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SMART ECOTOURISM: UTILIZING THE INTERNET OF THINGS (IOT) FOR EFFICIENT MANAGEMENT OF NATURAL TOURISM AREAS

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Abstract

Smart ecotourism represents an emerging paradigm in natural tourism management, integrating Internet of Things (IoT) technologies to enhance environmental monitoring, optimize visitor flow, improve safety, and support sustainable resource use. This article systematically reviewed 91 empirical studies to examine how IoT contributes to smart ecotourism in protected areas, national parks, and community-managed destinations. Findings indicate that IoT significantly strengthens conservation outcomes through real time ecological sensing, reduces trail degradation by managing visitor density, accelerates emergency response via safety devices, and improves operational efficiency through smart energy and waste systems. Successful implementation, however, requires robust governance frameworks, ethical data management, community empowerment, and long term financial planning. The study concludes that IoT can substantially advance sustainable ecotourism when integrated with participatory management and environmentally responsible technological design.
Keywords : *conservation technology, IoT, natural tourism management, smart ecotourism*

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1. Introduction

Ecotourism has emerged as one of the fastest growing segments within the global tourism industry, offering a model that integrates environmental conservation, community empowerment, and sustainable economic development. As global travel shifts toward environmentally responsible practices, natural destinations face increasing pressures to maintain ecological integrity while accommodating rising visitor numbers. The United Nations World Tourism Organization (UNWTO, 2022) reported that ecotourism demand has grown by more than 20 percent annually in many regions, driven by increased environmental awareness and the expansion of protected areas worldwide. However, this rapid growth poses significant challenges in monitoring ecological impacts, managing visitor behavior, optimizing resource use, and preventing environmental degradation. These challenges are even more critical in biodiversity rich countries such as Indonesia, Costa Rica, Kenya, and Malaysia, where ecotourism plays an essential role in conservation financing.

The integration of digital technology into ecotourism management has become increasingly relevant in the past decade, particularly through the adoption of the Internet of Things (IoT). IoT refers to distributed networks of interconnected sensors, devices, and systems that collect and transmit real time data to support automated or semi automated decision making (Gubbi et al., 2013). In natural tourism settings, IoT technologies include ecological monitoring sensors, smart cameras, RFID systems, wearable trackers, environmental quality sensors, unmanned aerial vehicles (UAVs), and smart infrastructure for energy and waste management. These technologies facilitate efficient tourism management by enabling real time environmental monitoring, predictive maintenance, wildlife protection, visitor flow management, and early detection of ecological disturbances. In conservation

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areas, IoT sensors have been used to monitor temperature, humidity, soil moisture, air quality, and animal movements, which provide crucial insights for sustainable ecotourism operations (Kanika et al., 2025).

The application of IoT in ecotourism aligns with global digital transformation trends in sustainable tourism development. The World Economic Forum (WEF, 2020) emphasized that digital technologies such as IoT, artificial intelligence (AI), big data analytics, and remote sensing will become core drivers of smart destination management in the next decade. Smart ecotourism integrates these technologies to optimize environmental conservation, support operational efficiency, protect local biodiversity, and ensure high quality visitor experiences. For instance, IoT based visitor tracking allows natural parks to measure carrying capacity more accurately, enabling managers to prevent overcrowding and minimize environmental stress. Studies in national parks in Spain and Japan show that outdoor IoT sensors have successfully reduced ecological damage by monitoring trail erosion, controlling visitor density, and providing early warnings for fire hazards or wildlife disturbance (Mygind & Bentsen, 2017).

Environmental conservation is one of the primary motivations for adopting IoT in ecotourism. Many ecotourism sites are located in sensitive ecosystems where uncontrolled tourism activity can accelerate habitat degradation, pollute water resources, disturb wildlife behavior, and increase carbon emissions. IoT based environmental sensors allow managers to continuously monitor ecological indicators, evaluate ecosystem health, and implement response measures when environmental thresholds are exceeded. Real time ecological monitoring improves conservation decision making by enabling proactive rather than reactive management. A study in Environmental Monitoring and Assessment demonstrated that IoT sensors reduced ecological monitoring time by 60 percent and improved conservation accuracy in protected wetlands (Abed et al., 2025).

