African Journal of Hospitality, Tourism and Leisure
ISSN: 2223-814X
2025, Vol. 14 No. 5 pp. 1183-1190

Smart Environmental Accounting: The Role of Digital Tools in Sustainable Hotel Management in an Emerging Economy

Celani John NYIDE
Department of Finance and Information Management, Durban University of Technology, Email: nyidec@dut.ac.za

Abstract

This study investigates how South African hotels incorporate smart technologies into Environmental Management Accounting (EMA) practices to enhance environmental accountability and sustainable management. Owing to the high consumption of energy, water, and other natural resources, the hospitality industry is under increasing pressure to reduce its environmental footprints. The EMA offers a mechanism for hotels to embed sustainability into their decision making. However, the integration of EMA with digital technologies remains underexplored in South Africa, an emerging economy. A qualitative multiple-case study design was employed, involving 27 semi-structured interviews with key hotel stakeholders across 3–5-star hotels in the KwaZulu-Natal and Gauteng provinces. Thematic analysis guided the identification of patterns and themes. The findings revealed that digital tools, such as Internet of Things (IoT) sensors, building management systems, and real-time dashboards, are increasingly being used to monitor environmental performance. When integrated with operational and financial workflows, these tools enhance decision making, reduce costs, and promote a sustainable culture. However, limited interoperability with legacy systems, high implementation costs, and insufficient technical expertise have been identified as the key barriers. Smart technologies have the potential to transform the EMA in the hotel sector, but their success hinges on organisational alignment, skill development, and supportive governance structures.

Keywords: Environmental management accounting; smart technologies; digital transformation; hospitality sector; sustainability reporting

How to cite this article: Nyide, C.J. (2025). Smart Environmental Accounting: The Role of Digital Tools in Sustainable Hotel Management in an Emerging Economy. African Journal of Hospitality, Tourism and Leisure, 14(5):1183-1190. DOI: https://doi.org/10.46222/ajhtl.19770720.709

Introduction

The global push towards sustainability has intensified the need for businesses to account not only for their financial performance but also for their environmental impact. The hospitality industry and hotels are resource-intensive operations that contribute significantly to environmental degradation through high energy and water consumption, food waste, and carbon emissions (Juvan et al., 2023; Ndzungu et al., 2024). In South Africa, an emerging economy in which the tourism sector is a key economic driver (McCarroll et al., 2024) and environmental challenges such as energy insecurity and water scarcity, the need for sustainable hotel management is both urgent and strategic (Dube et al., 2024; Juvan et al., 2023; Ledikwe, 2021). Environmental Management Accounting (EMA) has emerged as a valuable tool for capturing, analysing, and integrating environmental cost information into internal decision-making processes (Burritt et al., 2023; Zatini et al., 2025). Unlike traditional accounting systems that focus primarily on financial transactions, EMA encompasses both physical and monetary environmental data, enabling organisations to make informed choices that align operational efficiency with ecological stewardship (Liem & Hien, 2024; Zafar et al., 2024). However, EMA adoption in the South African hospitality sector remains limited and often fragmented (Nyide, 2019), largely because of challenges in data collection, lack of integration with core business systems, and skills gap in sustainability accounting (Nyahuna, 2022). Digital transformation offers a compelling solution for these limitations. Industry 4.0, such as the Internet of Things (IoT), Building Management Systems (BMS), data analytics platforms, and cloud computing, have enabled the real-time tracking of environmental resource usage and performance metrics (Bello, 2023; Kalyanam, 2021; Lee et al., 2021). These smart technologies support the collection of granular data, improve the traceability of resource flows, and enhance the ability of decision-makers to dynamically monitor environmental performance. When effectively integrated into EMA systems, these tools can help hotels not only reduce environmental impacts but also improve cost efficiency and regulatory compliance (Nyide, 2019; Rasit et al., 2022; Zafar et al., 2024). Despite the growing availability and application of such technologies globally, empirical evidence on their integration into EMA frameworks in the South African context is scarce (Fatoki, 2021; Mankgele et al., 2023; Stevens-King & Bello, 2023). Most EMA initiatives in local hotels remain operationally focused and lack strategic alignment with organisational goals or national sustainability frameworks such as the National Minimum Standard for Responsible Tourism and Sustainable Development Goals (SDGs) (Kagisho & Sao Joao, 2025; Velaoras et al., 2025). Moreover, the absence of a consolidated framework that incorporates smart technologies into EMA practices presents a critical gap in both practice and scholarship.

This study responds to this gap by exploring how South African hotels incorporate digital tools to enhance EMA practices and proposes a smart EMA model suited to the local hospitality sector. Drawing on qualitative data from selected 3–5-star hotels in the KwaZulu-Natal and Gauteng provinces, this study examines the extent of digital adoption, effectiveness of current practices, and barriers that hinder the full integration of smart technologies into environmental accounting. This study contributes to the theoretical advancement of EMA in the digital era and offers practical insights to hotel managers, sustainability practitioners, and policymakers. The remainder of this paper is organised as follows. The next section presents a review of the relevant literature on EMA and digital technologies in the hospitality sector. This is followed by the research methodology, key findings, discussion, and proposed Smart EMA Model. The paper concludes with policy and managerial implications as well as recommendations for future research.

