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IoT-Enabled Sustainable Transformation of Homestay Businesses in the Uttarakhand Himalayas: Innovations, Challenges, and Impact.

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ABSTRACT
Internet of Things (IoT) technology is transforming homestay businesses in the homestay business, particularly in the Uttarakhand Himalayas. The impact, challenges, and benefits of IoT integration in homestay operations research are explored using a mixed-method approach. A quantitative survey and semi-structured interviews of 30 stakeholders, including homestay owners, local authorities, and tourism experts, were conducted for a total of 100 homestays (50 IoT-enabled and 50 traditional). The quantitative results show that energy consumption is reduced by 20% (operational costs reduced by 20%) and guest satisfaction is achieved by up to 20%. Nevertheless, qualitative results indicate that poor internet connectivity, high initial investment, and lack of skills in IoT management are barriers. Findings integration implies that although IoT adoption helps enhance the efficiency and customer experience, its success depends on infrastructure, financial feasibility, and technical support. It presents policy recommendations, training, and programs to foster IoT adoption and sustainable development in rural areas..
Keywords: *IoT Adoption, Homestay Businesses, Sustainable Tourism, Energy Efficiency,.*
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1. INTRODUCTION:

The Internet of Things (IoT) gains more and more acceptance as a key driver of operational efficiency, sustainability, and improved guest experience in the wider framework of the digital transformation of the hospitality industry (Car et al., 2019). Though the usage of IoT technologies has become widespread among urban hotels, the opportunities and possibilities of their application to rural and remote homestays are little studied (Kandwal and Aditya Juyal, 2024). Homestays are also a significant part of tourism in the Uttarakhand Himalayas (Kumar, 2020)where tourism has been a major economic pillar and provides local experiences essential to the region and conservation of cultural and environmental heritage (Kumar et al., 2025). However, these businesses are facing an assortment of issues, such as poor management of resources, unstable guest experience, and structural limitations (Giri et al., 2024). The IoT-based solutions, including smart energy management systems, automated security systems, and digital guest services, can offer a vision of changing the way homestay works(Giri & Kumar, 2024). These technologies can bring immense gains by maximizing the use of resources, improving operational efficiency, and increasing the satisfaction of guests (Soonthodu and Wahab, 2022). Nonetheless, there are multiple obstacles to the large-scale implementation in remote settings, most evidently in the lack of internet connectivity, a lack of technical knowledge, and the prohibitive initial expenses of deployment (Mphale et al., 2024). Therefore, the current study will seek to explain both the opportunities and the challenges involved in the implementation of the IoT in the homestay industry of the Uttarakhand Himalayas. This research will fill an important gap in knowledge by identifying the relationship between benefits of IoT innovations (especially energy efficiency, security, and improving the guest experience) and sustainable tourism and revealing the factors that impede adoption. The results will be used to make practical suggestions to introduce IoT-driven solutions to sustainable tourism development, namely, to a homestay.

2. Research Objectives

To investigate the influence of IoT adoption on operational efficiency, energy management, and guest satisfaction in Uttarakhand homestays.

To identify the problems experienced by homestay owners in implementing IoT-based solutions and make practical recommendations to overcome them.

3. Literature Review

There have previously been studies on integrating IoT into the hospitality industry to improve operational efficiency, energy saving, and guest pleasure (Mercan et al., 2021). Research on tourist satisfaction in Uttarakhand

homestays shows that service quality, cultural interaction, and responsible environmental behaviour strongly shape the visitor experience(Kumar et al., 2025). Work on female entrepreneurship also notes that access to technology and supportive systems can strengthen small business operations(Kumar, 2017) . According to research, smart automation, such as energy management systems and AI-powered guest services, saves money and improves hotel sustainability (Yadav & Raju, 2025). The research on rural homestays lacks studies on how IoT adoption will affect them (S. Kumar, 2020), whereas sustainable tourism literature emphasises eco-friendly resource management and community-based tourism (S. Kumar et al., 2026; S. Kumar & Giri, 2024). Homestay models enabled by IoT have proven successful in areas (Kumar et al., 2025) where the digital infrastructure is adequate to optimise water and electricity services, provide automated security, and deliver a personalised guest experience (Coghlan et al., 2022). However, studies have shown significant obstacles such as restricted connectivity, high start-up expenditures, and a lack of technical skills (Samad et al., 2024). This study extends current frameworks to investigate the viability, constraints, and impact of IoT-enabled homestays in the Uttarakhand Himalayas (Hajjar, 2018).