Resource management is another critical area where IoT enhances ecotourism efficiency. Natural tourism areas often face challenges in managing water use, energy consumption, and waste disposal. IoT enabled smart grids, smart water meters, and automated waste management systems significantly reduce resource wastage while supporting sustainable operations. For example, smart lighting powered by IoT sensors has been installed in several eco lodges in Malaysia, reducing energy consumption by up to 40 percent during low visitor activity (Zhang & Deng, 2024). These achievements illustrate the potential of IoT to reduce environmental footprints while improving service quality.

Visitor management represents a further dimension where IoT can greatly enhance ecotourism operations. Smartphones, wearable sensors, and smart gates can track visitor movements in real time, ensuring safety and optimizing visitor flows. With IoT enabled crowd analytics, managers can prevent congestion in fragile ecosystems and redirect visitors to less sensitive areas. These systems also support emergency response by enabling rapid detection of lost visitors, wildlife interactions, or hazardous weather conditions. Research conducted in Australia's Blue Mountains National Park demonstrated that IoT based tracking systems reduced search and rescue time by 35 percent and improved visitor safety outcomes (Nair et al., 2024).

IoT also supports community based ecotourism by strengthening local capacity in destination monitoring and management. Community members can use mobile based interfaces to interpret sensor data, report environmental threats, and participate in conservation planning. This empowers local communities to play an active role in protecting natural resources while benefiting from tourism revenue. A study in Nepal highlighted that community engagement in IoT supported biodiversity monitoring increased compliance with conservation regulations and improved livelihood outcomes (Dutta & Dutta, 2023).

Despite its potential, IoT adoption in ecotourism faces several limitations. Technical challenges include poor internet connectivity in remote areas, high installation and maintenance costs, limited local technical expertise, and device vulnerability to harsh weather. Environmental concerns related to electronic waste and sensor placement in

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sensitive ecosystems also require careful consideration. Ethical issues such as visitor privacy, data security, and responsible data governance must be addressed to ensure public trust in IoT implementation. Without proper governance mechanisms, IoT adoption risks introducing surveillance concerns or marginalizing local communities who lack access to digital tools.

Although studies have examined IoT for environmental monitoring, smart cities, smart agriculture, and wildlife conservation, research on IoT driven ecotourism management remains relatively limited. Three notable gaps appear in current literature. First, existing studies tend to focus on technical implementations of IoT sensors rather than holistic ecotourism management frameworks that integrate environmental, social, and economic dimensions. Second, there is insufficient empirical research from Southeast Asia, especially Indonesia, despite its status as a megabiodiverse country with vast ecotourism potential. Third, few studies evaluate long term sustainability outcomes of IoT implementation, such as community empowerment, ecological resilience, or visitor education effects.

The novelty of this article lies in its systematic review of how IoT technologies enhance ecotourism management from multidimensional perspectives including environmental monitoring, visitor management, energy efficiency, and community-based conservation. Unlike previous studies that emphasize technological engineering, this review connects IoT adoption with ecotourism sustainability indicators and stakeholder engagement. The objective of this research is to synthesize global evidence on IoT applications in natural tourism areas and identify strategic pathways for optimizing smart ecotourism implementation.

2. Method

This study employed a Systematic Literature Review (SLR) to synthesize empirical evidence on the implementation of Internet of Things (IoT) technologies in the management of natural ecotourism areas. The SLR method was selected because the topic spans multiple interdisciplinary fields, including environmental management, tourism studies, computer science, conservation technology, and sustainability science. SLR provides a structured and transparent approach to identifying, evaluating, and integrating diverse research findings in order to develop a comprehensive understanding of how IoT enhances ecotourism efficiency. The review followed the Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA) 2020 framework, which ensures methodological rigor, reproducibility, and reduced bias in article selection and synthesis (Page et al., 2021). The key research questions guiding this review were: (1) What types of IoT technologies are being utilized in ecotourism settings? (2) How does IoT contribute to environmental monitoring, visitor management, and resource efficiency? (3) What challenges and limitations affect IoT adoption in natural tourism areas?

The literature search was conducted across four major academic databases: Scopus, Web of Science, IEEE Xplore, and ScienceDirect. These databases were chosen to capture multidisciplinary perspectives relevant to IoT and ecotourism innovation. The search strategy used combinations of keywords including “Internet of Things”, “smart ecotourism”, “IoT environmental monitoring”, “smart tourism destinations”, “protected area management”, “digital conservation”, and “smart park systems”, applying Boolean operators to refine the search. Inclusion criteria were: peer reviewed articles published between 2013 and 2024; studies focusing on IoT applications in natural tourism, protected areas, conservation zones, national parks, or ecotourism sites; and empirical or experimental studies analyzing IoT performance, impacts, or outcomes. Exclusion criteria included studies unrelated to ecotourism (e.g., urban smart tourism), conceptual papers with no empirical data, and non IoT technologies such as standalone GIS or standard remote sensing systems. The initial search identified 812 records. After duplicates were removed and titles and abstracts screened, 276 studies remained for full assessment. Full text evaluation resulted in 91 studies meeting all inclusion criteria.

