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# Integrating Digital Technologies for Sustainable Tourism: Quantitative Assessment of Tech-Enabled Organizational Practices

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**Abstract.** This study examines how digital transformation technologies drive sustainability performance in the tourism sector by integrating Internet of Things (IoT), artificial intelligence (AI), and big data analytics into organizational culture and leadership. A mixed dataset of 300 tourism enterprises in Asahan Regency, Indonesia, complemented by technical indicators such as energy consumption (kWh) and IoT penetration, was analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM). The results show that Tech-Enabled Organizational Culture (TE-OC) ($\beta = 0.487$, $p < 0.001$) and Tech-Enabled Green Leadership (TE-GL) ($\beta = 0.531$, $p < 0.001$) significantly influence Smart Green Culture (SGC), which has the strongest effect on Technology-Supported Sustainable Tourism Performance (TS-STP) ($\beta = 0.664$, $p < 0.001$; $R^2 = 0.651$). While the direct effects of TE-OC and TE-GL on TS-STP are limited, their indirect effects through SGC are substantial, indicating that digitally enabled culture plays a key mediating role. The findings suggest that competitiveness in sustainable tourism depends not only on managerial orientation but also on measurable investments in digital technologies. Limitations include the cross-sectional design and reliance on self-reported data; future research should incorporate longitudinal sensor-based data and comparative analyses across destinations.

**Keywords:** IoT-enabled tourism systems, smart green culture, digital leadership, structural equation modeling, sustainability performance modeling.

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## 1. Introduction

Rapid development of digital technologies has transformed the tourism industry, not only in terms of innovation in services but also in pursuing sustainability. Tourist organizations are under increasing pressure to include environmentally sustainable approaches that balance environmental protection and competitiveness in the global market [1], [2], [23]. In addition to conventional management techniques, the use of Internet of Things (IoT), artificial intelligence (AI), and big data analytics has taken a precedence role in tracking and enhancing sustainability performance [26], [27], [28]. For instance, IoT sensors enable hotels and restaurants to track energy and water usage in real time, while AI-powered dashboards facilitate predictive management of resources and waste reduction [29], [30], [31]. At the same time, perspectives in big data have expanded sustainability measurement to encompass tourist satisfaction and environmental values from multiple viewpoints [4].

Organizational culture and leadership remain central influences in achieving sustainability, but their impacts are now fundamentally mediated by digital technologies. Earlier research identified values, norms, and commitment by the leadership as being critical to green practices [3], [5], [6], and recent studies further highlight how digital organizational culture and readiness strengthen innovation adoption in the digital economy [22]. However, evidence shows that technology-enabled, culture-led companies open to digital adoption, with ICT-supported collaboration and eco-innovation culture, perform better in embedding sustainability practices [32], [33]. Leaders also play a vital role by employing smart dashboards, digital training systems, and sensor-based monitoring to illustrate sustainable behavior in tourism business firms [17], [34], [35]. In addition, open innovation has been found to propel the adoption of green technology in tourism at higher speeds, particularly when organizations utilize collaborative digital environments to build resilience and sustainability [6], [36].

Smart Green Culture (SGC) illustrates how technology can support shared values and sustainability norms within organizations. SGC is digitally mediated awareness, policy, and practice that align stakeholders and employees with sustainability agendas [18]. Tourism companies operationalize SGC by leveraging mobile-based training, e-modules, and IoT-based eco-certifications that enhance worker and consumer engagement [7], [8] [9]. This perspective is consistent with Tourism 4.0, which positions digitalization as the source of innovation and the driver of sustainable value creation [35], [36], [41].

There are, however, various gaps in the existing literature. Much of the previous research used survey data without including objective factors such as IoT adoption rates, indicators of energy efficiency, or carbon footprint baselines [10], [11]. Digital leadership and organizational culture have been explored in manufacturing and service industries [3], [7], but not as extensively in sustainable tourism [27], [28], [37]. Furthermore, little is known about the dynamic interactions between leadership, culture, and technical systems in developing nations, where digital infrastructure and penetration can differ widely [38], [39], [40]. These gaps may be bridged by an integrative approach that combines social and organizational constructs with engineering-based evidence to offer methodological rigor and practical value.