Literature review

EMA is broadly defined as the identification, collection, analysis, and use of physical and monetary environmental information to support internal decision-making (Burritt et al., 2002). The EMA provides insights into the environmental costs associated with organisational activities and enables managers to improve efficiency, reduce environmental impacts, and align with regulatory or voluntary environmental standards (Abdelhalim et al., 2023; Burritt et al., 2023; Gunarathne et al., 2023). Unlike traditional accounting systems that prioritise financial reporting, the EMA incorporates both material flow data and environmental cost structures, offering a more integrated view of sustainability performance (Mukwarami & Van Der Poll, 2024). In the hospitality industry, EMA plays a pivotal role in enhancing operational sustainability (Campos et al., 2022). Hotels consume vast quantities of electricity, water, and raw materials, and generate significant waste (Juvan et al., 2023). EMA tools such as Material Flow Cost Accounting (MFCA), Environmental Cost Accounting (ECA), and Lifecycle Costing (LCC) help hotels understand resource usage patterns, identify inefficiencies, and develop strategies for waste minimisation and cost savings (Mukwarami et al., 2023; Nyahuna, 2022; Nyide, 2019). However, effective implementation of EMA relies heavily on timely, accurate, and comprehensive data. This is a challenge for many organisations, particularly in developing countries, such as South Africa (Zafar et al., 2024; Zatini et al., 2025).

Digital transformation refers to the strategic adoption of digital technologies to fundamentally alter business processes, organisational structures, and value-creation mechanisms (Kraus et al., 2022). In environmental accounting, digital transformation introduces the possibility of real-time environmental data tracking, predictive analytics, and integrated performance dashboards (Adelakun et al., 2024). Technologies such as IoT, smart sensors, cloud computing, and Artificial Intelligence (AI) can enhance EMA by automating the collection, analysis, and reporting of environmental data (Adelakun et al., 2024). In South Africa, the uptake of these technologies has been uneven. While some high-end hotel groups have invested in Building Management Systems (BMS) and energy monitoring platforms, such as Group Energy Profile Analysis (GEPA) (Kalyanam, 2021; Nyide, 2019), these tools are often used in silos without integration into broader accounting or sustainability frameworks. Consequently, environmental data are underutilised, and the potential for strategic decision-making is limited.

Existing research on sustainability practices in South African hotels has primarily focused on energy efficiency, water conservation, and waste reduction (Mbasera et al., 2016; Mkwizu, 2025). Studies have highlighted a growing awareness of environmental responsibility among hotel operators, driven by operational cost pressures and reputational considerations. However, integration of EMA into routine management practices remains limited. A study by Nyahuna (2022) found that most hotels lacked structured systems for tracking environmental costs and that sustainability reporting was largely voluntary, ad hoc, and descriptive rather than data-driven. Similarly, Fatoki (2021) noted that small and medium-sized hotels often face resource and knowledge constraints that prevent them from adopting advanced EMA tools. Even among larger hotel chains, environmental data are seldom linked to financial systems or investment decision-making, limiting the strategic value of sustainability initiatives (Stevens-King & Bello, 2023). This situation is compounded by the lack of regulatory enforcement and standardised environmental reporting frameworks for the hospitality sector (Adelakun et al., 2024). Although the South African Department of Tourism has issued guidelines such as the National Minimum Standard for Responsible Tourism (2018), these remain non-binding, and there is no mandate for the integration of digital tools in environmental management or accounting (Ramaano, 2024).

The integration of smart technologies into EMA processes presents substantial benefits for hotels seeking to improve both their operational efficiency and environmental sustainability. One of the most significant advantages is the potential to enhance resource efficiency (Abdelhalim et al., 2023). Real-time monitoring systems allow hotel operators to continuously track energy and water consumption, identify inefficiencies, and promptly respond to anomalies (Nyahuna, 2022). This contributes not only to reduced environmental impact, but also to lower operational costs. Another key benefit is improved transparency and accountability (Gunarathne et al., 2023; Zafar et al., 2024). Automated data collection and reporting systems minimise human error and enable more accurate environmental performance assessments (Mankgele et al., 2023). Such systems also facilitate auditing and compliance with environmental regulations and certification schemes (Abdelhalim et al., 2023; Adelakun et al., 2024). Furthermore, smart EMA supports strategic decision-making by providing hotel managers with timely, data-driven insights that inform capital investments, procurement policies, and operational planning (Mankgele et al., 2023). Despite these advantages, the adoption of smart EMA systems in the hospitality sector is not a significant challenge. High initial investment costs remain a major barrier (Zatini et al., 2025), especially for small and medium-sized hotels that operate on tight budgets (Stevens-King & Bello, 2023). The acquisition of sensors, software, and data infrastructure requires substantial capital outlay (Kalyanam, 2021), often without immediate returns, making it difficult for management to justify expenditures (Adelakun et al., 2024). Technical expertise was another limiting factor. The implementation and maintenance of digital EMA tools requires skilled personnel proficient in both environmental accounting and digital technologies. In many South African hotels, this expertise is either absent or insufficiently developed (Fatoki, 2021; Nyahuna, 2022). Moreover, data generated by smart systems are frequently underutilised owing to the lack of integration with existing accounting platforms (Mkwizu, 2025). In many cases, environmental data are captured but not linked to financial or managerial reporting structures, resulting in missed opportunities for holistic sustainability analysis (Kagisho & Sao Joao, 2025).