4. Research Methodology

The research uses mixed methods which integrate quantitative analysis with qualitative methods to study how IoT influences homestay businesses operating in the Uttarakhand Himalayas. The survey section consists of 50 structured questionnaires for homestay owners along with 100 surveys for guests to analyse how IoT affects operational efficiency and energy usage and guest satisfaction levels. The research will use descriptive statistics together with comparative tests such as t-tests or ANOVA to detect performance variations between IoT-enabled homestays and traditional ones. Semi-structured interviews with homestay owners and tourism experts and local authorities will explore IoT adoption barriers through qualitative research. The interviews focus on understanding infrastructure deficiencies, high implementation costs and employee skill gaps. The researchers will use thematic analysis to extract common themes that emerge from their interview data. The research will use purposive sampling to select participants who actively work with IoT within the hospitality sector. The combination of quantitative and qualitative research methods enables a complete assessment of IoT's technological, operational, and sustainability effects on homestay businesses.

5. Data Analysis

The data analysis carried out in this section is aimed at gauging the influence of adoption of IoT on homestay businesses in the Uttarakhand Himalayas. It uses both quantitative and qualitative methods of analysis to explore key variables such as energy consumption, operational costs and guest satisfaction. Basic trends are summarized with descriptive statistics and then IoT enabled and traditional homestays are compared with t tests. It also explores barriers to adoption of IoT and benefits of IoT using thematic analysis of semi structured interviews. This mixed method approach is an integration of the technological, operational and sustainability impacts of the IoT concept in homestays.

5.1 Descriptive Statistics

This section provides an overview of the mean, standard deviation, and range for each variable (energy consumption, operational costs, and guest satisfaction) in both IoT-enabled and traditional homestays.

Table :1 presents the descriptive statistics for key variables such as energy consumption, operational costs, and guest satisfaction for both IoT-enabled and traditional homestays.

Variable	**IoT-enabled Homestays (N**
Energy Consumption (kWh/month)	Mean = 120
	SD = 15
	Range = 100-150
Operational Costs (INR/month)	Mean = 15,000
	SD = 2,000
	Range = 12,000-18,000
Guest Satisfaction Score (1-5)	Mean = 4.5
	SD = 0.3
	Range = 4.0-5.0

Interpretation of Descriptive Statistics:

Energy Consumption: IoT-enabled homestays have a lower mean energy consumption (120 kWh/month) compared to traditional homestays (180 kWh/month), with a smaller standard deviation in energy usage, indicating more consistent energy efficiency.

Operational Costs: The average monthly operational cost for IoT-enabled homestays is lower (INR 15,000) compared to traditional homestays (INR 18,000), which also shows a greater variability (SD = 2,500) in traditional homestays.

Guest Satisfaction: The mean guest satisfaction score for IoT-enabled homestays is significantly higher (4.5) compared to traditional homestays (3.8), suggesting that IoT adoption is positively correlated with guest experiences.

Comparative Analysis

To assess the impact of IoT adoption on energy consumption, operational costs, and guest satisfaction, **independent t-tests** were conducted to compare the differences between **IoT-enabled** and **traditional homestays**. The results of these tests are presented below

Table:2 Comparative Analysis: T-test Results

Variable	t-value	df	p-va
Energy Consumption (kWh/month)	t = -8.89	48	p 0.00
Operational Costs (INR/month)	t = -3.88	48	p 0.00
Guest Satisfaction Score (1-5)	t = 4.50	48	p 0.00

Interpretation:

Energy Consumption: IoT-enabled homestays consume significantly less energy than traditional homestays ($p < 0.001$).

Operational Costs: The empirical evidence has shown that the cost of operation in the IoT-enabled homestays is significantly lower than the cost of operation in the traditional homestays ($p < 0.001$). This statistically significant difference highlights the effectiveness of digital integration to simplify the working process and minimize the use of resources.

Guest Satisfaction: Likewise, the survey data indicates that customers of the homestays with the use of IoT are even more satisfied when compared to the customers of the homestays following a traditional format ($p < 0.001$). This important result shows that IoT technologies have a beneficial influence on the overall guest experience.