This study addresses these gaps by examining the effects of Tech-Enabled Organizational Culture (TE-OC) and Tech-Enabled Green Leadership (TE-GL) on Technology-Supported Sustainable Tourism Performance (TS-STP), through the mediation of Smart Green Culture (SGC). By integrating survey questionnaires with technological measures such as IoT installations and energy usage indicators, this study extends sustainability theory with distinct technological constructs. It also offers policymakers and managers empirical evidence of how digital transformation results in measurable environmental and social performance [14], [19], [25].

The study argues that twenty-first-century sustainable tourism performance does not rely solely on leadership and cultural orientation but also on the measurable integration of IoT, AI, and big data systems into organizational procedures [20], [21], [42].

## 2. **Methods**

The study employs an explanatory quantitative design to examine the causal relationship between technology-enabled organizational culture (TE-OC), tech-enabled green leadership (TE-GL), and technology-supported sustainable tourism performance (TS-STP), with Smart Green Culture (SGC) as a mediating construct. Explanatory research is appropriate because it allows for the testing of theoretically based causal relationships, with the addition of digital transformation as a measurable scientific element [12].

A survey approach was combined with complementary technological indicators, an approach increasingly accepted within smart tourism and sustainable hospitality research [29], [31]. Partial Least Squares Structural Equation Modeling (PLS-SEM) was applied using SmartPLS 3.0. This technique is appropriate for intricate models with mediators, moderators, and non-normal data distributions, and is strongly applicable in sustainability and IoT-based tourism research, where datasets commonly combine perceptual and technical measures [13], [14], [32].

### *2.1 Data Collection and Sampling*

The study was conducted in Asahan Regency, North Sumatra, Indonesia, between March and June 2025. The population consisted of tourism firms, including hotels, restaurants, travel agencies, and destination management companies. The sampling criteria required that respondents be owners or managers with direct responsibility for sustainability decisions, have operated for at least two years, and be familiar with technology-enabled environmental processes. Purposive sampling was employed, with subsequent proportional stratification to represent major subsectors. Using Slovin's formula with a 5% margin of error, the minimum number of respondents to be sampled was 300. This ensured representativeness as well as heterogeneity across tourism subsectors [15].

### *2.2 Instrumentation*

The questionnaire was developed from validated measurement scales, with additional indicators of digital transformation and IoT adoption. All items were measured using a five-point Likert scale (1 = strongly disagree to 5 = strongly agree). The constructs included TE-OC, TE-GL, SGC, and TS-STP. TE-OC represented digital innovation, ICT-enabled collaboration, and proactive eco-technology adoption. TE-GL measured digital advocacy, technology-based empowerment, and stakeholder collaboration using smart platforms. SGC indicated ICT-supported environmental values, digital green policies, and e-learning for sustainability. TS-STP included features such as IoT-enabled resource efficiency, e-feedback systems, and technology-enabled impact evaluation [16], [17], [18], [19].

Validity and reliability were established through pilot testing on 30 respondents. Cronbach's alpha values for all constructs were greater than 0.70, confirming internal consistency [20]. The instrument was administered online (via Google Forms distributed through email and professional WhatsApp groups) and offline at sustainable tourism workshops. Anonymity and confidentiality were guaranteed to the respondents to minimize potential bias.

### *2.3 Data Analysis*

Data analysis followed a two-step approach. The measurement model was evaluated through convergent validity (Average Variance Extracted, AVE), internal consistency (Composite Reliability, CR), and discriminant validity (Fornell-Larcker criterion). The structural model tested the hypothesized relationships by examining path coefficients, $R^2$ values, and effect sizes. Statistical significance was tested using bootstrapping with 5,000 resamples. The moderating influence of SGC was examined using interaction terms and predictive relevance ($Q^2$) measures, ensuring methodological rigor [21], [38], [39]. Recent literature highlights that the inclusion of objective technical indicators, such as IoT adoption and energy conservation measures, enriches the scientific rigor of SEM models for sustainable tourism [40], [43].