Theoretical framework: Socio-technical systems theory

To critically understand the complexities associated with the integration of smart technologies into EMA practices within the hotel sector, this study adopts the Socio-Technical Systems (STS) theory as its guiding analytical lens. Rooted in systems thinking, STS theory posits that organisational effectiveness depends on the joint optimisation of both technical and social subsystems (Baxter & Sommerville, 2011). The technical subsystem encompasses the tools, technologies, procedures, and infrastructure that support operational functions (Thomas, 2024). In contrast, the social subsystem includes individuals, teams, leadership structures, norms, and organisational culture (Dell et al., 2021). Applying STS theory to the context of smart EMA provides a holistic framework for analysing the multifaceted nature of digital transformation (Zhang et al., 2023). From this perspective, smart EMA is not merely a technical upgrade but a socio-technical evolution that reshapes how hotels collect, interpret, and act on environmental data. For example, the deployment of IoT-enabled sensors, BMS, and cloud analytics platforms constitutes the technical components of the system (Dell et al., 2021; Ranasinghe et al., 2021). However, the successful application of these tools depends heavily on the social component: how hotel staff are trained to use the technology, how managers interpret the data, and how these insights inform the decision-making processes (Thomas, 2024). This framework is particularly relevant in the South African hotel sector. Hotels that attempt to implement EMA technologies without fostering internal understanding or commitment often experience low utilisation (Kagisho & Sao Joao, 2025) and minimal strategic impacts (Mankgele et al., 2023). Conversely, organisations that invest in change management, capacity building, and cross-functional collaboration are more likely to achieve sustainable digital integration (Gunarathne et al., 2023). Thus, STS theory provides both a diagnostic and prescriptive lens for understanding and improving the implementation of smart EMA systems in complex organisational settings.

Methods

This study adopts a qualitative multiple-case study design to explore the integration of smart technologies into EMA practices in the South African hotel sector. A case study approach is particularly suited to understanding complex organisational phenomena within real-life contexts (Paparini et al., 2021). Given the exploratory nature of the research and the need to investigate digital and accounting practices in depth, the multiple-case design enabled a cross-case analysis while preserving the contextual richness of each study unit (Annamalah et al., 2025). The selected cases included five hotels operating in urban tourism hubs, three in KwaZulu-Natal, and two in Gauteng, ranging from independently owned boutique hotels to branches of international chains. Hotels were selected based on their star ratings (3–5 stars), visible engagement with sustainability practices, and willingness to participate. Purposeful sampling ensured that participating hotels had at least some experience with digital tools or sustainability reporting, enabling meaningful insights into the state of EMA digitalisation. Multiple sources of evidence were employed to ensure triangulation and enhance the validity of the findings. Twenty-seven interviews were conducted with hotel managers, finance officers, environmental sustainability coordinators, and facility maintenance staff members. The interviews lasted between 45 and 75 minutes, and were conducted either face-to-face or via video conferencing. The interview protocol focused on EMA practices and the use of digital tools (for example IoT sensors, BMS, and GEPA), data integration processes, and perceived barriers to implementation.

Table 1: Expanded demographic characteristics of the sample

Participant	Gender	Age (years)	Province	Functional Role	Years of Experience
1	Female	46–65	Gauteng	Finance Officer	05–10
2	Female	31–45	Gauteng	Finance Officer	05–10
3	Male	18–30	Gauteng	Hotel Manager	10–15
4	Male	46–65	Gauteng	Hotel Manager	10–15
5	Female	18–30	Gauteng	Hotel Manager	05–10
6	Female	31–45	Gauteng	Maintenance Manager	05–10
7	Female	46–65	Gauteng	Maintenance Manager	10–15
8	Female	46–65	Gauteng	Sustainability Coordinator	10–15
9	Male	46–65	Gauteng	Maintenance Manager	05–10
10	Female	18–30	Gauteng	Sustainability Coordinator	05–10
11	Male	31–45	KwaZulu-Natal	Finance Officer	10–15
12	Male	46–65	KwaZulu-Natal	Finance Officer	05–10
13	Female	46–65	KwaZulu-Natal	Maintenance Manager	05–10
14	Female	18–30	KwaZulu-Natal	Finance Officer	10–15
15	Female	18–30	KwaZulu-Natal	Hotel Manager	10–15
16	Female	31–45	KwaZulu-Natal	Hotel Manager	05–10
17	Female	18–30	KwaZulu-Natal	Hotel Manager	10–15
18	Female	46–65	KwaZulu-Natal	Hotel Manager	05–10
19	Female	18–30	KwaZulu-Natal	Hotel Manager	05–10
20	Male	18–30	KwaZulu-Natal	Maintenance Manager	05–10
21	Female	46–65	KwaZulu-Natal	Maintenance Manager	10–15
22	Male	46–65	KwaZulu-Natal	Maintenance Manager	10–15
23	Male	18–30	KwaZulu-Natal	Maintenance Supervisor	10–15
24	Male	46–65	KwaZulu-Natal	Sustainability Coordinator	10–15
25	Female	18–30	KwaZulu-Natal	Maintenance Manager	05–10
26	Female	18–30	KwaZulu-Natal	Sustainability Coordinator	10–15
27	Male	46–65	KwaZulu-Natal	Sustainability Coordinator	10–15

Where access was granted, site visits were conducted to inspect the hotels' digital infrastructure, including energy and water monitoring systems, smart meters, and building automation platforms. Observations focused on how the environmental data were collected, stored, and used in daily operations. Publicly available and internally shared documents such as annual sustainability reports, environmental audits, and accounting records were reviewed. These documents provide additional context regarding the alignment between environmental data and financial reporting as well as institutional policies on sustainability (Nasreen et al., 2025). All interviews were audio-recorded with participants' consent and subsequently transcribed verbatim. Field notes and observation logs were compiled to supplement the interview data and document reviews.

