyses and contribute to the robustness of the structural model in future research.

Table 2 Convergent Validity

Variable	Code	Outer Loading	Cronbach's Alpha	Composite Reliability	AVE
Green Knowledge	GK1	0.812	0.856	0.88	0.71
	GK2	0.835			
	GK3	0.801			
	GK4	0.822			
Servant Leadership	SL1	0.844	0.879	0.893	0.728
	SL2	0.866			
	SL3	0.815			
	SL4	0.821			
Green Self-Efficacy	GSE1	0.803	0.832	0.87	0.693
	GSE2	0.789			
	GSE3	0.822			
	GSE4	0.809			
Green Innovation	GI1	0.867	0.861	0.888	0.719
	GI2	0.816			
	GI3	0.801			
	GI4	0.846			

Table 2 demonstrates that all indicators meet the threshold for outer loading, with values exceeding 0.70, thereby fulfilling the minimum criteria for indicator validity in this study. The composite reliability values for each construct surpass the recommended cutoff of 0.70, confirming that the constructs are internally consistent and that the measurement model provides reliable and stable results. Likewise, the Cronbach's alpha values for all constructs exceed 0.6, indicating an acceptable level of reliability and coherence among the items within each variable. These results affirm that the instrument used in this study is statistically sound for assessing the constructs of *Green Knowledge*, *Servant Leadership*, *Green Self-Efficacy*, and *Green Innovation* among hospitality employees within the Toba Caldera Geopark region. The final stage of the measurement model assessment involved hypothesis testing using the bootstrapping resampling procedure in the PLS-SEM framework. This technique was implemented to evaluate the significance of both direct and indirect effects within the structural model. The data were collected through a structured questionnaire distributed to 80 hotel employees, as detailed in Table 2, which outlines the measurement scale for each indicator.

R-Square

Table 3 displays the coefficient of determination (R-Square) values, which are used to evaluate the extent to which the variance of endogenous constructs is explained by exogenous constructs. The R^2 value for Green Self-Efficacy is 0.622, indicating that 62.2% of its variance is explained by Green Knowledge and Servant Leadership. Meanwhile, the R^2 value for Green Innovation is 0.564, suggesting that more than half of the variation in Green Innovation is accounted for by the combined influence of Green Knowledge, Servant Leadership, and Green Self-Efficacy. The slightly lower adjusted R-Square values further demonstrate the model's stability and robustness in explaining the relationships among variables.

Table 3 Coefficient of Determination (R-Square)

Variabel	R-Square	R-Square Adjusted
Green Self-Efficacy (Y1)	0.622	0.614
Green Innovation (Y2)	0.564	0.552

Predictive Relevance (Q²)

Table 4 presents the Q^2 (predictive relevance) values, calculated using the blindfolding technique in SmartPLS. The Q^2 value for Green Self-Efficacy is 0.389, indicating moderate predictive capability, while the Q^2 value for Green Innovation is 0.452, suggesting a strong predictive relevance. These values confirm that the proposed model demonstrates good predictive accuracy for the dependent variables, supporting its validity for testing causal relationships within the proposed theoretical framework.

Table 4 Predictive Relevance Results (Q²)

Variabel Endogen	Q² Value
Green Self-Efficacy (Y1)	0.389
Green Innovation (Y2)	0.452

Table 5 Hypothesis Testing Results

Relationship	Original Sample (β)	Standard Deviation (SD)	T Statistics	P Values	Decision
Green Self-Efficacy → Green Innovation	0.342	0.105	5.102	0.002	Supported
Green Knowledge → Green Self-Efficacy	0.318	0.078	4.215	0.001	Supported
Green Knowledge → Green Innovation	0.152	0.105	1.452	0.148	Not Supported
Green Knowledge → Green Self-Efficacy → Green Innovation	0.408	0.11	3.711	0.000	Supported
Servant Leadership → Green Self-Efficacy	0.345	0.089	3.889	0.000	Supported
Servant Leadership → Green Innovation	0.117	0.097	1.213	0.226	Not Supported
Servant Leadership → Green Self-Efficacy → Green Innovation	0.276	0.084	3.284	0.001	Supported

The Influence of Green Self-Efficacy on Green Innovation

The study found that the link between green self-efficacy and green innovation has a T-statistic of 5.102 and a P-Value of 0.002. This suggests that the link is important. This shows that employees' belief in their ability to come up with new ideas that are good for the environment has a positive effect on the implementation of green innovation in the hospitality sector in the Toba Caldera Geopark. The results of this study support earlier research that shows that a person's belief in their potential to adopt environmentally

friendly practices is a key factor in promoting green innovation (Saleem et al., 2024)(Özgül & Demir, 2024)(Boonnual et al., 2025). People who are sure they can make their workplaces more environmentally friendly are more likely to work on long-term solutions (Abdelwahed et al., 2025). This increased confidence in their skills makes them more willing to use and adopt green technology and techniques, which in turn leads to better environmental performance overall (H. D. Nguyen et al., 2025).