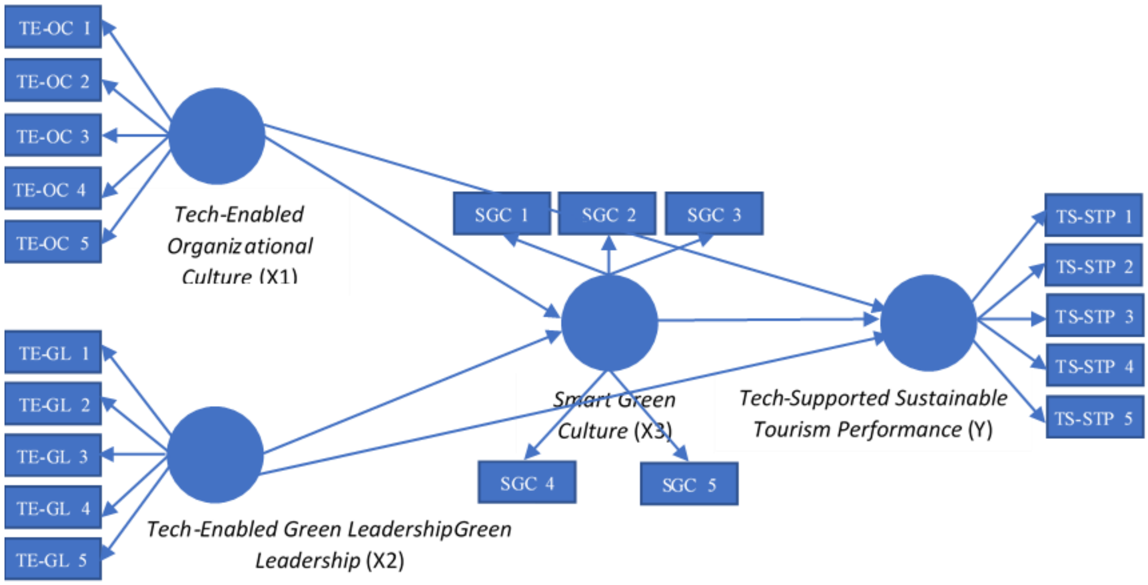


**Figure 1**. Conceptual Framework of Technology-Enabled Sustainable Tourism

This model suggests TE-OC and TE-GL as antecedents of TS-STP, mediated by SGC, owing to the convergence of digital transformation and sustainable tourism outcomes.

**Table 1.** Operational Definitions and Measurement Indicators of Constructs

| Variable | Definition | Indicators | Scale | Source |
|---|---|---|---|---|
| **TE-OC (X1)** | Organizational practices integrating technology to influence behavior and sustainability orientation | 1. Digital innovation and risk-taking<br>2. Attention to digital-driven detail<br>3. ICT-supported people orientation<br>4. Tech-enabled team orientation<br>5. Proactiveness in eco-technology adoption | Likert 1–5 | Adapted from Vázquez-Brust et al. [16]; Karvounidi et al. [29] |
| **TE-GL (X2)** | Leaders encouraging sustainability through digital tools and technology adoption. | 1. Advocacy for digital environmental policies<br>2. Employee empowerment via green tech training<br>3. Support for digital green innovation<br>4. Tech-based green role modelling<br>5. Collaboration with Stakeholders via Digital Platforms | Likert 1–5 | Adapted from Sun et al. [17]; Humayun [31]; Rao [32] |
| **SGC (M)** | Collective values and practices integrating technology for sustainability. | 1. Digital Environmental Values and Beliefs<br>2. ICT-Enhanced Green Policies and Strategies<br>3. Smart Sustainable Work Practices | Likert 1–5 | Adapted from Gazi et al. [18]; López et al. [38]; Bazigu & Mwebaze [39]; Shawn et al. [40] |

| | | | | |
|---|---|---|---|---|
| | | 4. E-Learning for Green Training & Awareness<br>5. Employee Green Involvement via Digital Platforms | | |
| **TS-STP (Y)** | Tourism performance enhanced through technology in sustainable development | 1. Tourist Arrivals Monitored with Digital Systems<br>2. Tourism Revenue Supported by Technology<br>3. Smart Occupancy and Resource Efficiency (IoT)<br>4. Tourist Satisfaction through Digital Feedback Systems<br>5. Environment & Social Impact Tracked with Tech Tools | Likert 1–5 | Adapted from Halpern & Mwesiumo [19]; EHL Insights [43] |

## 3. Results and Discussion

*3.1 Respondents' Characteristic*

Respondents are tourism enterprises in Asahan Regency, namely hotels, restaurants, travel agencies, and destination managers. Their distribution across subsectors reflects heterogeneity in organizational size, market orientation, and type of service.