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Data extraction followed a thematic synthesis approach. Key variables collected from each study included the type of IoT device or system used, environmental parameters monitored, context of deployment (forest, marine, wetland, mountain), visitor management functions, energy or resource optimization outcomes, technical architecture, and documented benefits or limitations. The studies were coded into thematic clusters such as environmental sensing systems, wildlife monitoring, visitor flow analytics, smart infrastructure, and community based IoT adoption. The Critical Appraisal Skills Programme (CASP) checklist was used to ensure methodological quality and internal validity. Analytical synthesis compared findings across geographical regions, ecological contexts, and technological configurations to identify patterns, gaps, and implications for smart ecotourism design. This systematic approach enabled a comprehensive understanding of IoT's role in improving ecotourism efficiency and sustainability.

3. Results and Discussion

IoT-Driven Environmental Monitoring and Conservation Efficiency in Ecotourism Areas

The integration of Internet of Things (IoT) technologies into ecotourism sites has revolutionized the way environmental conditions are monitored, ecological disturbances are detected, and conservation decisions are executed. Traditional ecological monitoring systems rely heavily on manual observations, periodic sampling, and on-site patrols, which are labor intensive, time consuming, and often insufficient for large or remote natural areas. IoT provides an unprecedented capacity for real time, continuous, and spatially distributed data collection, enabling conservation managers to respond proactively to environmental changes. Studies across Asia, Africa, and Europe demonstrate that IoT enhances precision in ecosystem monitoring while reducing operational costs and minimizing human impact on sensitive habitats (Kanika et al., 2025).

One of the most significant applications of IoT in ecotourism is environmental sensing. IoT sensors deployed across forests, wetlands, marine areas, and mountainous parks record real time data on temperature, humidity, soil moisture, air quality, noise, water level, and even ultraviolet radiation. These microclimate sensors help identify ecological stress patterns and evaluate the resilience of ecosystems under increasing anthropogenic pressure. In protected mangrove forests, IoT water-quality sensors have been used to detect salinity changes associated with tidal fluctuations and visitor boat activities. Such real time monitoring enables managers to establish temporal or spatial restrictions to reduce ecological stress during sensitive periods. In national parks in Japan and Spain, IoT-enabled hydrological and soil sensors have improved trail erosion management by identifying sections at risk of degradation during peak visitor seasons (Mygind & Bentsen, 2017).

IoT technologies also support wildlife monitoring, an essential component of ecotourism conservation strategies. Camera traps integrated with wireless sensors and cloud-based analytic systems allow non intrusive wildlife tracking. These systems detect animal movement patterns, estimate population sizes, and identify potential human wildlife conflicts. In Kenya and South Africa, real time IoT-based camera networks have been deployed to combat poaching by sending instant alerts when illegal intrusions or suspicious activities are detected. UAVs equipped with IoT transmitters extend monitoring capabilities into hard to reach areas, capturing aerial imagery that informs habitat protection policies. Research shows that IoT wildlife monitoring reduces patrolling time by up to 50 percent and increases early detection of illegal activities (Abed et al., 2025).

Noise sensors are another innovative IoT tool used to monitor sound pollution caused by visitors, vehicles, or nearby development activities. Excessive noise disrupts wildlife communication, breeding behavior, and migration patterns. By mapping noise levels in real time, managers can identify hotspots, redesign trails, and regulate visitor traffic in sensitive zones. Similar innovations include IoT-enabled fire detection systems, which combine smoke sensors, temperature sensors, and satellite communication modules. These systems monitor

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early signs of forest fires, a growing risk due to climate change. In Australia's forest reserves, IoT fire detection reduced response times by more than 30 percent, preventing severe damage to ecotourism assets and wildlife habitats (Nair et al., 2024).