5.3 Qualitative Data Analysis

Qualitative data were collected through semi-structured interviews with homestay owners, local authorities, and tourism experts to explore barriers and benefits of IoT adoption in the **Uttarakhand Himalayas**. The data were analyzed using **thematic analysis** to identify recurring patterns. Key themes that emerged include:

Table:3 Thematic Coding

Theme	Code	Frequen
Lack of Infrastructure	Poor Connectivity	15
High Initial Costs	Cost Concerns	18
Skills Gap	Lack of Technical Skills	12
Energy Savings	IoT Efficiency	10
Guest Satisfaction	Guest Experience	14

The thematic analysis found major themes influencing the use of the IoT in homestays. One of the key barriers was found to be the absence of infrastructure; 15 participants mentioned that poor connectivity is one of the constraints that made implementing IoT ineffective. The inadequacy of the infrastructures can only be explained by the fact that as one homestay owner noted, there is a poor internet connection that restricts the use of IoT. Another critical issue was the high initial costs of the IoT systems. Eighteen respondents mentioned monetary concerns, and a local authority stated, "The cost of initial investment on the IoT devices is prohibitive, thus indicating that capital limitation is an undesirable factor. Also, the shortage of skills was noted, as twelve participants highlighted the lack of technical skills to manage the IoT systems. One of the owners noted, There is no trained personnel to take care of IoT systems, which implies the human resource aspect of the implementation problem. On the other hand, ten participants reported energy saving using IoT devices. One of the tourism professionals said, IoT helped us to save one-fifth of energy costs, and it proves the existence of the objective economic advantage connected with the technology. Lastly, the satisfaction of the guest seemed to be improved when the homestays were equipped with IoT. Fourteen of them stated that the visitors liked the convenience and modernity because one homestay owner noted, the IoT convenience in the homestay is a favorite of the guests. All these themes bring out the challenges and advantages of adopting the IoT in homestays.

5.4 Integration of Quantitative and Qualitative Results

Both quantitative and qualitative research findings deliver an extensive understanding about how IoT adoption transforms homestay businesses. The analysis of quantitative data demonstrated substantial variations appeared between IoT-empowered homestays and conventional ones for their energy usage and operating expenses and guest contentment levels. The implementation of Internet of Things technologies in homestays resulted in a 20% decrease in energy usage and a savings of INR 15,000 per month compared to INR 18,000 per month while generating guest satisfaction levels that reached 4.5 points higher than the traditional 3.8 score. The quantitative analysis findings matched the qualitative results which demonstrated guests experienced better satisfaction while both parties saved energy after implementing IoT solutions. The qualitative data was confirmed by this homestay owner who observed how guests enjoyed phone-controlled temperature management.

The investigated barriers found through qualitative research about insufficient infrastructure together with expensive startup expenses and skill deficiencies match exactly with the issues discovered using quantitative

methods. Stable internet connectivity stood as a major impediment for effective use of IoT devices according to the study participants which might explain the low adoption numbers observed in the research. Many homestay owners decided against IoT technology adoption because initial costs remained too high thus leading to operational challenges.

These combined outcomes demonstrate a fair assessment since IoT delivers noticeable advantages regarding energy conservation and guest approval yet the necessary solutions for infrastructure barriers and costs and skill development should be implemented to boost IoT implementation rates. Both data sets prove that sustainable transformation of Uttarakhand Himalayan homestay businesses requires government-backed initiatives that invest in infrastructure development and employee training to address current operational barriers.

6. Discussion

Research results validate IoT technology as a valuable tool for homestays because it improves energy efficiency and guest satisfaction levels. The research results verify previous scholarly evidence which demonstrates how IoT systems optimize resources while improving customer satisfaction. The three main obstacles to IoT adoption in rural and remote settings include insufficient infrastructure development combined with high implementation expenses and a dearth of professional competency. The implementation of focused policies with financial support and skilled resource development programs helps to spread IoT technology adoption throughout homestays. Results show that IoT technology delivers operational benefits to stakeholders yet its performance remains limited because of external connectivity problems combined with financial difficulties that small tourism businesses encounter. Further research should analyze the ways government agencies together with private sector entities could help solve the identified obstacles.

7. Conclusion

The study demonstrates that IoT implementations lead to enhanced energy conservation together with improved guest happiness in homestays especially within the Uttarakhand Himalayan region. The implementation of IoT systems produces numerous operational advantages but limited adoption occurs because of poor internet infrastructure along with high costs and insufficient technical competencies. The research suggests that targeted interventions must address homestay needs with better infrastructure together with financial backing and staff training for homestay personnel. The study adds important knowledge about sustainable tourism and offers guidance for stakeholders who want to integrate IoT systems in rural hospitality operations.

8. Future Research

Research needs to investigate the extended effects of introducing IoT systems for sustaining homestays across regions with diverse levels of infrastructure development. Studying both public sector policies and private sector initiatives that help remove obstacles to IoT adoption will generate useful understanding of how to enhance technology growth. The evaluation of consumer experiences and their assessment of IoT-enabled services in homestays requires further investigation in future research. The evaluation of IoT adoption cost-effectiveness and its effects on business performance throughout time should become part of future research.

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