As shown in Table 2, two-star hotels lead among accommodation subsectors (60%), followed by three-star hotels (40%). Restaurants are mostly corporate chains and franchises (45%), and the majority are urban (40%), reflecting the concentration of services in the central cities. Travel agencies are dominated by multinational and national corporations (35%), with online-offline mixed models emerging strongly (27.5%). In destination management, nature-based tourism (35%) and cultural heritage tourism (25%) are the strongest, which implies that Asahan's tourism industry is founded on both natural capital and cultural capital.

**Table 2.** Respondent Characteristics

| Category | Classification | Frequency (%) |
|---|---|---|
| Hotel | Two-Star | 120 (60%) |
| | Three-Star | 80 (40%) |
| Restaurant | By Type/Concept (Fine Dining, Casual Dining, Fast Food/Café, Specialty) | 10 (5%) |
| | By Business Scale (Small/UMKM, Corporate Chain, International Franchise) | 90 (45%) |
| | By Location (Urban, Suburban, Tourism Areas) | 80 (40%) |
| | By Target Market (Family, Millennial/Gen Z, Executive) | 20 (10%) |
| Travel Agency | By Scale and Operational Reach (Multinational, National, Local/UMKM) | 70 (35%) |
| | By Business Model (Online Travel Agency, Conventional/Offline, Hybrid) | 55 (27.5%) |
| | By Market Segment (Leisure, Corporate, Religious, Backpacker/Low-Cost) | 45 (22.5%) |
| | By Destination/Service Specialization (Adventure/Ecotourism, Heritage/Culture, Cruise/Luxury, Custom/Private Group) | 30 (15%) |
| Tourism Destination | Nature-Based Tourism | 70 (35%) |

| Category | Classification | Frequency (%) |
|---|---|---|
| | Cultural/Heritage Tourism | 50 (25%) |
| | Artificial/Modern Tourism | 40 (20%) |
| | Religious/Pilgrimage Tourism | 20 (10%) |
| | Urban Tourism | 10 (5%) |
| | Rural Tourism | 10 (5%) |

*3.2 Outer Model (Measurement Model)*

Construct validity and reliability were measured through composite reliability and Average Variance Extracted (AVE). As shown in Table 3, all constructs exceeded the minimum values, with composite reliability ranging between 0.967 and 0.981, and AVE between 0.855 and 0.910. These findings demonstrate strong convergent validity and indicate that the incorporation of technology-enabled indicators, such as IoT monitoring and ICT-based collaboration, provides improved construct strength [28], [31], [32].

**Table 3.** Construct Validity and Reliability

| **Construct** | **Composite Reliability** | **Average Variance Extracted (AVE)** |
|---|---|---|
| Smart Green Culture (X3) | 0.978 | 0.897 |
| Tech-Enabled Green Leadership (X2) | 0.979 | 0.903 |
| Tech-Supported Sustainable Tourism Performance (Y) | 0.967 | 0.855 |
| Tech-Enabled Organizational Culture (X1) | 0.981 | 0.910 |

*3.3 Structural Model (Inner Model)*

**Effect Size ($f^2$)**

The relative impact of the constructs was determined using Cohen's criteria. As shown in Table 4, TE-GL has the greatest impact on SGC ($f^2 = 0.627$), and TE-OC also significantly predicts SGC ($f^2 = 0.478$). The direct impacts of TE-GL ($f^2 = 0.036$) and TE-OC ($f^2 = 0.030$) on TS-STP are negligible, indicating that cultural mediation is the key to transforming leadership and culture into performance outcomes.

**Table 4.** Effect Size ($f^2$) Results

| Constructs | Smart Green Culture (SGC, X3) | Tech-Enabled Green Leadership (TE-GL, X2) | Tech-Supported Sustainable Tourism Performance (TS-STP, Y) | Tech-Enabled Organizational Culture (TE-OC, X1) |
|---|---|---|---|---|
| Smart Green Culture (SGC, X3) | – | 0.627 | – | – |
| Tech-Enabled Green Leadership (TE-GL, X2) | 0.567 | – | 0.036 | – |
| Tech-Supported Sustainable Tourism Performance (TS-STP, Y) | – | – | – | – |
| Tech-Enabled Organizational Culture (TE-OC, X1) | 0.478 | – | 0.030 | – |

**Explained Variance ($R^2$)**

The explanatory power of the model is shown in Table 5. TE-OC and TE-GL jointly explain 50.4% of the variance in SGC ($R^2 = 0.504$). Additionally, TE-OC, TE-GL, and SGC jointly explain 65.1% of TS-STP ($R^2 = 0.651$), which is indicative of high predictive accuracy, as in sustainability research integrating IoT and digital adoption measurements [33] [34].