Thematic analysis was employed to identify patterns and derive meaning from the qualitative data (Christou, 2022). The analysis followed a systematic coding process, using both inductive and deductive approaches. Initially, open coding was applied to the transcripts and observation notes to generate preliminary categories related to digital EMA practices, tools used, and organisational processes. These codes were then grouped into broader themes aligned with the research objectives, including (1) technology adoption and usage, (2) integration with accounting systems, (3) organisational enablers and barriers, and (4) implications for decision-making and sustainability performance. The deductive component was informed by STS theory, which served as the study's analytical lens. As such, coding also focuses on distinguishing technical factors (for example, hardware, software, and infrastructure) from social dimensions (for example, human expertise, leadership support, and organisational culture). NVivo software was used to manage and organise the data coding process, enabling cross-case comparisons and theme saturation validation.

Cross-case analysis further strengthened the reliability of the findings by identifying recurring patterns and unique differences among the five cases. Triangulation of interview responses, observations, and documents enhanced the credibility of the study and reduced the potential for respondent bias. To ensure the rigour of the study, strategies were employed to address credibility, transferability, dependability, and confirmability. Credibility was reinforced through member checking, where selected participants were invited to review the interview summaries and preliminary findings. Transferability was facilitated by providing detailed descriptions of the research context and case profiles, which allowed readers to judge the applicability of the findings to other settings. Dependability was achieved by maintaining an audit trail of the research process, including interview guides, coding frameworks, and data logs. Confirmability was ensured through reflexive journaling and peer debriefing with academic colleagues who were not involved in the data collection process. Ethical clearance for conducting this research was obtained from the University of KwaZulu Natal's Humanities and Social Sciences Research Ethics Committee under the protocol reference number HSS/0251/015D. All participants provided informed consent, and anonymity was maintained by assigning codes to the hotels and interviewees. Participation was voluntary and respondents were assured that their responses would be treated confidentially and used solely for academic purposes.

Results

This section presents the findings of the study in alignment with three overarching objectives: (1) to explore the extent to which smart technologies have been integrated into EMA practices in South African hotels; (2) to examine the perceived benefits and limitations associated with these tools; and (3) to understand how digital innovations contribute to sustainable hotel operations. A total of 27 participants drawn from hotels across two provinces, KwaZulu-Natal and Gauteng, were interviewed. The sample included finance officers, hotel managers, environmental sustainability coordinators, and maintenance staff with varying years of experience, ranging from 5 to over 15. The thematic analysis produced four principal themes that illuminated the levels and dynamics of digital transformation in EMA: (1) Adoption and Awareness of Smart EMA Tools, (2) Integration into Operational Processes, (3) the Perceived Benefits of Smart EMA, and (4) Barriers to Implementation. Participants were referenced by their assigned numbers (P1–P27) as per the demographic table to reflect their role, location, and experience.

Adoption and awareness of smart EMA tools

The extent of awareness and adoption of smart EMA tools varied considerably across hotel categories and provinces. Hotels situated in urban centres, particularly KwaZulu-Natal, exhibited higher degrees of digital integration. Participants in senior managerial roles expressed familiarity with EMA systems and acknowledged their role in improving sustainability reporting. For instance, P4, a hotel manager from Gauteng with over ten years of experience, stated, "We use digital dashboards to monitor electricity consumption daily. This allows us to adjust our operations to avoid waste." Nevertheless, some participants noted that the available technologies were underutilised or not explicitly connected to the EMA systems. P2, a finance officer from Gauteng, highlighted, "Although we record environmental data, it's mostly manual and doesn't flow into our cost accounting systems." This sentiment was echoed by P1, who observed that environmental records were "often an afterthought, maintained for compliance but not integrated into budget planning." Such gaps in strategic alignment were particularly evident in Gauteng-based hotels compared to their KwaZulu-Natal counterparts. Several sustainability coordinators in KwaZulu-Natal (P24, P26) confirmed the presence of smart monitoring devices for energy and waste but expressed concern that these were not linked to accounting frameworks. P24 stated, "We have meters and dashboards, but our financial reporting system doesn't speak to them." These discrepancies reflect a disconnect between environmental monitoring and financial systems, which constrains the EMA's potential.

Integration into operational processes

The participants differed in the degree to which the smart EMA tools were embedded in operational processes. In hotels with higher EMA maturity, real-time monitoring systems were integrated into accounting workflows and informed decision-making. P24, a sustainability coordinator with over a decade of experience, explained, "Our water usage is tracked digitally, and those figures are converted to Rands in our internal reporting. It shows us how much we spend on inefficiency." Some participants also indicated that digital platforms enabled interdepartmental collaboration and facilitated early detection of inefficiency. P13, a maintenance manager from KwaZulu-Natal, noted, "We have a centralised platform where staff can log maintenance issues or report leaks. That helps us catch wasteful practices early." Similarly, P6, a maintenance manager from Gauteng, added, "Sensors installed in our boiler rooms alert us if consumption spikes. That saves us thousands monthly." However, hotels with limited integration treat environmental data as peripheral. P12, a finance officer in KwaZulu-Natal, mentioned, "We do track some environmental metrics, but there is no financial incentive attached to them." This observation supports prior literature highlighting the importance of aligning EMA initiatives with core financial objectives to enhance uptake and relevance.

