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# Digital synergy for hospitality sustainability: a moderated mediation model of IoT, data-driven decision-making, AI, and hotel sustainable performance

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**Introduction:** As sustainability becomes a strategic priority in the hospitality industry, digital transformation—particularly through the adoption of the Internet of Things (IoT)—offers new opportunities to enhance hotel sustainable performance (HSP). However, the mechanisms and boundary conditions through which IoT adoption improves HSP outcomes remain underexplored, particularly the roles of data-driven decision-making (DDM) and artificial intelligence (AI). Accordingly, this study examines the impact of IoT adoption on hotel sustainable performance, investigates the mediating role of data-driven decision-making, and assesses the moderating role of AI in strengthening these relationships.

**Methods:** Grounded in the Resource-Based View and Dynamic Capabilities Theory, this study analyzed survey data collected from 211 managers working in four- and five-star hotels in Saudi Arabia. Partial least squares structural equation modeling (PLS-SEM) was employed to test the proposed relationships, including the mediating role of data-driven decision-making and the moderating role of artificial intelligence (AI).

**Results:** The findings show that IoT adoption positively influences both data-driven decision-making and hotel sustainable performance. Data-driven decision-making partially mediates the relationship between IoT adoption and sustainable performance. In addition, artificial intelligence significantly strengthens the effects of IoT adoption on data-driven decision-making and on sustainable performance.

**Discussion:** These results demonstrate that integrating IoT with data-driven and artificial intelligence-enabled capabilities enhance hotels' environmental, social, and economic performance. The study contributes to digital sustainability research by clarifying the mechanisms through which IoT creates value and offers practical guidance for hospitality managers seeking to leverage digital transformation to achieve sustainability goals.

## KEYWORDS

data-driven culture, Dynamic Capabilities Theory, hotel sustainability, Internet of Things, Resource-Based View (RBV), triple bottom line

# 1 Introduction

Sustainability has become a global priority shaping business strategies across all sectors, and the hospitality industry, in particular, faces growing pressure to operate in more environmentally responsible ways (Abdou, 2025; Mansoor et al., 2025). Hotels are known for their high energy, water, and material consumption, as well as for generating considerable waste (Abdou et al., 2022a; de Waal Malefyt, 2025). With increasing awareness among consumers, policymakers, and industry stakeholders about environmental concerns, hotels are now under greater scrutiny to reduce their ecological footprint (Chang et al., 2025). In response, technological innovation has taken center stage, with digital tools offering promising solutions for improving efficiency and sustainability (Gajić et al., 2024). Through automation, these technologies can optimize energy and water use, handle repetitive tasks, minimize waste, and improve resource management, contributing to stronger sustainable performance (Mercan et al., 2021; Singh, 2025). Among these technologies, the Internet of Things (IoT) plays an essential role in driving this transformation process.

The Internet of Things (IoT) has become a transformative technology in the hospitality industry, allowing hotels to better track, control, and use their resources, which can greatly enhance their sustainability performance (Elkhwesky and Elkhwesky, 2023; Nadkarni et al., 2020; Wynn and Lam, 2023). IoT refers to a network of connected devices, sensors, and systems that gather and share data instantly, supporting automated decisions and smoother operations (Chung and Tan, 2025; Kiran and Wynn, 2022). In hotels, IoT is used in various ways, such as smart energy management, water-saving systems, waste tracking, and automated building controls (Shani et al., 2023; Sharma and Gupta, 2021). These technologies not only help reduce environmental impact but also boost efficiency and improve the overall guest experience (Chen et al., 2022; Gajić et al., 2024).

Although interest in using IoT within the hotel industry is increasing, important research gaps still exist. Most past studies have mainly explored the benefits, challenges, and opportunities of IoT adoption in improving services, enhancing guest experiences, and gaining a competitive edge (e.g., Car et al., 2019; Sharma and Gupta, 2021). Some have also looked at the direct relationship between technology use and sustainability outcomes (e.g., Gajić et al., 2024; Poulas and Kakoulli, 2023). However, few studies have examined the underlying processes that explain how IoT actually leads to better sustainable performance, leaving the mechanisms connecting IoT and sustainability largely unclear.

This study highlights the role of data-driven decision-making (DDM) as a key capability that enables hotels to collect, analyze, and use data for better strategic and operational decisions. Data-driven decision-making is viewed as a mediating factor linking IoT adoption to sustainable performance, as it allows hotels to turn IoT-generated data into actionable insights for improving efficiency. For example, data-driven decision-making can help interpret operational data from IoT systems to minimize energy use and manage resources more effectively (Nadkarni et al., 2020). Further, despite the clear advantages of IoT, its adoption in hotels—especially in developing countries like Saudi Arabia—remains a relatively new research area. Most previous studies on IoT have

focused on industries such as manufacturing, healthcare, and logistics (e.g., Kalsoom et al., 2021; Li et al., 2024; Venkata Lakshmi et al., 2021; Zrelli and Rejeb, 2024), while limited attention has been given to its impact on sustainability in the hospitality sector. Saudi Arabia's hotel industry presents a unique context for such research, given its rapid expansion, supportive regulations, and growing commitment to sustainability in line with Vision 2030 (Abdou et al., 2022b). Thus, there remains a gap in understanding how IoT adoption influences hotel sustainable performance (HSP) within this setting. Moreover, although Artificial Intelligence (AI) and IoT are increasingly being integrated into practice, academic studies have yet to fully explore how AI moderates the relationships between IoT and HSP and between IoT and DDM. This gap is particularly important, as AI has the potential to amplify the effectiveness of IoT systems, leading to smarter decision-making and stronger sustainability outcomes.

Building on these research gaps and guided by the Resource-Based View (RBV) (Barney, 1991) and Dynamic Capabilities Theory (DCT) (Teece et al., 1997), this study aims to examine how IoT implementation influences sustainable performance in the hotel industry. The research specifically focuses on the mediating role of data-driven decision-making and the moderating role of Artificial Intelligence (AI) in the relationships between IoT and sustainable performance, as well as between IoT and data-driven decision-making.

Based on these objectives, the study seeks to explore several key questions. First, it examines how the implementation of IoT influences both sustainable performance and data-driven decision-making in the hotel industry. Second, it investigates the extent to which data-driven decision-making mediates the relationship between IoT adoption and hotel sustainable performance. Finally, the study explores how the application of Artificial Intelligence (AI) moderates the links between IoT and DDM, as well as between IoT and HSP. Together, these questions aim to provide a comprehensive understanding of how technological and managerial capabilities interact to enhance sustainability outcomes in the hospitality sector context.

## 2 Theoretical background and hypotheses development

### 2.1 Resource-Based View (RBV) and Dynamic Capabilities Theory (DCT)

This study adopts both the Resource-Based View (RBV) and Dynamic Capabilities Theory (DCT) to investigate how hotels can leverage Internet of Things (IoT) technologies to strengthen their sustainable performance. According to RBV (Barney, 1991), firms achieve competitive advantage by owning resources that are valuable, rare, difficult to copy, and not easily replaceable. Within the hotel industry, IoT systems, digital infrastructures, and data analytics serve as strategic resources that can boost operational efficiency, enhance guest satisfaction, and support sustainability initiatives. In this sense, implementing IoT provides hotels with a critical technological foundation that can differentiate them from their competitors. Yet, RBV has been critiqued for its static perspective, as it emphasizes the possession of resources rather than

how they are dynamically applied and adapted in rapidly evolving sectors like hospitality (El Shafeey and Trott, 2014; Lin and Wu, 2014).

To address the limitations of the Resource-Based View, this study also draws on Dynamic Capabilities Theory (DCT) (Teece et al., 1997), which focuses on the processes through which organizations adapt and reconfigure their resources in response to changing environments. DCT emphasizes three key activities: sensing, seizing, and transforming resources. In this study, dynamic capabilities allow hotels to detect opportunities from IoT-generated data, act on them through data-driven decision-making, and adjust operations using AI to maintain a competitive edge and enhance sustainability outcomes. By integrating RBV and DCT, the study provides a more complete perspective on the role of IoT, AI, and DDM in the hospitality sector context.