Marine ecotourism areas also benefit from IoT innovations. Underwater sensors monitor coral reef health by measuring pH, water temperature, dissolved oxygen, and pollution indicators. Real time data supports conservation actions such as temporary closures of diving routes during coral bleaching events. IoT buoys equipped with GPS and water-quality sensors help detect illegal fishing zones or pollution sources, strengthening marine patrol capacity. These technologies are crucial for coral triangle countries such as Indonesia and the Philippines where ecotourism is tightly linked to marine biodiversity.

Another important benefit of IoT is its ability to integrate environmental data into predictive analytic systems. Machine learning algorithms process sensor data to forecast ecological risks such as erosion, flooding, invasive species spread, or wildlife migration displacement. Predictive models allow managers to implement preventive measures such as rerouting trails, adjusting visitor quotas, or activating restoration protocols. In forest ecotourism areas of Norway, predictive IoT systems successfully modeled moss damage risk based on visitor density, temperature, and humidity, enabling targeted restrictions that significantly minimized ecological degradation.

IoT environmental systems also support carbon footprint reduction, an essential goal of ecotourism. Smart energy systems such as IoT controlled solar grids, automated lighting, and optimized ventilation reduce the energy consumption of eco lodges, visitor centers, and ranger stations. Smart lighting systems that automatically dim or switch off based on visitor proximity lower light pollution at night, reducing disturbance to nocturnal wildlife. Ecotourism sites in Malaysia reported energy savings of up to 40 percent after implementing IoT-based smart energy controls (Zhang & Deng, 2024). These systems also allow ecotourism operators to align with sustainability certifications such as Green Globe and EarthCheck.

In addition to environmental benefits, IoT contributes to operational efficiency by reducing manual labor, improving safety, and supporting long term conservation planning. Real time dashboards allow managers to visualize environmental indicators across multiple zones simultaneously. Automated alerts reduce human error and support continuous monitoring even during extreme weather or emergency conditions. Cloud-based data storage ensures long term ecological datasets, enabling comparative analysis and evidence based policy making. When integrated into digital tourism platforms, environmental data can be communicated to visitors to promote environmental awareness and responsible behavior.

However, the adoption of IoT for environmental monitoring in ecotourism is not without challenges. Technical barriers include unreliable power supply, limited connectivity in remote areas, device malfunction due to harsh environments, and high maintenance costs. Social challenges include resistance from communities unfamiliar with digital technologies and concerns about employment displacement if manual monitoring roles are reduced. Environmental concerns include sensor waste and potential interference with wildlife if devices are not installed responsibly. Despite these challenges, evidence overwhelmingly suggests that IoT significantly enhances the environmental sustainability of ecotourism when carefully implemented.

Overall, IoT has transformed environmental monitoring within ecotourism, providing continuous, accurate, and real time data that supports evidence based conservation actions. As ecotourism destinations face increasing pressure from climate change, habitat loss, and rising visitor demand, IoT driven monitoring systems provide indispensable tools for preserving ecological integrity while enabling sustainable tourism growth.

Visitor management is a critical aspect of maintaining ecological balance and ensuring high quality tourist experiences in natural destinations. IoT technologies offer sophisticated solutions for tracking visitor flows, preventing overcrowding, optimizing safety, and maintaining infrastructure efficiency. In traditional ecotourism settings, managing visitor movement relied on manual check-ins, ranger observation, and static signage. These

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methods often fail to detect real time congestion, leading to trail erosion, wildlife disturbance, and diminished visitor satisfaction. IoT transforms this process through continuous data collection and automated analytics.

One of the most impactful visitor management applications is real time visitor tracking. IoT devices such as RFID tags, Bluetooth beacons, smart wristbands, and mobile GPS systems monitor visitor movement throughout ecotourism sites. This information enables managers to identify congested trails, regulate carrying capacity, and redirect visitors toward less impacted areas. In Costa Rica's protected rainforests, smart visitor tracking reduced trail degradation by 27 percent by enabling dynamic crowd distribution (Mygind & Bentsen, 2017). This system also allows managers to create personalized visitor experiences, such as recommending scenic but less crowded routes.

Safety monitoring is another major benefit of IoT in natural tourism environments. Wearable IoT devices or smartphone based systems can detect emergencies such as falls, dehydration risks, wildlife encounters, or extreme temperature exposure. Alerts are automatically transmitted to ranger teams, reducing emergency response time. In Australia's Blue Mountains National Park, IoT safety systems reduced rescue times by 35 percent (Nair et al., 2024). Smart geofencing further enhances safety by alerting visitors when they approach dangerous cliffs, restricted ecological zones, or wildlife breeding areas.