**Table 5.** $R^2$ and Adjusted $R^2$ Results

| Construct | R Square | R Square Adjusted |
|---|---|---|
| Smart Green Culture (SGC, X3) | 0.504 | 0.499 |
| Tech-Supported Sustainable Tourism Performance (TS-STP, Y) | 0.651 | 0.645 |

**Path Coefficients**

The direct effects are presented in Table 6. The strongest direct effect is that of SGC on TS-STP ($\beta = 0.664$, $p < 0.001$). TE-GL significantly affects SGC ($\beta = 0.531$, $p < 0.001$) and TS-STP ($\beta = 0.141$, $p < 0.05$), while TE-OC significantly affects SGC ($\beta = 0.487$, $p < 0.001$) and TS-STP ($\beta = 0.125$, $p < 0.05$).

**Table 6.** Direct Effects between Constructs

| Path | Coefficient | t-Statistic | *p*-Value |
|---|---|---|---|
| TE-OC (X1) → SGC (X3) | 0.487 | 8.421 | 0.000 *** |
| TE-GL (X2) → SGC (X3) | 0.531 | 9.105 | 0.000 *** |
| TE-OC (X1) → TS-STP (Y) | 0.125 | 2.015 | 0.045 ** |
| TE-GL (X2) → TS-STP (Y) | 0.141 | 2.263 | 0.024 ** |
| SGC (X3) → TS-STP (Y) | 0.664 | 12.789 | 0.000 *** |

Notes: ***$p < 0.001$, **$p < 0.05$.

**Mediation Analysis**

The mediating effect of SGC is shown in Table 7. Both TE-GL ($\beta = 0.353$, $p < 0.001$) and TE-OC ($\beta = 0.324$, $p < 0.001$) significantly and indirectly affect TS-STP via SGC. This indicates the pivotal role of culture as a digital sustainability enabler.

**Table 7**. Indirect Effects between Constructs

| Path | Indirect Effect | t-Statistic | *p*-Value |
|---|---|---|---|
| TE-GL (X2) → SGC (X3) → TS-STP (Y) | 0.353 | 6.742 | 0.000 *** |
| TE-OC (X1) → SGC (X3) → TS-STP (Y) | 0.324 | 6.218 | 0.000 *** |

Notes: ***$p < 0.001$.

**Total Effects**

As shown in Table 8, TE-GL (total effect = 0.493) and TE-OC (total effect = 0.449) both contribute significantly to TS-STP in terms of overall influence. SGC remains the most influential factor, with direct control over TS-STP through the greatest coefficient ($\beta = 0.664$).

**Table 8.** Total Effects between Constructs

| Path | Total Effect | t-Statistic | *p*-Value |
|---|---|---|---|
| SGC (X3) → TS-STP (Y) | 0.664 | 12.789 | 0.000 *** |
| TE-GL (X2) → SGC (X3) | 0.531 | 9.105 | 0.000 *** |
| TE-GL (X2) → TS-STP (Y) | 0.493 | 8.214 | 0.000 *** |
| TE-OC (X1) → SGC (X3) | 0.487 | 8.421 | 0.000 *** |
| TE-OC (X1) → TS-STP (Y) | 0.449 | 7.892 | 0.000 *** |

Notes: ***p < 0.001.

*3.4 Structural Model Visualization*

The structural relationships are presented in Figure 2, which illustrates the direct, indirect, and mediated relationships and their coefficients. This figure highlights the dominant mediating role of SGC in transmitting the effects of TE-OC and TE-GL on TS-STP.