## 2.2 The impact of IoT on HSP

The IoT is reshaping the hospitality sector by providing advanced solutions that promote sustainability. By enabling more effective management of resources and streamlining operations, IoT creates opportunities for performance gains that were previously unattainable (Liu et al., 2025; Mercan et al., 2021). These technologies establish intelligent systems capable of responding to changing environmental conditions in real time, thereby improving resource efficiency and supporting more sustainable hotel operations (Hassan and Eassa, 2025; Poullas and Kakoulli, 2023). From an economic and social perspective, the adoption of IoT allows hotels to achieve superior performance. For instance, from a financial perspective, IoT helps optimize operational processes, reduce energy and resource expenses, and provide actionable insights for informed decisions on pricing, staffing, and service delivery. These improvements not only lower costs but also increase profitability and strengthen competitive positioning (Sharma and Gupta, 2021; Rajesh et al., 2022). On the social front, IoT enhances guest experiences by enabling personalized services, improving safety through intelligent monitoring systems, and supporting sustainability initiatives that align with the expectations of today's environmentally conscious travelers (Sharma and Gupta, 2021; Rajesh et al., 2022). Collectively, these advantages contribute to financial growth while fostering guest trust, loyalty, and a positive reputation within local communities (Shani et al., 2023).

With respect to environmental considerations, IoT-enabled smart thermostats and lighting systems allow hotels to adjust energy consumption based on room occupancy and external conditions. These systems can automatically reduce energy use when rooms are unoccupied or when weather conditions permit, thereby optimizing efficiency without compromising guest comfort (Khatua et al., 2020; Li et al., 2020). By minimizing reliance on manual adjustments, IoT helps reduce human error and ensures consistent energy savings. Similarly, IoT contributes to water conservation through smart showerheads, faucets, and leak detection technologies, which monitor and regulate water use in real time (Ali et al., 2022). This not only prevents unnecessary water wastage but also enables hotels to quickly detect leaks or

inefficiencies that might otherwise remain unnoticed, enhancing overall environmental performance (Kalsi et al., 2025). From a waste management perspective, IoT is increasingly enabling hotels to implement smarter and more efficient practices. For instance, by enabling real-time monitoring of waste generation, IoT systems allow managers to implement targeted strategies for recycling and waste reduction. Advanced automated IoT-based sorting systems further minimize landfill contributions by efficiently separating recyclable materials, thereby enhancing sustainability through more effective resource management (Saha et al., 2017; Gajić et al., 2024). These innovations not only lower operational costs but also yield positive environmental outcomes (Singh et al., 2024). By leveraging IoT to reduce their carbon footprint, hotels position themselves as leaders in sustainability within the hospitality sector. Based on the previous, it is proposed that:

**H1:** *The adoption of IoT technologies has a significant positive impact on HSP.*

## 2.3 The impact of IoT and data-driven decision-making

Data-driven decision-making refers to the process of making strategic and operational choices based on accurate, timely, and relevant data rather than intuition or past experiences (Malik, 2024). In the context of hotels, the IoT plays a pivotal role in supporting data-driven decision-making by generating vast amounts of real-time data on operations and processes (Nadkarni et al., 2020). This data can be analyzed to provide actionable insights that guide strategic initiatives, enhance operational efficiency, and improve guest experiences, ultimately driving overall business performance (Malik, 2024). IoT sensors capture a wide range of metrics, including energy and water usage, guest preferences, room occupancy, and environmental conditions (Li et al., 2020). The continuous flow of real-time information allows hotel managers to make timely and informed decisions, moving beyond reliance on historical records or subjective assessments. By aggregating and interpreting operational data, IoT equips hotels with a clear and objective understanding of performance, illustrating a core mechanism through which IoT enhances data-driven decision-making. For instance, energy management systems powered by IoT supply real-time insights into areas and times of highest energy consumption within hotels (Ferreira, 2023). This information allows managers to pinpoint inefficiencies, apply adaptive energy strategies, and forecast peak usage periods, ultimately reducing waste and cutting operational costs. In addition, IoT supports predictive maintenance, which is a critical aspect of data-driven decision-making (Shaik, 2019). The integration of real-time data collection with advanced analytics has transformed decision-making in the hotel industry. By leveraging these objective, data-driven insights, managers can enhance operational efficiency and elevate guest experiences, moving beyond reliance on historical trends or intuitive judgment. Based on this, we propose that.

**H2:** *The adoption of IoT technologies has a significant positive impact on data-driven decision-making.*

## 2.4 The impact of data-driven decision-making on HSP

In the context of the hospitality industry, hotels that implement data-driven decision-making can more effectively identify operational inefficiencies, optimize resource utilization, and adopt sustainability initiatives based on reliable insights (Chaudhuri et al., 2024; Malik, 2024). By analyzing data, hotels gain a clearer understanding of energy consumption patterns, sources of waste, and opportunities to manage resources more efficiently across different operations and time periods. This informed management approach not only reduces environmental impact but also enhances overall sustainability performance (Huang et al., 2023; Nisar et al., 2021). From an economic perspective, data-driven decision-making supports sustainable growth by improving revenue management, lowering costs, and streamlining operations (Chatterjee et al., 2023). Data analytics enables hotels to fine-tune pricing strategies, forecast demand accurately, and allocate resources effectively, boosting profitability while maintaining high service standards. Moreover, data-driven decision-making facilitates proactive maintenance, efficient workforce scheduling, and better inventory control, contributing to long-term operational stability (Aziz et al., 2024). On the social front, leveraging data allows hotels to deliver personalized guest experiences, enhance employee wellbeing through workforce analytics, and strengthen community engagement via local impact initiatives (Punia et al., 2025; Xu et al., 2019; Stankevičiute, 2024).

Empirical research highlights the positive impact of data-driven decision-making on various sustainability outcomes. For example, studies of data-driven manufacturing firms indicate that data-driven decision-making is instrumental in boosting sustainable performance. By converting large volumes of data into actionable insights, organizations can optimize resource utilization, reduce waste, and align operations with principles of the circular economy. This transition from intuition-based to evidence-based decision-making not only improves environmental outcomes but also strengthens long-term competitiveness (Awan et al., 2021; Hindle and Vidgen, 2018). In addition, Chaudhuri et al. (2024) reported that, across 416 Indian organizations, a strong data-driven culture significantly enhanced sustainable organizational performance. Based on these findings, we hypothesize that.

**H3:** *Data-driven decision-making has a significant positive impact on HSP.*

## 2.5 Mediating role of data-driven decision-making in the IoT–HSP relationship

In this study, we argue that data-driven decision-making serves as a crucial mechanism through which the adoption of IoT technologies enhances HSP. The mediating role of data-driven decision-making in the IoT-sustainability relationship is grounded in both the Resource-Based View (RBV) and Dynamic Capabilities Theory (DCT). From the RBV perspective, IoT constitutes a valuable and strategic technological resource that provides hotels with a competitive edge (Barney, 1991). However, DCT emphasizes

that possessing resources alone is insufficient; organizations must develop dynamic capabilities to deploy and adapt these resources effectively in a changing environment (Teece et al., 1997).