Perceived benefits of smart EMA

There was a shared view among participants that digital EMA tools have measurable operational advantages. Frequently cited benefits include cost reductions, improved regulatory compliance, and increased stakeholder engagement. P11, a finance officer with over a decade of experience, shared, "Since we implemented smart meters, we've seen a consistent reduction in our utility bills, roughly 8 to 10% annually." In a similar vein, P1 noted that visual dashboards helped "communicate environmental performance clearly to senior management and facilitated informed decision-making." Smart EMA tools also contributed to achieving certification targets. P3, a hotel manager from Gauteng, highlighted, "When we went for GreenKey certification, having digital records made the audit process seamless. Everything was traceable." This sentiment was echoed by P8, a sustainability coordinator, who noted that smart EMA platforms improved the hotel's image with eco-conscious guests. Transparent data have been reported to foster accountability. P21, a maintenance manager from KwaZulu-Natal, described how weekly energy reports encouraged operational teams to become "more mindful of how equipment is used, especially during peak hours." Participants generally agreed that the cultural shift towards sustainability was more pronounced in organisations that visualised their performance regularly and tied it to operational metrics.

Barriers to implementation

Although the benefits were widely acknowledged, the implementation was not without challenges. The foremost barrier was cost. Several participants cited high upfront expenses as deterrent. P23, a maintenance supervisor, noted, "Our management hesitates because of the capital needed for sensors and software. They want results before investment, not after." P5, a hotel manager from Gauteng, raised a similar concern, emphasising that smart tools were often perceived as luxuries rather than necessities. Another concern is the technical capacity. P11 pointed out, "We have the tools, but we don't fully use them because staff need training." The lack of internal expertise in data analytics and software integration makes it difficult for hotels to derive value from the existing systems. Moreover, the interoperability with existing legacy systems has been highlighted as a significant hurdle. P22, a maintenance manager from KwaZulu-Natal, remarked, "Our accounting software is old, and syncing it with real-time energy data is nearly impossible." A final set of barriers related to organisational culture and regulatory support. P19 observed, "There's no formal requirement from government to report environmental costs, so it becomes a low priority." P10, a sustainability coordinator, explained that "EMA isn't part of our KPIs, so even if you believe in it, you're not measured on it." These responses underscore the importance of policy and institutional frameworks for shaping EMA practices. The participants stressed the need for sector-wide standards, clear incentives, and formal recognition of environmental metrics in hospitality performance benchmarks. Altogether, the findings suggest that while South African hotels recognise the value of smart EMA tools, structural and cultural challenges continue to limit their full potential. Addressing these issues is essential to leveraging digital innovations for sustainable hotel management.

Discussion

This study explores the integration of smart technologies into EMA` practices in the South African hotel sector, with the aim of unpacking how digital tools support sustainability, enhance operational efficiency, and reveal barriers to implementation. The findings, interpreted through the lens of socio-technical systems theory, resonate with and extend prior literature on digital transformation and sustainability accounting, while offering nuanced insights specific to the hospitality industry in a developing country context. The first objective, to assess the extent to which smart technologies are integrated into EMA practices, revealed growing awareness among participants of the strategic value of digital tools. However, adoption remains uneven, echoing earlier research by Zatini et al. (2025), which highlights the gap between environmental awareness and the institutionalisation of EMA in organisational systems. Similar to findings in developed markets, the participants in this study acknowledged the utility of smart meters and monitoring dashboards (Kong et al., 2022). However, unlike their counterparts in mature economies, South African hotels often lack the integration needed to fully leverage this data in decision-making (Nyahuna, 2022; Nyide, 2019). For instance, while hotels, such as those represented by participants P4 and P24, adopted real-time energy and water tracking tools, these systems are often siloed and do not interface with financial management systems. This finding supports Ghosh & Wolf's (2021) notion that technological adoption in environmental accounting is most effective when paired with aligned managerial and accounting practices. The second objective focuses on how smart EMA tools are integrated into the operational processes. These findings reinforce the work of Gunarathne et al. (2023), who argued that meaningful EMA integration depends on aligning environmental data with strategic planning and operational metrics. In hotels where integration was more advanced, such as those represented by P13 and P6, smart EMA tools enabled cross-departmental responsiveness and data-driven interventions. These hotels have operationalised sustainability by linking digital insights directly to cost-saving measures and performance indicators. Conversely, several participants indicated that despite possessing digital tools, their organisations had yet to incorporate environmental data into routine accounting and managerial workflows. This aligns with the results of Zatini et al. (2025), who argued that the absence of integrated frameworks can reduce EMA initiatives to symbolic gestures rather than substantive management tools.