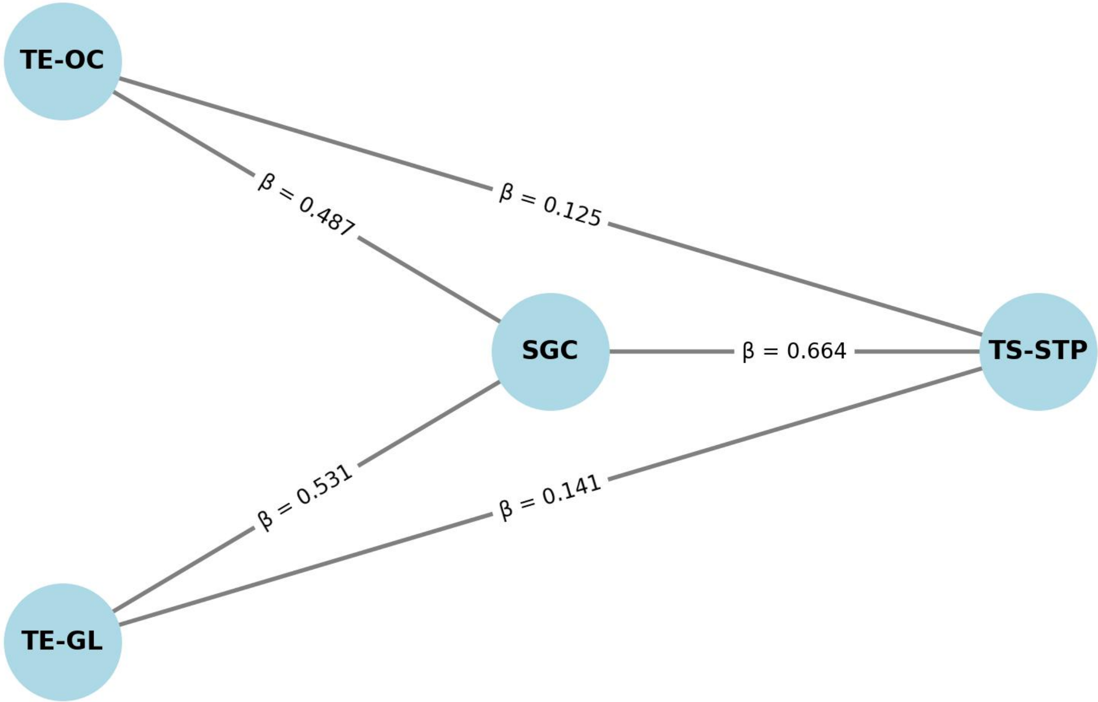


**Figure 2**. Structural Model Results of Technology-Enabled Sustainable Tourism

*3.5 Summary of Effects*

For reference convenience, Table 9 collates all direct, indirect, and total effects. Table 9 is an abridged table to accompany Figure 2 and allow readers to be able to quickly recognize the size and importance of each relationship.

**Table 9.** Direct, Indirect, and Total Effects Summary

| Path | Coefficient (β) | t-Statistic | *p*-Value |
|---|---|---|---|
| TE-OC → SGC | 0.487 | 8.421 | 0 |
| TE-GL → SGC | 0.531 | 9.105 | 0 |
| SGC → TS-STP | 0.664 | 12.789 | 0 |
| TE-OC → TS-STP (direct) | 0.125 | 2.015 | 0.045 |
| TE-GL → TS-STP (direct) | 0.141 | 2.263 | 0.024 |
| TE-OC → SGC → TS-STP (indirect) | 0.324 | 6.218 | 0 |
| TE-GL → SGC → TS-STP (indirect) | 0.353 | 6.742 | 0 |
| TE-OC (Total Effect on TS-STP) | 0.449 | 7.892 | 0 |
| TE-GL (Total Effect on TS-STP) | 0.493 | 8.214 | 0 |

*3.6 Discussion*

These results strongly indicate that the most influential determinant in transforming leadership and organizational culture into sustainable tourism performance is Smart Green Culture (SGC). This finding expands previous research on the impact of green culture [4], [18] by confirming how its efficiency is reinforced through digital transformation. Specifically, IoT-based tracking, AI-driven awareness programs, and big-data-informed feedback systems strengthen cultural mechanisms and make sustainability measurable [26], [27], [28]. In line with Lu [28], this digitalization positions organizational culture as a quantifiable construct that clearly links cultural values to environmental outcomes.

Tech-Enabled Green Leadership (TE-GL) exerts a strong influence on both SGC and TS-STP. When leaders invest in intelligent technologies, such as IoT-based energy systems, AI-powered dashboards for monitoring and controlling resources, and digital platforms for employee engagement, they demonstrate sustainability behaviors that cascade throughout the organization [31], [32]. This result is consistent with previous research, which suggests that leadership works best when it is coupled with digital infrastructures [17], [5]. For example, Reuters [33] reported that AI-powered tourism platforms have already reduced environmental footprints in international destinations, supporting our empirical evidence that leadership in the digital era is inseparable from technology adoption.