In the hospitality industry, IoT enables real-time collection and analysis of data on energy use, guest behavior, and resource consumption, making environmental monitoring central to sustainable operations (Mercan et al., 2021; Nadkarni et al., 2020). This data forms the foundation for data-driven decision-making, allowing managers to optimize resources, streamline processes, and plan strategically for sustainability objectives (Awan et al., 2021; Chaudhuri et al., 2024). Research by Malik (2024) confirms that when hotels leverage IoT to support evidence-based decisions, they improve operational efficiency, reduce environmental impact, and enhance overall sustainable performance. In this context, data-driven decision-making acts as a dynamic capability, converting IoT-generated data into actionable strategies that lead to improved environmental, economic, and social outcomes. Based on this theoretical and empirical foundation, the following hypothesis is proposed:

**H4:** *Data-driven decision-making significantly mediates the IoT–HSP relationship.*

## 2.6 The moderating role of AI

Artificial Intelligence (AI) is defined as “the tangible real-world capability of non-human machines or artificial entities to perform, task solve, communicate, interact, and act logically as it occurs with biological humans” (Gil de Zúñiga and Goyanes, 2024, p. 317). In the hospitality industry, AI is becoming a transformative force, providing tools to embed sustainability into operations, services, and strategic decisions (Filimonau et al., 2025; Zahidi et al., 2024). AI strengthens the impact of IoT on sustainable performance by analyzing real-time data on energy consumption, guest behavior, and operational processes, which might otherwise remain underutilized (Gajić et al., 2024; Chung and Tan, 2025). For instance, AI-driven systems can adjust lighting and HVAC, reduce food and material waste, and monitor carbon emissions against sustainability targets (Jabeen et al., 2022; Semwal et al., 2024). AI also supports social sustainability by optimizing workforce management, enhancing staff wellbeing, analyzing guest feedback, and promoting collaboration with local suppliers (Al-Romeedy and Alharethi, 2024; Limna, 2023). Economically, AI improves demand forecasting, supply chain efficiency, and cost reduction, further supporting sustainable practices (Liu et al., 2025; Shkalenko and Nazarenko, 2024). Empirical studies highlight that integrating AI with IoT enables hotels to adopt innovative approaches to environmental sustainability, achieving energy savings and process automation while improving their green profile (Bibri et al., 2023). Based on this discussion, we propose:

**H5:** *AI significantly moderates the relationship between IoT and HSP, strengthening the positive effect of IoT on hotel sustainable performance.*

In the hospitality industry, adopting IoT enables hotels to collect extensive data on energy consumption, guest behavior, water use, and other operational resources (Nadkarni et al., 2020; Mercan et al., 2021). Proper utilization of this data supports

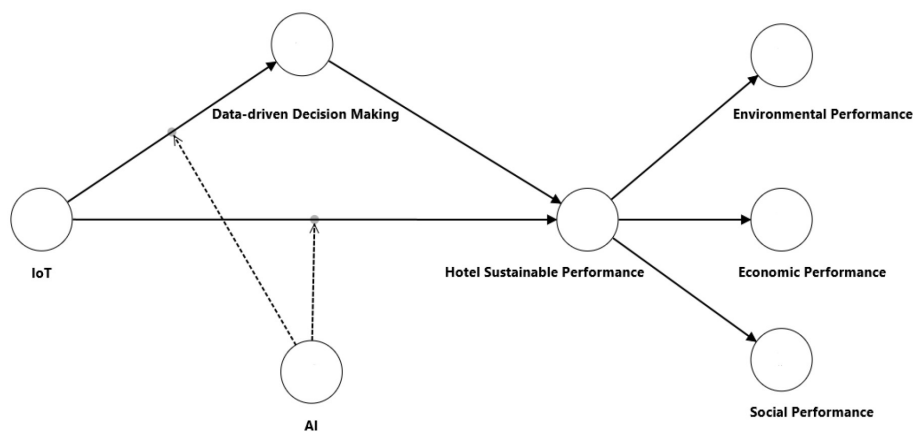


FIGURE 1  
The study's conceptual framework.

data-driven decision-making, helping hotels enhance efficiency, implement predictive maintenance, and adopt more sustainable practices (Domínguez-Cid et al., 2022; Shaik, 2019). Artificial Intelligence (AI) further strengthens data-driven decision-making by using technologies such as machine learning, natural language processing, and predictive analytics to process large volumes of IoT data more efficiently and accurately, transforming it into actionable insights (Kavitha and Chinnasamy, 2021; Al-Okbi et al., 2025). AI algorithms can detect complex patterns, forecast trends, and recommend optimal decisions based on IoT data, thereby reinforcing the link between IoT adoption and data-driven decision-making capabilities. For instance, integrating AI with IoT allows hotels to move from descriptive analytics (understanding what happened) to prescriptive analytics (determining what should be done), facilitating more effective decision-making (Gandhi and Kumar, 2024; Kumar and Kumar, 2023). This perspective aligns with the RBV and DCT, suggesting that combining valuable technological resources, such as IoT and AI, enables organizations to analyze information efficiently and translate data into strategic, sustainability-oriented actions (Barney, 1991). Accordingly, the following hypothesis is proposed:

**H6:** AI significantly moderates the relationship between IoT and data-driven decision-making, enhancing the positive effect of IoT on data-driven decision-making.

The research conceptual framework is presented in Figure 1.

## 3 Materials and methods

### 3.1 Sampling and procedure

This study employed a convenience sampling method to collect data from hotel managers with direct responsibility for operational and sustainability-related decisions. The target population consisted of managers, executives, and their assistants from four- and five-star hotels across Saudi Arabia, given their

significant adoption of technological innovations and commitment to sustainable practices. By focusing on this sample, the study ensures that respondents possess the necessary expertise and experience to provide reliable and informed insights regarding the implementation of IoT technologies, data-driven decision-making, and Artificial Intelligence (AI) in hotel operations. While this approach facilitated access to participants with relevant expertise, it may introduce selection bias, which is acknowledged as a limitation of the study.

To collect the data, an online survey was developed and administered to the targeted participants. The questionnaire was structured to capture demographic information, IoT adoption, data-driven decision-making, AI applications, and hotel sustainable performance. Following Hair et al. (2019), a minimum of 155 cases is required for SEM analysis when the expected path coefficients ( $P_{min}$ ) range between 0.11 and 0.20 at a 0.05 significance level, while Boomsma (1982) recommends at least 200 cases for reliable structural equation modeling. A total of 400 participants were invited via email, with a personalized invitation link, a welcome note, and a brief overview of the study's purpose. To enhance the response rate, reminder emails were distributed 2 and 4 weeks after the initial invitation. Data collection took place over nearly 2 months, from May to July 2025, providing sufficient time to reach and engage the targeted hotel managers. In total, 211 valid responses were obtained, yielding a response rate of 52.8%, which is considered adequate for PLS-SEM analysis. Table 1 presents the demographic characteristics of the respondents.

This study adhered to recognized ethical standards for research involving human participants. Before beginning the online survey, all participants were provided with an informed consent form outlining the study's purpose, their voluntary participation, and their right to withdraw at any time without consequence. They were also assured that their responses would remain completely anonymous and confidential, and that the information collected would be used solely for academic research purposes. To confirm their willingness to participate, respondents were asked to indicate their consent by selecting "I agree" before accessing the survey questions.

TABLE 1 Demographic information of the sample.

Category	Frequency (n = 211)	%
<b>Gender</b>		
Male	176	83.4
Female	35	16.6
<b>Experience</b>		
1-5 years	128	60.7
6-10 years	42	19.9
11-15 years	25	11.8
More than 15	16	7.6
<b>Education</b>		
High school/Diploma	44	20.9
Bachelor degree	145	68.7
Postgraduate degree	22	10.4
<b>Position</b>		
GM/Hotel Manager	25	11.8
Assistant GM	38	18.0
Department Director/Executive	71	33.7
Department heads	45	21.3
Assisstanrt Dep. Heads	32	15.2

### 3.2 Measures of study and data analysis

To enhance both construct validity and measurement reliability, previously validated scales were adapted for this study. A five-point Likert scale, ranging from “Strongly Disagree” (1) to “Strongly Agree” (5), was used for the constructs of IoT, DDM, and AI. For assessing hotel sustainable performance, participants were asked to rate their hotels’ performance on a five-point scale ranging from 1 “very low” to 5 “very high”. This approach reflects managers’ subjective perceptions of sustainability performance, which are commonly used in hospitality and management research where objective indicators are difficult to access. The study adopted a cross-sectional design, capturing responses at a single point in time.