The perceived benefits of smart EMA, as articulated by the participants and forming the third objective of this study, reflect a convergence of operational, strategic, and reputational gains. Hotels reporting positive outcomes described reductions in utility bills, improved audit trails for certification, and a cultural shift towards sustainability accountability. These outcomes echo the literature on environmental cost accounting, which posits that real-time data not only support compliance and efficiency but also strengthen stakeholder trust (Burritt et al., 2023). The case of P11, who reported a significant drop in utility costs following the implementation of smart meters, supports the findings of Rasit et al. (2022) that the digital EMA can yield direct financial savings when systematically applied. Furthermore, P3's remarks about the ease of certification processes suggest that smart EMA tools serve both internal management and external reporting functions, an observation made by Gunarathne et al. (2023); Zatini et al. (2025), who described such tools as bridges between operational sustainability and external accountability. The cultural shift enabled by digital transparency, as observed by P21 and P8, reflects the broader impact of smart EMA on organisational norms. This corresponds with the argument made by Halim (2023), who maintains that accounting systems are not merely technical infrastructures but also cultural artefacts that influence behaviour. In this study, the visibility of environmental data enhanced awareness and accountability among staff, reinforcing the behavioural dimension of sustainability transformation. However, the study also identified substantial barriers that hindered the widespread and effective implementation of smart EMA. High capital costs, a lack of technical expertise, system incompatibility, and limited regulatory incentives have emerged as the most pressing obstacles. These findings echo those of Burritt et al. (2023), who pointed out cost and complexity as persistent barriers to EMA adoption in resource-constrained settings. P23 and P5's concerns about return on investment reflect the hesitation documented by Kong et al. (2022), who note that organisations often deprioritise sustainability investments when short-term financial returns are uncertain.

The knowledge and skills gap, particularly among non-specialist staff, highlights the need for capacity building, an issue that resonates with the call by Lisnawati et al. (2024) for greater investment in environmental accounting education and training. P11's observation that "we have the tools, but we don't fully use them" exemplifies the disconnect between technological availability and effective utilisation. This is particularly problematic given that environmental data, unlike traditional accounting data, often require contextual interpretation and specialised expertise to inform decision-making. The lack of policy incentives and sector-specific standards has limited their adoption. This finding adds a South African perspective to the broader debate on the role of governance in promoting EMA. As observed by P19 and P10, the absence of legal mandates or reporting requirements weakens organisational commitment. This finding aligns with that of Abdelhalim et al. (2023), who argue that regulatory frameworks serve as key levers for institutionalising environmental accounting practices. Without such mandates, hotels are left to pursue EMA out of intrinsic motivation or market-based incentives, factors which, as this study shows, are not yet strong enough to drive universal uptake. In light of these findings, the sociotechnical systems theory, which underpins this study, is a fitting lens for interpretation. The theory posits that successful digital transformation hinges on the co-evolution of technology, organisational structures, and human agency (Dell et al., 2021; Ghosh & Wolf, 2021). In the EMA context, the partial and fragmented adoption of digital tools reflects an imbalance between these components. While technological artefacts (for example dashboards, sensors, and meters) are increasingly present, the accompanying organisational reforms and human capacity development remain inadequate. As such, the potential of smart EMA to transform environmental accounting in the hotel sector remains only partially realised.

In summary, this discussion reveals both the progress and limitations of the application of smart EMA in the South African hotel industry. There is promising evidence of innovation and its impact, particularly in selected hotels that have digital tools aligned with strategy and operations. However, systemic barriers, including costs, capacity, and regulatory inertia, continue to constrain broader adoption. The findings highlight the importance of integrated approaches that combine technology with supportive organisational and institutional structures. Addressing these gaps is critical if smart EMA moves from isolated best practices to sector-wide norms in the pursuit of sustainable hotel management. This study explores the integration of smart technologies into EMA practices in the hotel sector of an emerging economy. This revealed how digital tools can improve sustainability and operational efficiency. The findings, framed within the socio-technical systems theory, extend the existing discourse on environmental accounting by situating digitalisation as both a technological and organisational transformation. This study makes three important theoretical contributions to the literature: First, it enriches EMA literature by positioning smart EMA as a hybrid construct that combines environmental cost accounting with digital innovation. This reconceptualisation extends previous frameworks (Burritt et al., 2023; Gunarathne et al., 2023) by showing that sustainability accounting can be enhanced through data-driven monitoring, automation, and real-time decision making. Second, this study advances the socio-technical systems theory by illustrating that successful technological integration in EMA depends not only on technical artefacts, such as sensors and dashboards, but also on the alignment of organisational culture, leadership, and human capability. Third, it contributes to an emerging economic perspective that has been largely underrepresented in prior EMA research, demonstrating how institutional and infrastructural conditions shape the adoption of digital tools in sustainability management.

Conclusion

Grounded in socio-technical systems theory, this study sought to understand how digital innovations are reshaping environmental accounting practices and promoting sustainable management. Through a qualitative design involving 27 participants across Gauteng and KwaZulu-Natal, this study revealed both the progress and challenges in the uptake of smart EMA tools. The findings confirm that smart technologies, such as IoT-enabled monitoring systems and real-time dashboards, have begun to transform how hotels in South Africa collect, analyse, and use environmental data. In cases where digital tools were embedded within financial and operational workflows, hotels reported benefits, such as cost savings, enhanced regulatory compliance, and improved staff accountability. Participants highlighted that these systems not only streamlined reporting processes, but also served as catalysts for cultural change, reinforcing sustainability values across departments. Nonetheless, this study also uncovered significant constraints that hinder the widespread adoption and effective use of smart EMA tools. High implementation costs, a lack of technical expertise, incompatibility with existing accounting systems, and a weak regulatory environment are consistently cited as barriers. These issues highlight a broader need for strategic alignment, capacity development, and supportive policy interventions if digital EMA systems reach their full potential in the hospitality industry. From a theoretical standpoint, the socio-technical systems perspective proved essential in understanding the complexity of smart EMA adoption. The interplay between technology, people, and organisational systems emerged as a defining factor in whether digital EMA tools were effectively institutionalised or remained underutilised. While South African hotels are taking important steps towards digital transformation in environmental accounting, the journey is far from complete. For smart EMA to become a standard practice rather than an exception, hotels must invest not only in technology but also in the skills, structures, and cultures that support sustainable management. Future research should explore scalable models of EMA integration and assess their long-term impacts across various hospitality contexts.