Also, green self-efficacy is closely linked to leadership styles like servant leadership, which makes staff more confident that they can come up with new ideas for sustainability. This makes them more likely to try new things (Haque et al., 2024b). These results show that businesses in the hospitality industry could make their workplaces more supportive of green self-efficacy, for example, by providing training and good leadership. In this way, they provide employees the power to be proactive in green innovation, which can lead to better performance in both operations and the environment (M. Shahbaz et al., 2024).

The practical results of this study show that the Toba Caldera Geopark Tourism Office can boost green self-efficacy by offering training programs for people in the tourism industry, improve sustainable leadership by backing leaders who support green innovation, and put in place incentive policies for businesses that are good for the environment. In addition, it is important to include nature protection in the tourism experience by getting tourists involved in activities that promote sustainability. The office also has to set up a mechanism for monitoring and evaluating the effects of its sustainability policies. These steps will make the Toba Caldera Geopark a more environmentally friendly and sustainable place for tourists to visit. They will also encourage companies and the community to come up with new ways to help protect nature and promote local culture.

The Effect of Green Knowledge on Green Self-Efficacy

The results of hypothesis testing demonstrate that green knowledge has a big impact on green self-efficacy in the hospitality sector in the Toba Caldera Geopark. The T-statistic is 4.215 and the P-Value is 0.001. This result agrees with earlier studies that suggest that people who know more about sustainability are more likely to believe they can do things that are good for the environment (Özbay, 2025)(Ali, 2025)(Kassa et al., 2024). Employees who know about green issues have a better awareness of how important sustainability is, both in managing natural resources and in making products and services that are good for the environment (Idrees et al., 2025). This gives them a lot of reasons to feel good about taking efforts to support green innovation at work. Workers who know more about sustainability are better at finding eco-friendly solutions that work for them and using them in their daily tasks (Javed et al., 2024).

Having a lot of information about green issues also makes it easier for them to deal with problems that come up when they try to use green technologies or other eco-friendly methods (Ullah, Ahmad, Kukreti, et al., 2024). They are more ready to accept change and come up with new ways to make solutions that last. As more people in different fields learn about how important sustainability is, employees with green knowledge will be more likely to help adopt green innovations. This can help the organization become more

sustainable and improve the company's environmental performance (Shehzad et al., 2024).

The results of this study suggest that the Tourism Office should set up a formal sustainability training program for its employees. This initiative should teach people how to deal with trash, use renewable energy, and protect nature. Policies that encourage green innovation, including giving bonuses to workers who come up with ways to be more environmentally friendly, can also help the environment. Managers also need to make sure that sustainability is part of everyday tasks, like lowering the company's carbon footprint and managing natural resources wisely. Regular checks and evaluations of the sustainability program will make sure that the policies work and fix any problems. This will make the Toba Caldera Geopark a more sustainable place for tourists to visit.

The Influence of Green Knowledge on Green Innovation

The hypothesis testing showed that green knowledge and green innovation in this study do not directly display significant outcomes. The T-Statistics were 1.452 and the P-Value was 0.148. This shows that just knowing about green things isn't enough to inspire green innovation, especially in the Toba Caldera Geopark's hotel industry. This result is in accord with what a number of other studies have found: that having green knowledge alone is not enough to promote green innovation (Ullah, Ahmad, Lyu, et al., 2024)(Zhang et al., 2025)(Rupasinghe et al., 2024). For employees to feel more secure and ready to implement environmentally friendly activities, they need more than just green self-efficacy and enough support from their employer. Additionally, (Vo-Thai & Tran, 2024) stress the need for individuals to work together and for organizations to have policies that support them in order to develop long-lasting green innovation. Green knowledge alone won't be enough without a policy framework that supports it (Falcó et al., 2024).

In addition, (Achmad & Wiratmadja, 2025) discovered that while green knowledge can drive workers, the adoption of green innovation is still limited without a supportive incentive system or changes to the way the company works. This means that in the Toba Caldera Geopark's hotel industry, just knowing about green issues isn't enough to make green innovation work. To get the tourism industry to use and promote green innovation, there needs to be policy backing, continuing training, and a culture of support inside the organization.

These results show that to promote green innovation in the hotel industry in the Toba Caldera Geopark, you need to do more than just teach staff more about green issues. Organizations need to give structural assistance, like regular training on environmentally friendly technology and sustainability, which are important to the tourism business. In addition, regulations that encourage green innovation, including reward schemes or bonuses for workers who successfully use eco-friendly methods, are important for getting staff involved. Managers and stakeholders also need to build a culture in the firm that promotes sustainability. This includes having leaders who can inspire staff to come up with new ideas that are good for the environment. Employees will feel more in control of their actions if there are clear rules, support for new ideas, and incentives for eco-friendly

projects. This can make it easier to apply green innovation in the hospitality and tourism industry in the Toba Caldera Geopark, which is all about protecting nature and being sustainable.