Fifteen measurement items were drawn and modified from Gajić et al. (2024) to evaluate IoT; for instance, “IoT sensors reduce energy consumption by controlling light and temperature,” and “IoT devices track inventory in real time.” Data-driven decision-making was measured through five questions derived from Ashaari et al. (2021); for example, “Our hotel utilized data-based insights to support decision making.” Moreover, an 8-item scale adapted from Gajić et al. (2024) was used to evaluate the AI application; an example includes “AI analyzes guest feedback and resolves requests faster.” Additionally, to evaluate hotel sustainable performance, a 10-item scale adapted from Abdou et al. (2022b) and Cheah et al. (2019) was applied. Hotel sustainable performance was modeled as a higher-order construct incorporating economic, environmental, and social performance. Representative items include “Reducing

hotel costs (i.e., energy and water consumption costs) in the long term,” “Improving the hotel’s environmental situation,” and “Providing more social or environmentally friendly services in the community.” All study constructs and their related items are presented in the [Supplementary file Appendix A](#).

The questionnaire was first developed in English and then translated into Arabic by two bilingual researchers. To ensure accuracy and alignment between both versions, two additional experts conducted a back-translation into English. Afterward, to ensure the content validity of the study measures, all constructs and their indicators were reviewed by a panel of experts consisting of three university professors and four senior hotel managers. Their feedback was used to refine the wording, clarity, and relevance of the items before the final questionnaire was administered. Following this expert evaluation, a pilot test was conducted with 20 hotel managers to further assess the clarity, validity, and reliability of the survey instrument. Based on the feedback received, minor modifications were made to improve the overall quality of the questionnaire before full-scale data collection.

Using PLS-SEM, reliability and validity were assessed through Cronbach’s alpha, Composite Reliability (CR), Average Variance Extracted (AVE), and the Heterotrait-Monotrait ratio (HTMT) criteria.

## 4 Results

### 4.1 Common Method Bias (CMB)

An online survey was used to collect data at a single point in time. As is common in behavioral research, the potential for CMB was carefully considered (Kock, 2015). To minimize this risk, several procedural and statistical measures were applied. Respondents were assured that their participation was voluntary and that their answers would remain completely anonymous and confidential to encourage honest and unbiased responses. The questionnaire items were written in clear and simple language, and the order of questions was randomized to reduce response patterns and prevent bias caused by item sequencing (Nancarrow et al., 2001). In addition, collinearity assessment as well as Harman’s single-factor test were conducted to statistically test for CMB. The results in [Table 2](#) indicated that all variance inflation factor (VIF) values were below the recommended threshold of 3.3, confirming that CMB did not pose a significant issue in this study (Kock, 2015). Further, the analysis confirmed that one factor accounted for only 39.421% of the total variance, which is lower than the critical 50% limit, supporting the absence of significant CMB (Podsakoff et al., 2003).

### 4.2 Measurement model assessment

To examine both the measurement and structural aspects of the model and test the study’s hypotheses, Partial Least Squares Structural Equation Modeling (PLS-SEM) was used. PLS-SEM is a flexible, variance-based statistical method that works well for models of varying complexity (Hair et al., 2019). It is particularly useful when the data is not normally distributed, the sample size is

TABLE 2 Collinearity statistics (VIF).

Construct	DDM	Environmental	Economic	Social	HSP
AI	1.438				1.573
DDM					1.573
HSP		1.000	1.000	1.000	
IoT	1.352				1.654
AI x IoT	1.141				1.215

moderate or small, or there are some missing values, as it provides more accurate and reliable estimates than traditional least squares techniques (Becker et al., 2023).

Following the guidelines of Hair et al. (2019), a reflective measurement model was assessed through several key criteria: indicator reliability, internal consistency reliability, convergent validity, and discriminant validity. First, for indicator reliability, items with loadings above 0.708 were considered acceptable, indicating that they adequately reflect their respective constructs (Hair et al., 2019). Table 3 and Figure 2 shows that all standardized item loadings are above 0.708 and statistically significant at  $p < 0.001$ . Second, regarding internal consistency reliability, Cronbach's alpha ( $\alpha$ ) and Composite Reliability (CR) were calculated. Both measures exceeded the recommended threshold of 0.70 for all constructs, confirming the consistency of the scales (Hair et al., 2019). Third, Convergent validity was evaluated by examining the Average Variance Extracted (AVE) for each construct. All constructs achieved AVE values greater than 0.50, confirming adequate convergent validity (Fornell and Larcker, 1981).

Finally, Discriminant validity was assessed using the Heterotrait-Monotrait ratio (HTMT) criterion. All HTMT values were below the 0.85 threshold, confirming that each construct is empirically distinct from the others (Henseler et al., 2015) (see Table 4).

### 4.3 Structural model assessment and hypothesis testing

The structural model analysis, performed with 5,000 bootstraps, is presented in Table 5 and Figure 3. The results indicate that IoT significantly influences HSP, with a  $\beta$  of 0.323 and a  $t$ -value of 8.318. Likewise, IoT strongly affects data-driven decision-making ( $\beta = 0.438$ ,  $t = 9.016$ ), confirming Hypotheses H1 and H2. Further, the results demonstrate that IoT has a significant and positive impact on data-driven decision-making ( $\beta = 0.240$ ;  $t = 5.738$ ), supporting H3.

The study also validated the mediating function of data-driven decision-making, revealing that IoT indirectly influences HSP through data-driven decision-making ( $\beta = 0.105$ ,  $t = 4.475$ ,  $p = 0.000$ , CI [0.046, 0.156]). This means that when hotel managers use IoT data to make informed, evidence-based decisions, they can better manage resources, reduce waste, and improve sustainable practices. In other words, part of IoT's positive effect on sustainable performance operates through the enhancement of data-driven managerial capabilities, highlighting the critical role of data-driven

decision-making in translating technological adoption into tangible sustainability outcomes. Hence, H4 is accepted.

The moderating role of AI was also confirmed. According to results in Table 6 and Figures 4, 5, the interaction between AI and IoT has a significant moderating effect on HSP ( $\beta = 0.093$ ,  $t = 2.805$ ,  $p = 0.005$ ,  $f^2 = 0.035$ ), indicating that the benefits of IoT for hotel sustainable performance are greater when AI is applied extensively. Additionally, AI strengthened the impact of IoT on data-driven decision-making ( $\beta = 0.196$ ,  $t = 5.407$ ,  $p < 0.001$ ,  $f^2 = 0.065$ ), indicating that combining AI with IoT allows hotels to make more effective and informed data-driven decisions. As a result, hypotheses H5 and H6 are supported. Overall, all the proposed relationships in the model were confirmed, demonstrating the robustness and validity of the conceptual framework.

Finally, the effect size ( $f^2$ ) values are presented in Table 6. Based on Cohen (1988) standards, small ( $f^2 \geq 0.02$ ), medium ( $f^2 \geq 0.15$ ), and large ( $f^2 \geq 0.35$ ), all calculated values were observed to be between small and medium.

### 4.4 Assessing the explanatory power and predictive relevance of the structural model

This research measured the structural model's explanatory power and predictive relevance by evaluating  $R^2$  and  $Q^2_{\text{predict}}$  statistics. Following Hair et al. (2019), the coefficient of determination ( $R^2$ ) is evaluated as substantial (0.75), moderate (0.50), or weak (0.25). Table 6 shows that the integration of IoT and AI contributed to 36.4% of the variance in data-driven decision-making, demonstrating that the model possesses moderate explanatory strength. For hotel sustainable performance, IoT, AI, and data-driven decision-making had a strong combined effect, explaining 75.1% of its variance and underscoring the model's high explanatory power.