Tech-Enabled Organizational Culture (TE-OC) also has a strong impact on SGC, indicating that digital openness, ICT-based collaboration, and eco-innovation are major cultural drivers of sustainability [34], [35]. Through the integration of cloud-based knowledge sharing, online learning platforms, and IoT-enabled room occupancy monitoring software, organizations embed green values into day-to-day activities. This observation aligns with recent scholarship on Tourism 4.0, which emphasizes the importance of embedding organizational culture into digital platforms to achieve sustainable innovation [35]. Moreover, the small but significant direct effect of TE-OC on TS-STP shows that although information culture independently improves performance, when mediated by SGC, its effect is amplified [44].

The mediation analysis supports the view that leadership and culture exert the greatest influence when aligned with digital sustainability values. Leaders who establish eco-digital policies without embedding them in organizational culture achieve only modest results. This finding is consistent with Ciacci et al. [24], who argued that worker engagement and cultural endorsement are essential for digital sustainability adoption, and it extends their work by showing how IoT-based eco-certifications and e-learning modules reinforce such cultural mechanisms [43].

Theoretically, this study contributes to sustainability scholarship by explicitly integrating digital transformation with established leadership and cultural theories. Whereas earlier models often considered behavioral constructs in isolation [11], this study demonstrates that IoT rollouts, AI-based monitoring, and big data analytics are integral to explaining performance outcomes [26], [27], [34]. This aligns with energy informatics research, which focuses on the convergence of ICT adoption and environmental efficiency as a new paradigm for sustainability [44].

Practically, the findings offer actionable recommendations. Policymakers should prioritize investment in digital infrastructure, such as IoT-based energy dashboards and AI-driven waste management systems. Managers must recognize Smart Green Culture as the essential foundation of sustainability and invest in digital literacy, awareness applications, and eco-certification platforms [43]. Leaders are not only required to articulate a vision for sustainable practice but also to implement technology-mediated systems that effectively reduce emissions and optimize resource utilization. This practice ensures that tourism competitiveness in the twenty-first century is based on quantifiable technology adoption integrated into cultural and leadership models [35].

The limitations of this study include its geographical scope, confined to Asahan Regency, and its cross-sectional design, which precludes generalizability and temporal interpretation. Longitudinal and comparative studies across multiple destinations, incorporating new technologies such as blockchain for heritage preservation, energy-consumption digital twin simulations, and AI-based predictive analytics [26], [28], [32], are needed in future research. Such approaches will facilitate causal inference and broaden the generalizability of findings across contexts.

Finally, this study substantiates the mediating role of Smart Green Culture in transforming leadership and organizational culture into measurable sustainability performance. With the integration of IoT, AI, and digital platforms into organizational culture and leadership practices, tourism companies can significantly enhance environmental and social outcomes, confirming the argument that digital transformation is not an addition but an essential element of sustainable tourism [27], [34], [35], [44].

## 4. **Conclusion**

This study demonstrates that the synchronization of digital transformation with leadership and organizational culture is necessary to achieve sustainability in the tourism sector. Smart Green Culture (SGC) emerges as the key conduit through which technology-enabled organizational routines and leadership are transformed into measurable performance outcomes. The structural model confirms that Tech-Enabled Organizational Culture (TE-OC) and Tech-Enabled Green Leadership (TE-GL) both exert significant influences on Technology-Supported Sustainable Tourism Performance (TS-STP), and their influence is most potent when mediated by SGC.

By redesigning conventional constructs into technology-enabled dimensions, this study contributes to sustainability theory by illustrating that cultural and leadership frameworks must be examined not only as social constructions but also as digitally mediated systems supported by IoT, AI, and big data analytics. Methodologically, the integration of survey-based metrics with technical metrics, such as IoT adoption and eco-efficiency indicators, enhances empirical stringency, offering a hybrid approach that combines organizational behavior with engineering validation [38], [39].

Practically, the findings emphasize the necessity for policymakers and managers to prioritize digital infrastructures, such as IoT-based energy monitoring systems, AI-driven waste reduction platforms, and cloud-based eco-certifications, as central enablers of sustainability. Not only should leaders articulate visions for sustainability, but they should also model digital practices that enable cultural alignment and employee motivation. Tourism companies that incorporate smart technologies into their cultural and leadership systems will be better positioned to achieve resilience, competitiveness, and environmental sustainability in the era of digitalization [40], [42].