References

Abdelhalim, A. M., Ibrahim, N. & Alomair, M. (2023). The Moderating Role of Digital Environmental Management Accounting in the Relationship between Eco-Efficiency and Corporate Sustainability. *Sustainability*, *15*(9), 7052. https://doi.org/10.3390/su15097052

Adelakun, B. O., Antwi, B. O., Ntiakoh, A. & Eziefule, A. O. (2024). Leveraging AI for sustainable Accounting: Developing Models for Environmental Impact Assessment and Reporting. *Finance & Accounting Research Journal*, *6*(6), 1017–1048. https://doi.org/10.51594/farj.v6i6.1234

Annamalah, S., Aravindan, K. L., Ahmed, S. & Sentosa, I. (2025). Exploring the Relevance and Rigour of Case Study Research in Business: A Contemporary Perspective. *Journal of Sustainability Research*, *7*(2), e250032. https://doi.org/10.20900/jsr20250032

Baxter, G. & Sommerville, I. (2011). Socio-technical Systems: From Design Methods to Systems Engineering. *Interacting with Computers*, *23*(1), 4–17. https://doi.org/10.1016/j.intcom.2010.07.003

Bello, O. A. (2023). The Role of Data Analytics in Enhancing Financial Inclusion in Emerging Economies. *International Journal of Developing and Emerging Economies*, *11*(3), 90–112. https://doi.org/10.37745/ijdee.13/vol11n390112

Burritt, R. L., Hahn, T. & Schaltegger, St. (2002). Towards a Comprehensive Framework for Environmental Management Accounting—Links Between Business Actors and Environmental Management Accounting Tools. *Australian Accounting Review*, *12*(27), 39–50. https://doi.org/10.1111/j.1835-2561.2002.tb00202.x

Burritt, R. L., Schaltegger, S. & Christ, K. L. (2023). Environmental Management Accounting – Developments Over the Last 20 years from a Framework Perspective. *Australian Accounting Review*, *33*(4), 336–351. https://doi.org/10.1111/auar.12407

Campos, F., Lima Santos, L., Gomes, C. & Cardoso, L. (2022). Management Accounting Practices in the Hospitality Industry: A Systematic Review and Critical Approach. *Tourism and Hospitality*, *3*(1), 243–264. https://doi.org/10.3390/tourhosp3010017

Christou, P. A. (2022). How to use Thematic Analysis in Qualitative Research. *Journal of Qualitative Research in Tourism*, *3*(2), 79–95. https://doi.org/10.4337/jqrt.2023.0006

Dell, N. A., Maynard, B. R., Murphy, A. M. & Stewart, M. (2021). Technology for Research Synthesis: An Application of Sociotechnical Systems Theory. *Journal of the Society for Social Work and Research*, *12*(1), 201–222. https://doi.org/10.1086/713525

Dube, K., Nhamo, G., Kilungu, H., Hambira, W. L., El-Masry, E. A., Chikodzi, D., Chapungu, L. & Molua, E. L. (2024). Tourism and Climate Change in Africa: Informing Sector Responses. *Journal of Sustainable Tourism*, *32*(9), 1811–1831. https://doi.org/10.1080/09669582.2023.2193355

Fatoki, O. (2021). Environmental Orientation and Green Competitive Advantage of Hospitality Firms in South Africa: Mediating Effect of Green Innovation. *Journal of Open Innovation: Technology, Market, and Complexity*, *7*(4), 223. https://doi.org/10.3390/joitmc7040223

Ghosh, R. & Wolf, S. (2021). Hybrid Governance and Performances of Environmental Accounting. *Journal of Environmental Management*, *284*, 111995. https://doi.org/10.1016/j.jenvman.2021.111995

Gunarathne, N., Lee, K.-H. & Hitigala Kaluarachchilage, P. K. (2023). Tackling the Integration Challenge Between Environmental Strategy and Environmental Management Accounting. *Accounting, Auditing & Accountability Journal*, *36*(1), 63–95. https://doi.org/10.1108/AAAJ-03-2020-4452

Halim, P. A. (2023). Evaluation of Technical and Cultural Barriers to Digital Accounting System Implementation in Modern Organizations. *Atestasi: Jurnal Ilmiah Akuntansi*, *6*(2), 916–930. https://doi.org/10.57178/atestasi.v6i2.1001

Juvan, E., Grün, B. & Dolnicar, S. (2023). Waste Production Patterns in Hotels and Restaurants: An Intra-Sectoral Segmentation Approach. *Annals of Tourism Research Empirical Insights*, *4*(1), 100090. https://doi.org/10.1016/j.annale.2023.100090

Kagisho, S. & Sao Joao, E. (2025). Sustainability-Oriented Resilience and Regenerative Adaptations in the Hospitality Industry: Lessons from Gauteng. *Studia Periegetica*, *46*(2), 135–156. https://doi.org/10.58683/sp.2022

Kalyanam, A. K. (2021). Building Management System (BMS) an In- Depth Overview (Understanding BMS, Its Operation, Necessity, and the Role of IoT). *Journal of Advances in Developmental Research*, *12*(1), 1–12. https://doi.org/10.5281/zenodo.14540874