To further test the model's predictive relevance,  $Q^2_{\text{predict}}$  values were examined. Following Hair et al. (2019), values above zero confirm predictive relevance. Using the  $PLS_{\text{predict}}$  function in SmartPLS version 4.1.1.4, all constructs produced positive  $Q^2_{\text{predict}}$  values. Specifically, data-driven decision-making showed a value of 0.343 and HSP 0.702, highlighting that the model effectively predicts hotel sustainability performance.

## 5 Discussion

The purpose of this study was to investigate how IoT, data-driven decision-making, and AI can collectively improve hotel

TABLE 3 Constructs' validity and reliability.

First-order construct	Second-order construct	Items	Factor loading	$\alpha$	CR	AVE
Internet of Things		IOT1	0.750***	0.944	0.95	0.559
		IOT2	0.748***			
		IOT3	0.807***			
		IOT4	0.754***			
		IOT5	0.786***			
		IOT6	0.730***			
		IOT7	0.725***			
		IOT8	0.713***			
		IOT9	0.782***			
		IOT10	0.710***			
		IOT11	0.726***			
		IOT12	0.780***			
		IOT13	0.733***			
		IOT14	0.757***			
		IOT15	0.709***			
Data-driven decision-making		DDM1	0.868***	0.874	0.909	0.668
		DDM2	0.786***			
		DDM3	0.847***			
		DDM4	0.847***			
		DDM5	0.730***			
Environmental performance		HSP1	0.767***	0.857	0.903	0.701
		HSP2	0.791***			
		HSP3	0.900***			
		HSP4	0.883***			
Economic performance		HSP5	0.914***	0.947	0.966	0.905
		HSP6	0.963***			
		HSP7	0.976***			
Social performance		HSP8	0.769***	0.782	0.815	0.594
		HSP9	0.760***			
		HSP10	0.783***			
AI application		AI1	0.917***	0.973	0.977	0.842
		AI2	0.934***			
		AI3	0.925***			
		AI4	0.909***			
		AI5	0.927***			
		AI6	0.921***			
		AI7	0.921***			
		AI8	0.885***			
	Hotel sustainable performance	<i>Environmental performance</i>	0.963***	0.921	0.936	0.602
		<i>Economic performance</i>	0.940***			
		<i>Social performance</i>	0.761***			

\*\*\* $p < 0.001$ .

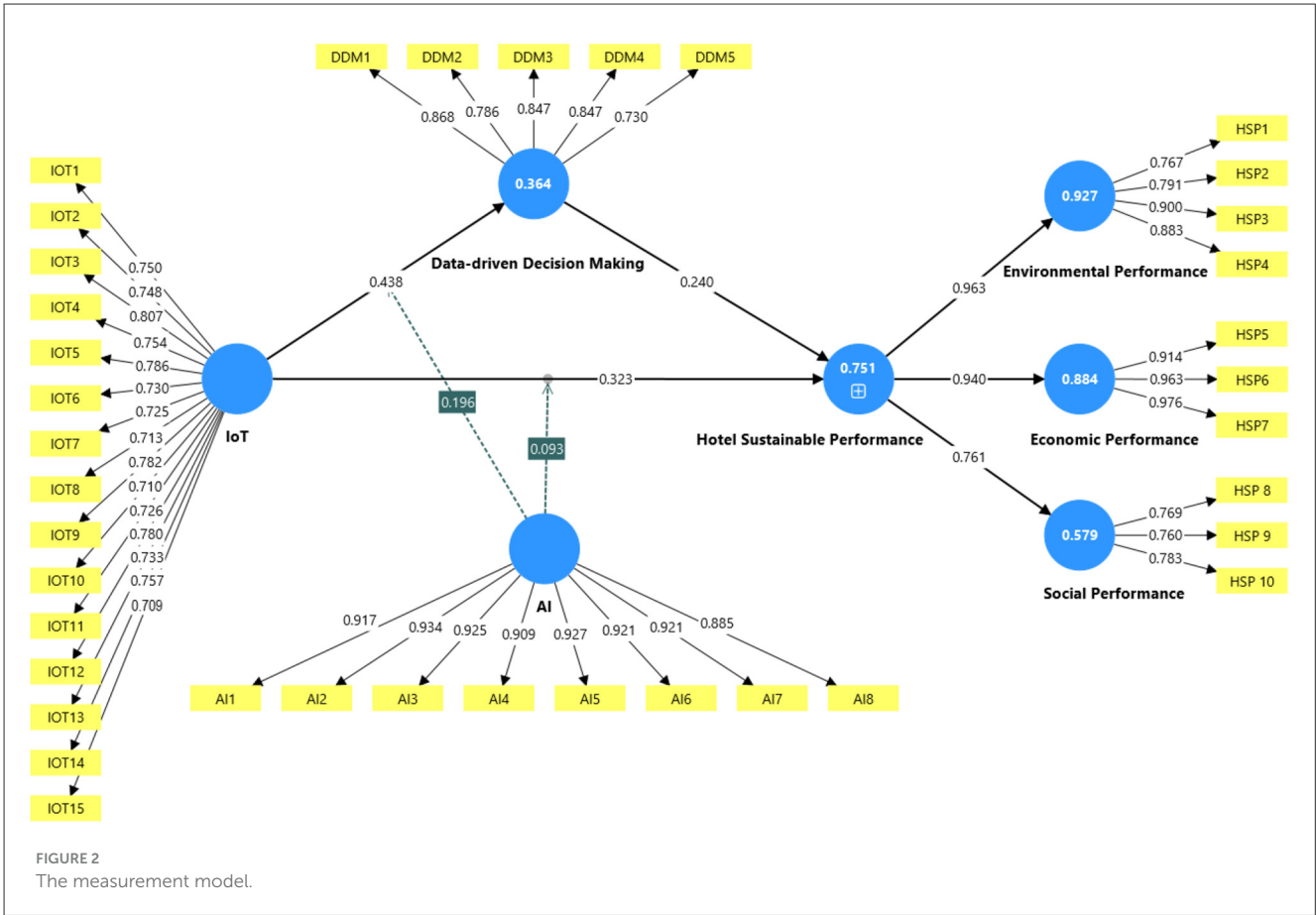


TABLE 4 Heterotrait–monotrait ratio (HTMT).

Constructs	AI	DDM	HSP	IoT	AI x IoT
AI					
DDM	0.476				
HSP	0.782	0.728			
IoT	0.528	0.584	0.770		
AI x IoT	0.347	0.012	0.177	0.255	

sustainable performance. Based on RBV and DCT, the research examined IoT’s direct and indirect effects on sustainability, with data-driven decision-making as a mediator and AI as a moderator. Drawing on the RBV and DCT, the results emphasize that IoT serves as a strategic technological resource enabling hotels to identify and capitalize on sustainability opportunities. Further, data-driven decision-making and AI function as internal capabilities that transform IoT-generated data into actionable insights, driving advancements in ecological performance, cost efficiency, and social wellbeing.