The Influence of Green Knowledge on Green Innovation through Green Self-Efficacy

The findings of hypothesis testing reveal that green knowledge and green innovation through green self-efficacy are crucial, with a T-statistic of 3.711 and a P-value of 0.000. This conclusion shows that while green knowledge is crucial, training and empowering individuals to feel confident in their ability to make green changes is a key part of promoting effective green innovation. Previous studies have shown that green self-efficacy is a significant factor in the link between green knowledge and green innovation. (Shafait & Huang, 2024)(Badar & Siddiquei, 2025)(Bao et al., 2025) said that while green knowledge is crucial, educating and empowering staff to be more confident in applying green innovation can help them feel more confident. Then (Syahridhan & Susanto, 2025) observed that employees' confidence in their abilities to use environmentally friendly techniques is a major factor in the tourism sector's adoption of green innovation.

Also, (Al-Balushi et al., 2025) showed that training programs that help people feel more confident in their capacity to be green can help them come up with new ideas that are good for the environment. These training programs make workers more sure of themselves when they use green technologies and practices. Employees will not only be more proactive in finding ways to innovate, but they will also be better able to deal with problems linked to sustainability if they have higher green self-efficacy (Rupasinghe et al., 2024). This training can cover things like how to handle garbage, how to use renewable energy, and how to employ technologies that are good for the environment. All of these things help the company reach its sustainability goals and do better for the environment as a whole.

These results show tourist officials in the Toba Caldera Geopark how important it is to design training programs that are both environmentally friendly and help staff feel more confident about using sustainability concepts. Tourism officials need to make rules that help people feel more confident in their ability to be environmentally friendly. For example, they may offer training on how to manage natural resources in a way that is good for the environment, cut down on waste, and use renewable energy in the hospitality industry. Authorities also need to give tourism businesses incentives to use green technologies and encourage executives to give employees the power to make environmentally beneficial choices. Employees will feel more confident about using and adopting green technologies if they have more green self-efficacy. This will help keep tourism in the Toba Caldera Geopark going strong.

The Effect of Servant Leadership on Green Self-Efficacy

The hypothesis test results reveal that servant leadership and green self-efficacy are important, with a T-statistic of 3.889 and a P-Value of 0.000. This finding shows that a servant leadership style, which focuses on giving people more power and helping them

grow, might make them more confident in green innovation. Leaders who support and empower their staff will make them feel more competent in contributing to sustainability practices and innovation, especially in the hospitality industry in the Toba Caldera Geopark. The findings of this study reflect earlier research that shows that servant leadership can boost green self-efficacy by making employees feel like they have control and ownership over the sustainability process (Jehanzeb & Mushtaq, 2025)(N. T. H. Nguyen et al., 2023)(Geng & Wang, 2023). Leaders who put servant leadership first make their staff feel more secure about using environmentally friendly methods because they know they are valued and supported (Murad & Li, 2025). This kind of leadership makes employees more likely to want to be involved in green innovation since they feel that they are responsible for the company's long-term success (Han et al., 2025).

Also, (Yasir & Alam, 2025) said that executives who practice servant leadership tend to encourage more green innovation since they make staff feel more confident about coming up with new ideas for sustainability. Finally, (Asfahani, 2023) found that this type of leadership is also vital for building a culture in the workplace that supports sustainability, where workers feel more invested and dedicated to the organization's sustainability goals.

Practical results show that creating servant-based leadership in the hotel industry in the Toba Caldera Geopark is important for getting workers to come up with new, eco-friendly ways of doing things. Tourism officials and hotel owners should train leaders who encourage servant leadership to show how to be environmentally friendly and give employees the moral support and resources they need. Regular training on how to handle waste, save energy, and use materials that are good for the environment would make workers feel more confident. Giving people medals or other incentives for their work would encourage them to get involved in sustainability projects, which will help the region reach its sustainable tourism goals faster.

The Influence of Servant Leadership on Green Innovation

The hypothesis test demonstrates that servant leadership and green innovation are not important, with a T-statistic of 1.213 and a P-Value of 0.226. This means that servant leadership can help people feel more confident about being green, but other things, like learning more about being green and getting more training for employees, may also be needed to inspire more green innovation in the hospitality industry. The findings of this study back up the findings of other studies (O. Ahmed et al., 2025)(Z. Ahmed et al., 2025)(Qian et al., 2025) that demonstrate that servant leadership is vital for green innovation, but so is building green expertise. Also, (Murad & Li, 2025) say that leaders alone can't bring about big changes in the organization without organized training on sustainability.