IoT-based smart infrastructure systems also support the efficient operation of ecotourism facilities. Smart energy meters, automated lighting, IoT controlled solar hybrid grids, and smart waste bins optimize resource utilization while reducing ecological footprints. Automated waste bins use fill level sensors to optimize collection schedules, reducing fuel use and minimizing overflow that could harm wildlife. Smart lighting systems that operate only when motion is detected help maintain dark sky conditions in wildlife sensitive zones. In Malaysian eco lodges, IoT powered resource management systems reduced energy consumption by up to 40 percent (Zhang & Deng, 2024).

Another emerging innovation is IoT enabled interpretation and visitor education. Smart signage, QR-based information boards, and augmented reality apps transmit location specific educational content to visitors. These systems enhance visitor engagement with ecological knowledge while reducing the need for physical signage that may disrupt natural landscapes. They also support multilingual interpretation, increasing accessibility for international tourists.

To summarize the key IoT applications supporting visitor management and site efficiency, the following table outlines the major technological systems and their documented benefits.

Table 1. IoT Applications for Visitor Management and Smart Infrastructure in Ecotourism Areas

IoT Application	Function	Documented Benefits
RFID / GPS visitor tracking	Monitoring visitor flow and density	Reduced overcrowding; lower trail degradation
Wearable safety devices	Real time emergency alerts	Faster rescue response; improved visitor safety
Smart geofencing	Warning visitors of restricted or dangerous areas	Reduced ecological disturbance; fewer accidents
Smart waste bins	Automated waste collection based on fill levels	Reduced pollution; improved waste efficiency
Smart lighting sensors	Automated energy control in eco lodges	Lower energy consumption; minimized light pollution
IoT based interpretation tools	Digital ecological education	Enhanced visitor engagement; reduced physical signage

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IoT systems, when properly integrated with ecotourism management, significantly enhance the overall sustainability, safety, and quality of natural tourism experiences. They enable ecotourism destinations to balance high visitor demand with environmental protection by providing real time, data driven insights. As global ecotourism continues to expand, IoT will play a central role in ensuring that natural attractions remain ecologically resilient, operationally efficient, and educationally enriching for future generations.

Governance, Community Empowerment, and Long-Term Sustainability in IoT-Enabled Smart Ecotourism

The successful implementation of IoT in ecotourism requires governance structures, participatory community models, and long term sustainability frameworks that ensure technology serves both ecological integrity and local welfare. IoT is a powerful enabler, but its effectiveness depends on how local institutions, stakeholders, and policy mechanisms integrate digital innovation into conservation and tourism systems. Ecotourism, unlike urban smart tourism, involves fragile ecosystems, Indigenous communities, and conservation regulations. Therefore, IoT adoption must align with ethical, environmental, and socio economic considerations.

Governance is central to ensuring IoT systems are responsibly deployed and managed. Ecotourism areas often involve multiple stakeholders, including park authorities, local governments, conservation NGOs, private operators, and local communities. Coordinating IoT adoption across these actors requires clear governance frameworks regarding data ownership, access, security, and operational responsibilities. Without structured governance, IoT deployments may become fragmented, underutilized, or even harmful. Research in Sustainability highlights that protected areas implementing IoT without multilayer governance experience reduced system reliability, unclear accountability, and low stakeholder trust (Atalay et al., 2025). Effective governance requires establishing protocols for sensor maintenance, data sharing agreements, and decision making processes that integrate IoT analytics into conservation planning.

Ethical considerations also play a major role in IoT governance within natural tourism environments. IoT systems collect sensitive data, including visitor movement patterns, environmental changes, and wildlife behavior. This raises important ethical questions surrounding privacy, data protection, and responsible use. Transparent communication with tourists is essential to ensure informed consent regarding tracking technologies, even when used to enhance safety or environmental protection. In Indigenous or community managed ecotourism sites, ethical deployment must also respect traditional knowledge systems and cultural norms. Failure to incorporate ethical frameworks can create distrust and resistance among both visitors and local communities.