First, this study found that IoT adoption has a significant influence on HSP, supporting earlier studies that recognize the value of smart technologies in driving sustainability (Liu et al., 2025; Mercan et al., 2021; Rajesh et al., 2022; Sharma and Gupta, 2021). The IoT’s ability to monitor resources such as energy, water,

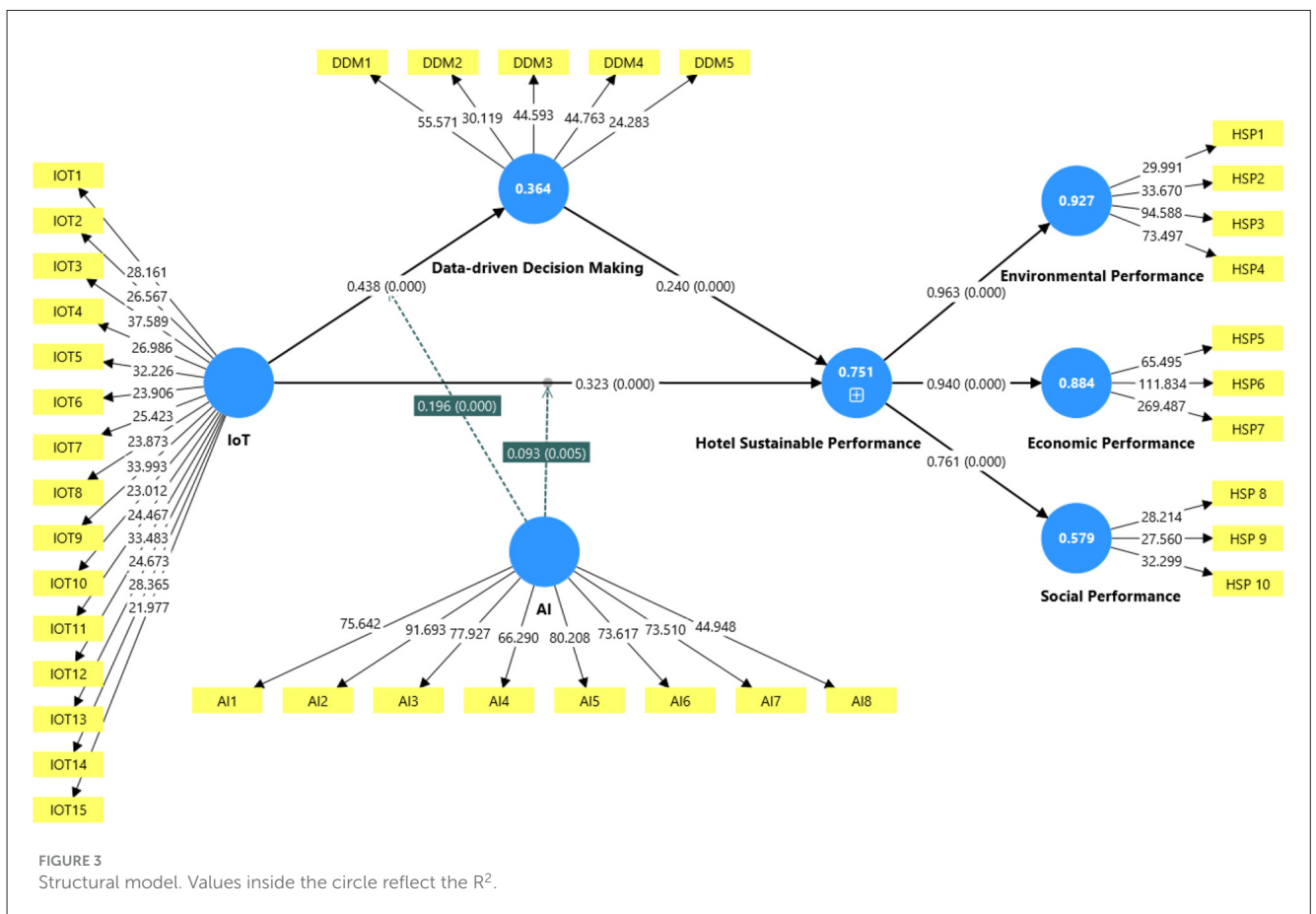
and waste in real-time enhances efficiency and environmental performance (Gajić et al., 2024; Saha et al., 2017; Singh et al., 2024). These results also align with the RBV, which regards technology as a key, hard-to-copy resource that strengthens a firm’s competitive advantage (Barney, 1991). Moreover, the study demonstrates that IoT contributes to sustainability not only through environmental gains but also by enhancing economic efficiency and generating social benefits.

Second, the study’s findings reveal that IoT significantly influences data-driven decision-making, aligning with earlier research that shows how digital systems support managers in making timely and precise decisions (Li et al., 2020; Ferreira, 2023; Domínguez-Cid et al., 2022). This indicates that by implementing IoT systems to monitor energy consumption, guest behaviors, and maintenance requirements, hotel managers are able to make well-informed decisions rather than relying only on intuition. This supports the Dynamic Capabilities Theory (DCT), illustrating how hotels can identify and capitalize on opportunities through data-driven insights.

Third, the findings show that data-driven decision-making significantly contributes to the improvement of hotel sustainability outcomes. More specifically, when hotels make decisions based on data, they can handle resources more effectively, prevent unnecessary waste, and enhance productivity. IoT data helps managers recognize emerging problems quickly, manage assets efficiently, and make investment choices that promote both sustainability and profit (Chaudhuri et al., 2024). The finding

TABLE 5 Test of hypotheses.

Paths	Path coefficient	t-values	p-values	r <sup>2</sup>	2.5%	97.5%	Remarks
<b>Direct paths</b>							
IoT -> HSP	0.323	8.318	0.000	0.254	0.246	0.398	Accepted
IoT -> DDM	0.438	9.016	0.000	0.224	0.342	0.534	Accepted
DDM -> HSP	0.24	5.738	0.000	0.147	0.161	0.325	Accepted
<b>Mediation paths</b>							
IoT -> DDM -> HSP	0.105	4.475	0.000		0.046	0.156	Accepted
<b>Moderation paths</b>							
AI x IoT -> HSP	0.093	2.805	0.005	0.035	0.03	0.156	Accepted
AI x IoT -> DDM	0.196	5.407	0.000	0.065	0.128	0.269	Accepted



reinforces the principles of RBV and DCT, suggesting that firms must continuously develop and reconfigure their valuable resources to sustain a competitive edge. Consistent with prior evidence (e.g., Aziz et al., 2024; Pascual-Fernández et al., 2021), it underscores that data-driven management plays a pivotal role in achieving comprehensive sustainability outcomes, economic, environmental, and social.

Fourth, regarding the mediation relationship between IoT and HSP, the study reveals that data-driven decision-making plays a partial mediating role in strengthening the

connection between IoT adoption and hotel sustainability outcomes. In other words, while IoT directly contributes to sustainability by enabling real-time monitoring and control of hotel operations, its impact becomes more substantial when decisions are guided by data analytics and evidence-based insights. Through data-driven decision-making, hotels can transform raw IoT-generated data into strategic knowledge, helping managers anticipate maintenance needs, allocate resources more effectively, and design proactive sustainability initiatives that reduce costs and environmental impact (Awan et al., 2021; Chaudhuri et al., 2024;

Malik, 2024; Mercan et al., 2021). Based on the previous discussion, we can conclude that hotels that invest in developing strong data-driven decision-making capabilities are better positioned to translate technological data into actionable strategies, resulting in more efficient resource use, reduced environmental impact, and enhanced sustainability outcomes overall.

Fifth, the moderation results confirm that AI amplifies the influence of IoT across major pathways, strengthening its impact on both hotel sustainable performance ( $\beta = 0.093, t = 2.436$ ) and data-driven decision-making ( $\beta = 0.196, t = 5.406$ ). These findings are consistent with prior studies and highlight AI's capacity to strengthen hotels' sensing and seizing abilities through automated data analysis and trend prediction. In particular, AI significantly enhances the IoT-HSP connection, suggesting that hotels combining AI with IoT experience higher sustainability performance than those relying solely on IoT technologies. These findings are consistent with prior evidence that the joint use of IoT and AI optimizes operational efficiency, reduces environmental impact, and advances holistic sustainability objectives (Chung and Tan, 2025; Gajić et al., 2024). Moreover, the study reveals that AI significantly strengthens the IoT-DDM relationship, implying that AI empowers hotels to interpret vast IoT data sets for predictive insights. For instance, AI technologies can forecast