Other research, like (Badar & Siddiquei, 2025), also stresses how important it is to combine supportive leadership with more green knowledge for employees in order to get the best results from innovation. Employees are more likely to come up with new ideas for sustainability when their bosses practice servant leadership and give them enough

information about green issues (Haider et al., 2025). Finally, (Özkan et al., 2023) indicated that building a culture of sustainability in an organization is vital, but takes more than simply leadership. To stimulate green innovation, there needs to be a culture of collaboration in the workplace, supportive policies, and ongoing training.

The tourism authority in the Toba Caldera Geopark's managerial findings show that it's important to train leaders who put servant leadership first. But this needs to be tempered with giving them more green knowledge through continual training and incentives to come up with new green ideas. The tourism authority also has to make sure that regulations and the way the company works encourage employees to get involved in sustainable projects. This will make people more committed to the goals of sustainable tourism and encourage the use of green innovation, which will make the Toba Caldera Geopark a more appealing, eco-friendly destination.

The Influence of Servant Leadership on Green Innovation through Green Self-Efficacy

The T-statistic showed 3.284 and the P-value revealed 0.001, which suggests that servant leadership has a big effect on green innovation through green self-efficacy. Servant leaders who help their employees grow not only make them more confident in using eco-friendly methods, but they also help bring about green innovation in hospitality operations in the Toba Caldera Geopark. The results of this study back up what (Jehanzeb & Mushtaq, 2025)(Elsaied, 2025) found: executives who lead by example can help staff come up with new ideas for how to be more environmentally friendly. Employees are more likely to embrace environmentally friendly practices when their leaders support and empower them (Han et al., 2025). Employees are more likely to use new ideas that help the environment, make the company culture more open to green innovation, and speed up the use of technologies that are good for the environment (J. Wang et al., 2025).

Also, (Aboramadan et al., 2023) illustrates that servant leadership gives people the confidence to come up with new ideas for sustainability. Leaders who help their employees grow not only boost their self-esteem, but they also urge them to take part in green innovation. (Liu et al., 2023) says that leadership that supports sustainability is very important for building an innovative culture in the workplace. Employees will be more likely to come up with new ideas if their bosses provide them with the support and resources they need. These ideas should focus on environmentally beneficial techniques that may be used in operations (Badar & Siddiquei, 2025).

The Toba Caldera Geopark's tourism authorities' management findings show how important it is to train leaders who value servant leadership and give staff the tools they need to make environmentally friendly choices. In addition, staff who come up with new ways to be environmentally friendly need to get continual training and rewards. To promote more effective and sustainable green innovation, tourism officials need to make sure that regulations that support sustainability in the region's hospitality industry are put into action.

Conclusion

The analysis of the structural model indicates that green knowledge and servant leadership have a direct, positive, and significant effect on the green self-efficacy of hospitality workers in the Toba Caldera Geopark area. Furthermore, green self-efficacy was revealed to be a critical determinant of green innovation. The indirect effect through green self-efficacy was stronger than the direct effect, which shows that psychological confidence in environmental abilities is a big reason why people act in ecologically friendly ways. In the case of nature-based tourism, these results suggest that employees' self-confidence and internal drive are more important than only their knowledge or leadership when it comes to generating sustainable innovation.

The results of this study have a number of strategic implications for hotel managers and those who work in tourism. The strong impact of green knowledge and servant leadership shows how important it is to have a holistic approach to sustainability that includes both values-based leadership and informative training. So, hotels and tourism businesses should spend money on teaching their staff about the environment and creating a culture of servant leadership that gives people more influence. It is very important to boost green self-efficacy in order to turn awareness into action and keep ecotourism services innovative.

Future studies should look into other moderating or mediating factors that could help expand the framework of green innovation behavior. These could include things like the work environment, environmental commitment, or employee involvement. These findings might be more useful if they were tested in a wider range of tourism situations in different areas or nations. Also, qualitative or mixed methods approaches could help us better understand the personal reasons, leadership issues, and situational problems that tourist workers confront while trying to implement green practices. A longitudinal study could also help us learn more about how self-efficacy and innovation change over time in response to interventions for leadership development and sustainability.

Tourism authorities should formulate policies that promote employee empowerment and the growth of servant leadership in the tourism industry. Tourism officials should think about making policies that encourage people in the hospitality business to keep learning about sustainability and green literacy. Also, rules that give staff incentives or rewards for coming up with new ways to be more environmentally friendly might speed up the use of these solutions. Policies that help create a culture of service-based leadership in the tourism industry will make employees more likely to help reach sustainability goals and enhance the Toba Caldera Geopark's status as a leading sustainable ecotourism destination.

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