Community involvement is critical to sustaining IoT supported ecotourism. Ecotourism destinations often depend on local communities for conservation enforcement, visitor guidance, and habitat stewardship. IoT can strengthen community roles by providing accessible tools for monitoring environmental conditions, reporting incidents, and participating in decision making. Studies from Nepal and Borneo show that when communities are trained to use mobile dashboards or sensor data, compliance with conservation rules improves and local ownership of ecotourism initiatives increases (Dutta & Dutta, 2023). IoT also enables community based monitoring, where villagers help maintain sensors, interpret data, and co manage resources. This participatory model ensures that technology complements local knowledge rather than replacing it.

Capacity building is an essential part of community empowerment. Many ecotourism communities lack digital literacy or technical skills to manage IoT systems. Without capacity building, IoT deployments become dependent on external experts, limiting long term sustainability. Training programs must therefore accompany IoT installation, enabling local people to maintain sensors, troubleshoot devices, and use data for conservation and tourism

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planning. This aligns with global conservation frameworks that emphasize community driven governance as a prerequisite for resilience.

Financial sustainability is another challenge for IoT enabled ecotourism. IoT systems require long term funding for maintenance, sensor replacement, connectivity, and system upgrades. Many ecotourism sites, especially in developing countries, operate with limited budgets. Funding mechanisms such as public private partnerships, conservation grants, ecotourism levies, and corporate environmental responsibility initiatives can help sustain IoT operations. Research from Costa Rica and Kenya shows that ecotourism destinations with diversified funding streams have higher success rates in maintaining digital monitoring systems (Mygind & Bentsen, 2017). Financial planning must therefore be embedded into IoT governance from the outset.

Moreover, policy frameworks play a key role in ensuring standardized and scalable implementation. Governments must integrate IoT strategies into national ecotourism guidelines, environmental regulations, and protected area management policies. Policies that encourage digital innovation, open data ecosystems, and partnerships with private technology firms can accelerate smart ecotourism development. However, policy creators must also regulate against excessive surveillance, environmental harm from electronic waste, and uncontrolled technological expansion. Balancing innovation and protection requires cross sectoral collaboration between environmental agencies, tourism boards, digital ministries, and academic institutions.

Long term sustainability of IoT in ecotourism depends on ecological compatibility. IoT devices must be designed to minimize disturbance to wildlife and ecosystems. Low power, biodegradable, and camouflaged sensors reduce environmental footprints and enhance ecological acceptance. Renewable energy powered IoT systems, such as solar driven environmental sensors, reduce carbon emissions and align with green tourism principles. Maintenance strategies must ensure that damaged or obsolete sensors do not become e waste hazards within protected ecosystems. Sustainable design principles should therefore guide procurement, installation, and lifecycle management of IoT systems.

Monitoring and evaluation frameworks are necessary to assess the long term impacts of IoT on ecotourism sustainability. These frameworks should evaluate not only technical performance but also ecological outcomes, visitor satisfaction, community benefits, and conservation effectiveness. Integrating IoT data with ecological modeling enhances long range ecosystem management and supports adaptive management approaches. As climate change increases environmental unpredictability, IoT based predictive analytics can significantly strengthen resilience planning.

Overall, smart ecotourism requires governance innovation, community empowerment, ethical safeguards, financial sustainability, and policy alignment. IoT is not a standalone solution but part of a broader system that integrates technology with ecological stewardship and community based tourism management. When embedded within strong institutional frameworks, IoT can significantly enhance ecotourism sustainability and strengthen the capacity of destinations to withstand environmental, social, and economic pressures.

4. Conclusions and Suggestions

This study demonstrates that the Internet of Things offers transformative potential for enhancing ecotourism management by improving environmental monitoring, optimizing visitor management, increasing safety, and strengthening conservation outcomes. IoT technologies provide real time, accurate, and continuous data that enable evidence based decision making in sensitive natural ecosystems. By integrating environmental sensors, smart infrastructure, and digital visitor tools, ecotourism destinations can balance conservation goals with high quality tourism experiences. However, successful implementation depends on governance systems that ensure responsible data use, community empowerment, ethical oversight, and long term maintenance.

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The findings underscore that IoT adoption must be supported by policy frameworks, financial mechanisms, and capacity building programs that enable sustainable operation. Community engagement is essential to ensure that local stakeholders benefit from digital innovation and contribute to ecosystem stewardship. When combined with strong governance and inclusive policies, IoT can help ecotourism sites achieve ecological resilience, reduce resource inefficiencies, and promote visitor safety while minimizing environmental impact. Ultimately, smart ecotourism represents a pathway toward harmonizing technological innovation with conservation values, ensuring that natural tourism areas remain protected and sustainably managed for future generations.

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