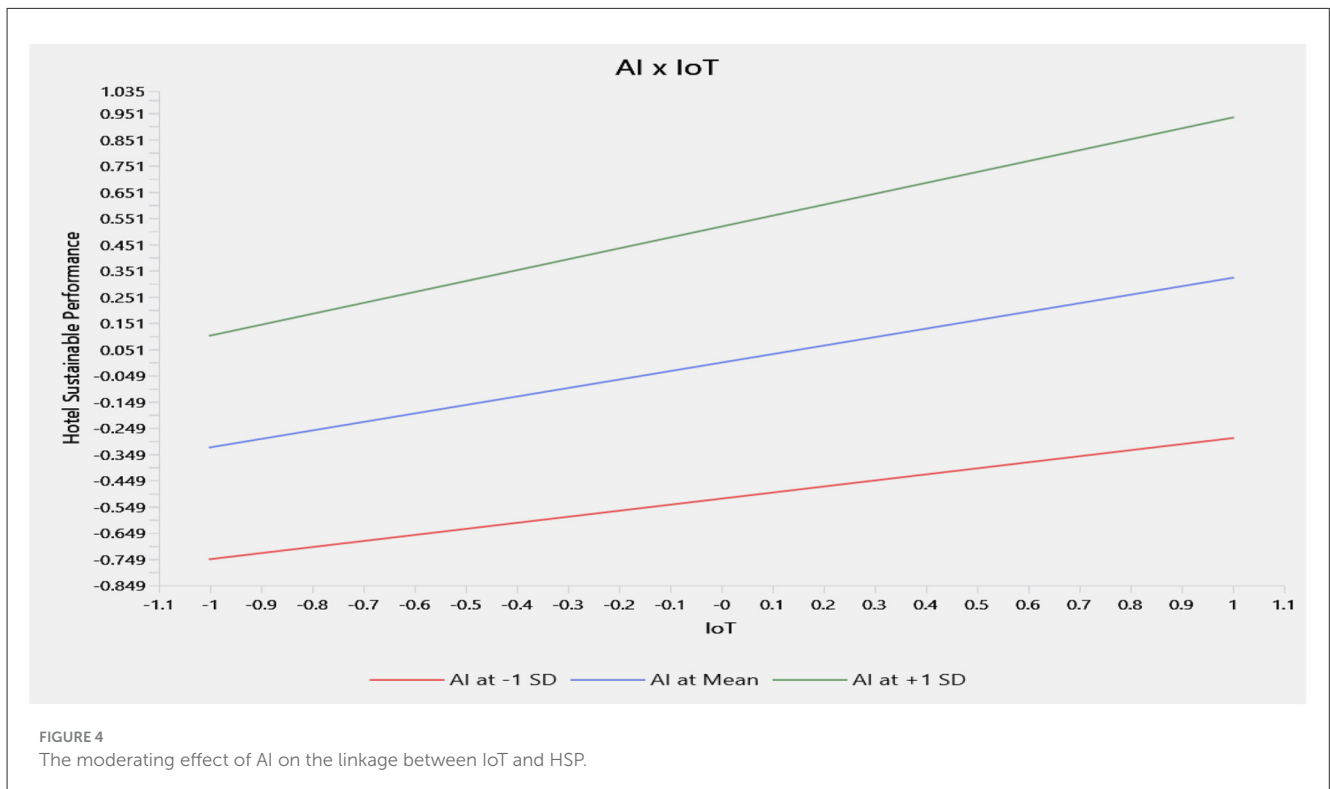
energy demands or detect equipment problems in advance. These results are consistent with previous research (Al-Okbi et al., 2025; Kavitha and Chinnasamy, 2021), confirming that AI-IoT integration enhances decision-making speed, accuracy, and sustainability through the transition from descriptive to prescriptive analytics.

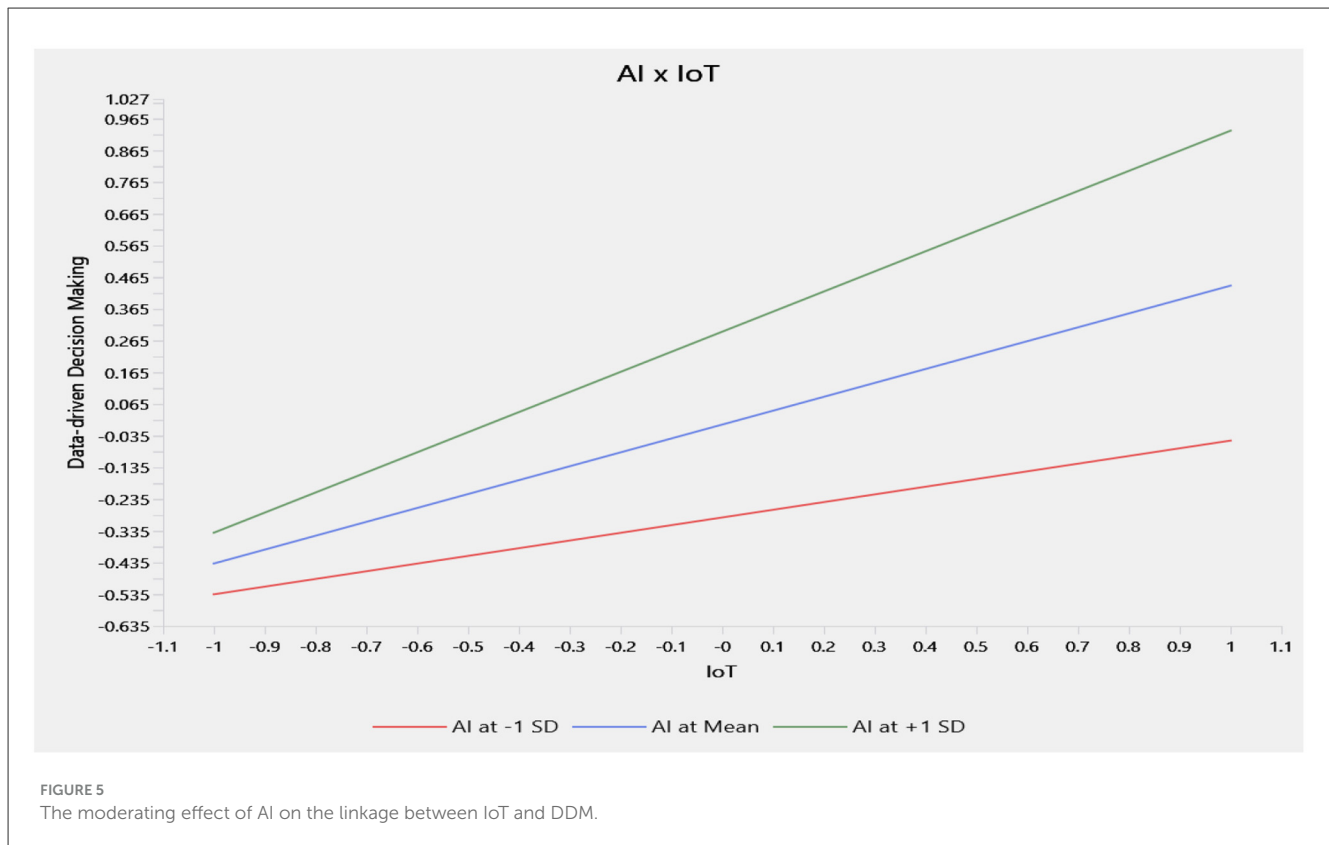
Taken together, the mediation and moderation results provide important theoretical and managerial insights. The partial mediation of DDM suggests that IoT adoption does not automatically guarantee superior sustainable performance; instead, hotels benefit most when they are able to translate IoT data into systematic, evidence-based decisions. This reinforces the view that digital technologies must be complemented by strong analytical and organizational capabilities. At the same time, the moderating role of AI shows that the impact of IoT is not fixed but depends on the level of AI adoption. When AI is extensively used, IoT data can be processed in more intelligent ways, shifting hotels from reactive monitoring to predictive and prescriptive decision-making. This digital synergy between IoT, DDM, and AI helps explain why some hotels achieve significantly higher sustainability outcomes than others, even when they have access to similar technological tools.