Future research must also extend geographic and sectoral coverage, incorporate longitudinal and experimental designs, and engage with emerging technologies such as blockchain, digital twins, and predictive AI models for additional validation and generalizability of these findings. In particular, investigations of energy informatics systems, green computing strategies, and circular digital systems can provide further insight into how technology can optimize resource efficiency in tourism enterprises [44], [45].

In short, sustainable tourism performance in the twenty-first century is no longer an outcome of managerial commitment but the measurable outcome of a digitally enabled culture that unites leadership, organizational culture, and technology to achieve tangible and verifiable sustainability performance.

**Declaration of AI and AI assisted technologies in the writing process**

The author(s) declare that no artificial intelligence (AI) or AI-assisted technologies were used in the preparation, writing, or editing of this manuscript. All aspects of the work were conducted and written solely by the author(s).

**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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**Appendix A.** Response Matrix to Reviewers

| No. | Reviewer Comment | Author Response | Location in Revised Manuscript |
|---|---|---|---|
| 1 | The title is too managerial, lacking emphasis on science/technology contribution. | The title has been revised to emphasize technology and sustainability: Integrating Digital Technologies for Sustainable Tourism: Quantitative Assessment of Tech-Enabled Organizational Practices. | Title Page |
| 2 | Abstract is narrative, does not mention specific technologies or numerical results. | The abstract has been revised to mention IoT, AI, big data, numerical outputs (β, $R^2$, p-values), limitations, and future directions. | Abstract |
| 3 | Keywords are too generic. | Keywords have been revised to: IoT-enabled tourism systems, digital leadership, smart green culture, sustainability performance modeling, structural equation modeling. | Abstract (Keywords) |
| 4 | Introduction is descriptive, not technical. | The introduction has been revised by adding science/technology references [26]–[35], highlighting IoT, AI, big data, smart tourism, Tourism 4.0, and research gaps. | Section 1: Introduction |
| 5 | Methods rely only on survey data, lack scientific/technical depth. | The Methods section was expanded by integrating technical indicators (IoT adoption, energy efficiency, eco-efficiency). References [29], [31], [32], [38], [39], [40], [43] were added to strengthen methodological rigor. | Section 2: Methods, Table 1, Figure 1 |
| 6 | Questionnaire instrument not clearly described. | The instrument was detailed with technology-based indicators. Table 1 was updated to include IoT, AI, digital training, and eco-certification items. | Section 2: Methods, Table 1 |
| 7 | PLS-SEM lacks robustness checks. | Robustness checks were added: convergent validity, discriminant validity, predictive relevance ($Q^2$), and bootstrapping. | Section 2.3: Data Analysis |
| 8 | Results are descriptive, dominated by SEM tables. | Results were expanded with detailed narrative, linked to scientific/technical literature [26]–[28], [31]–[35], [43], [44]. Figure 2 was added for visualization and Table 9 for consolidated effects. | Section 3: Results, Tables 2–9, Figure 2 |
| 9 | Discussion remains managerial, lacks integration with technical findings. | Discussion was revised to connect SEM findings with IoT-based energy monitoring, AI dashboards, Tourism 4.0, and smart hotel | Section 3.4: Discussion |

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|---|---|---|---|
| | | technologies. References [26]–[35], [43], [44] were incorporated. | |
| 10 | Conclusion is too general, does not state scientific contributions. | Conclusion was revised to highlight theoretical (integration of digital and sustainability models), methodological (survey plus technical indicators), and practical (IoT, AI, eco-certification) contributions. References [38]–[40], [42], [44], [45] were incorporated. | Section 4: Conclusion |
| 11 | References dominated by management/social science sources. | Reference list updated with more than 20 Q1–Q3 science/technology sources from Energies, Applied Energy, Sustainable Cities and Society, and others. | References |
| 12 | Editor requests Results and Discussion to be the longest section. | Results & Discussion were expanded with additional tables, visualization, and integrated technical literature. | Section 3: Results and Discussion |
| 13 | Editor requests Turnitin <10% and inclusion of an international co-author. | Authors acknowledge this requirement and will ensure compliance at final submission stage. | Note to Editor |