The findings also contribute to circular economy (CE) understanding by demonstrating how IoT, DDM, and AI collectively promote resource efficiency, waste minimization, and closed-loop operational processes. IoT enables real-time tracking of energy, water, and waste, supporting reduction, preventive maintenance, and extended asset lifecycles—core CE principles. DDM translates these data streams into strategic decisions that prioritize reuse, recycling, and intelligent resource allocation, while AI strengthens these pathways by predicting equipment failures,

TABLE 6 Predictive power and relevance of the study's model.

Constructs	R <sup>2</sup>	Q <sup>2</sup> <sub>predict</sub>
Data-driven decision-making	36.4	0.343
Hotel sustainable performance	75.1	0.702





optimizing consumption, and enabling regenerative resource flows. Integrating these insights with RBV and DCT provides a deeper theoretical explanation of how digital transformation enables hotels to transition from linear to circular systems. IoT functions as a valuable technological resource (RBV), whereas DDM and AI serve as dynamic capabilities (DCT) that allow hotels to sense data-driven opportunities, seize them through evidence-based decisions, and reconfigure operations toward circularity and long-term sustainability. Overall, the study shows that superior sustainability performance emerges not merely from adopting digital tools but from strategically combining technological resources with strong analytical and decision-making capabilities that embed circular economy principles into hotel operations.

## 6 Theoretical and practical implications

### 6.1 Theoretical implications

This study offers several meaningful contributions to the literature on digital transformation and hotel sustainability. First, it fills a notable empirical gap by examining how Internet of Things (IoT) adoption influences hotel sustainable performance within the context of Saudi Arabia—a rapidly expanding hospitality market committed to advancing sustainability in line with national strategies such as Vision 2030 (Abdou et al., 2022b). Second, by introducing data-driven decision-making (DDM) as a mediating

mechanism, the study presents a comprehensive model that explains how technological adoption translates into improved sustainable performance. This contribution advances prior research by recognizing that the value of IoT does not stem solely from the technology itself but from hotels' ability to convert IoT-generated data into strategic insights and informed managerial action. Third, the investigation of AI as a moderating factor reveals its important role in strengthening the effects of IoT on both decision-making and hotel sustainable performance, emphasizing AI's value as a key enabler of digital transformation. Fourth, the research extends the Resource-Based View (RBV) by empirically demonstrating that IoT and AI represent valuable, rare, and difficult-to-imitate resources that contribute to competitive and sustainable advantages. While prior studies have primarily emphasized efficiency and operational benefits, this study shows how digital resources influence environmental, economic, and social sustainability dimensions, offering a broader interpretation of RBV within hospitality contexts. Fifth, the study advances Dynamic Capabilities Theory (DCT) by illustrating how hotels use DDM as a capability to sense opportunities from IoT data, seize them through informed decisions, and transform operational processes toward sustainability. The moderated mediation structure introduced in this research underscores that digital technologies yield value only when paired with dynamic capabilities that enable learning, adaptation, and strategic reconfiguration. Overall, the moderated mediation model introduced in this research provides a novel and clear framework for understanding how technological resources and managerial capabilities interact to enhance sustainable performance in the hospitality sector.

## 6.2 Practical implications

The findings of this study offer several practical insights for hotel managers, technology providers, and policymakers seeking to improve sustainability in the hospitality industry. First, hotel managers should prioritize the adoption of Internet of Things (IoT) technologies such as smart energy, water, and waste management systems to enhance resource efficiency, reduce operational costs, and minimize environmental impact. However, the partial mediation effect of data-driven decision-making highlights that simply adopting IoT is not enough. Hotels must cultivate a strong data-driven culture, ensuring that managers and employees possess the analytical skills necessary to interpret IoT-generated data and transform it into evidence-based sustainability strategies. Second, the study highlights the strategic importance of AI as a moderating factor that amplifies the benefits of IoT. By integrating AI with IoT, hotels can move from reactive to predictive management—using intelligent systems to anticipate maintenance needs, optimize energy consumption, and enhance overall operational sustainability.

Third, hotel managers and executives should align their digital transformation initiatives with long-term sustainability goals and national strategies such as Saudi Vision 2030. Training programs that enhance data literacy and sustainability awareness among staff are vital to realizing these digital benefits. Furthermore, communicating sustainability achievements to guests can strengthen social responsibility perceptions and brand reputation. Finally, collaboration with technology providers and government bodies is recommended to support the implementation of IoT- and AI-enabled sustainability solutions through financial incentives, green certifications, and industry partnerships. Such coordinated efforts will enable hotels to achieve superior environmental, economic, and social performance while maintaining competitiveness in the digital era.

## 7 Limitations of the study and further research

The present study acknowledges several limitations that provide directions for future research. First, its cross-sectional design restricts causal inference; therefore, longitudinal studies are recommended to track how IoT, AI, and organizational capabilities evolve and affect hotel sustainability over time. Second, since data were drawn from four- and five-star hotels in Saudi Arabia, the findings may not generalize to smaller establishments or different regions. Future research could conduct cross-country or multi-category comparisons to examine the influence of cultural, regulatory, and digital maturity differences. Third, although this study is based on the RBV and DCT, integrating alternative theoretical perspectives, such as Institutional Theory or the Technology–Organization–Environment (TOE) framework, could enrich the understanding of how external and contextual factors shape hotels' digital sustainability practices. Fourth, while this study focused on IoT, AI, and DDM, future studies might investigate additional mediating or moderating variables such as innovation capability, green HRM, green digital transformational

leadership, or organizational learning. Finally, although the study provides valuable insights, sustainability performance was measured using subjective managerial assessments rather than objective performance metrics. Self-report measures may introduce perceptual bias and limit the precision of sustainability evaluations. Future studies should incorporate objective data, such as certified sustainability audits, water and energy consumption records, waste management data, or carbon emissions per guest, to validate and strengthen the measurement of sustainability outcomes.

## 8 Conclusion

This study investigated how the integration of the Internet of Things (IoT), data-driven decision-making (DDM), and Artificial Intelligence (AI) enhances hotel sustainable performance (HSP) in Saudi Arabia. The findings show that IoT adoption directly improves environmental, economic, and social sustainability outcomes, confirming that digital technologies form a critical foundation for sustainable hotel operations. The results further reveal that DDM partially mediates the IoT–HSP relationship, indicating that the strongest sustainability gains emerge when hotels actively transform IoT-generated data into evidence-based decisions. This highlights that technology alone is insufficient; analytical and managerial capabilities are essential for converting digital information into meaningful sustainability actions. Additionally, the moderating effects of AI demonstrate its role as a capability-enhancing tool that strengthens the influence of IoT on both DDM and HSP, enabling hotels to improve sensing, prediction, and operational optimization.

Based on these insights, several important implications arise for stakeholders. First, hotels should invest in IoT technologies while ensuring that managers possess the analytical capabilities to convert digital data into effective sustainability actions. Second, it is critical to strengthen data-driven decision-making by training staff to interpret and utilize IoT-generated information. Third, integrating AI with IoT should be prioritized to enable predictive management, optimize resource consumption, and enhance overall sustainability outcomes. Future research could examine long-term impacts through longitudinal designs, investigate additional mediating and moderating variables, conduct cross-country or cross-category comparisons, and explore how digital technologies further support circular economy practices in the hospitality sector.

## Data availability statement

The original contributions presented in the study are included in the article/[Supplementary material](#), further inquiries can be directed to the corresponding author.

## Ethics statement

The studies involving humans were approved by Research Ethics Committee—King Faisal University. The studies were conducted in accordance with the local legislation and institutional

requirements. The participants provided their written informed consent to participate in this study.

## Author contributions

AA: Conceptualization, Formal analysis, Methodology, Software, Supervision, Validation, Writing – original draft. HS: Conceptualization, Data curation, Funding acquisition, Methodology, Software, Visualization, Writing – review & editing.

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## Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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## Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/frsus.2025.1727952/full#supplementary-material>

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