Kong, Y., Javed, F., Sultan, J., Hanif, M. S. & Khan, N. (2022). EMA Implementation and Corporate Environmental Firm Performance: A Comparison of Institutional Pressures and Environmental Uncertainty. *Sustainability*, *14*(9), 5662. https://doi.org/10.3390/su14095662

Kraus, S., Durst, S., Ferreira, J. J., Veiga, P., Kailer, N. & Weinmann, A. (2022). Digital Transformation in Business and Management Research: An Overview of the Current Status Quo. *International Journal of Information Management*, *63*, 102466. https://doi.org/10.1016/j.ijinfomgt.2021.102466

Ledikwe, A. (2021). Determinants of Behavioural Intention Towards Travel Applications in an Emerging African Economy: A Perspective on the Hospitality Industry. *African Journal of Hospitality, Tourism and Leisure*, *10*(6), 1882-1895. https://doi.org/10.46222/ajhtl.19770720.198

Lee, J. Y., Irisboev, I. O. & Ryu, Y.-S. (2021). Literature Review on Digitalization in Facilities Management and Facilities Management Performance Measurement: Contribution of Industry 4.0 in the Global Era. *Sustainability*, *13*(23), 13432. https://doi.org/10.3390/su132313432

Liem, V. T. & Hien, N. N. (2024). The Impact of Managers' Attitudes Towards Environmental Management Accounting and Green Competitive Advantage in Vietnam Manufacturers. *Heliyon*, 10 (13), e33565. https://doi.org/10.1016/j.heliyon.2024.e33565

Lisnawati, L., Aryati, T. & Gunawan, J. (2024). Implementation of Digital Innovation on Sustainability Performance: The Moderating Role of Green Accounting in the Industrial Sector. *Eastern-European Journal of Enterprise Technologies*, 127 (13), 59–68. https://doi.org/10.15587/1729-4061.2024.298639

Mankgele, K., Mmakola, S. & Chidi., M.M (2023). Green Human Resource Management and Environmental Performance of Hotels in South Africa: Mediating and Moderating Role of Environmental Concern and Green Human Capital. *International Journal of Research in Business and Social Science (2147- 4478)*, 12 (8), 180–187. https://doi.org/10.20525/ijrbs.v12i8.2942

Mbasera, M., Du Plessis, E., Saayman, M. & Kruger, M. (2016). Environmentally-friendly Practices in Hotels. *Acta Commercii*, *16*(1). https://doi.org/10.4102/ac.v16i1.362

McCarroll, M. J., LaVanchy, G. T. & Kerwin, M. W. (2024). Tourism Resilience to Drought and Climate Shocks: The Role of Tourist Water Literacy in Hotel Management. *Annals of Tourism Research Empirical Insights*, *5*(2), 100147. https://doi.org/10.1016/j.annale.2024.100147

Mkwizu, K. (2025). Tourism in Africa: Opportunities and Challenges - Perspectives from Eastern and Southern Africa. *ASFI Research Journal*, e12048. https://doi.org/10.70040/asfirj-dvfg-r2wa

Mukwarami, S., Nkwaira, C. & Van Der Poll, H. M. (2023). Environmental Management Accounting Implementation Challenges and Supply Chain Management in Emerging Economies' Manufacturing Sector. *Sustainability*, *15*(2), 1061. https://doi.org/10.3390/su15021061

Mukwarami, S. & Van Der Poll, H. M. (2024). Critical Environmental Management Accounting Practices Influencing Service Delivery of Growing Cities in A Developing Economy: A Review and Conceptual Framework. *Environment Systems and Decisions*, *44*(3), 710–739. https://doi.org/10.1007/s10669-023-09960-9

Nasreen, T., Baker, R. & Rezania, D. (2025). Sustainability Reporting – A Systematic Review of Various Dimensions, Theoretical and Methodological Underpinnings. *Journal of Financial Reporting and Accounting*, *23*(3), 1057–1088. https://doi.org/10.1108/JFRA-01-2022-0029

Ndzungu, L., Roeloffze, A. & Kleynhans, C. (2024). Green Choices: Exploring Environmental Responsible Practices and Their Impact on Guest Intention in Dinokeng Accommodation Establishments. *African Journal of Hospitality, Tourism and Leisure, 13*(1):207-212. https://doi.org/10.46222/ajhtl.19770720.499

Nyahuna, T. (2022). The Choice of Environmental Management Accounting Practices Adopted by Managers: Evidence from the Hotel Sector in KwaZulu Natal, South Africa. *Indonesian Journal of Social and Environmental Issues (IJSEI)*, *3*(2), 154–158. https://doi.org/10.47540/ijsei.v3i2.618

Nyide, C. J. (2019). Better Resource Management: A Qualitative Investigation of Environmental Management Accounting Practices Used by the South African Hotel Sector. *Tourism and Leisure*, *8* (4), 1–10.

Paparini, S., Papoutsi, C., Murdoch, J., Green, J., Petticrew, M., Greenhalgh, T. & Shaw, S. E. (2021). Evaluating Complex Interventions in Context: Systematic, Meta-Narrative Review of Case Study Approaches. *BMC Medical Research Methodology*, *21*(1), 225. https://doi.org/10.1186/s12874-021-01418-3

Ramaano, A. I. (2024). Sustainable Tourism Development Activities and Planning Systems in Vhembe District, Limpopo Province, South Africa: A Comprehensive Eco-Touristic and Sustainability Perspective. *Arab Gulf Journal of Scientific Research*, *42*(4), 1832–1848. https://doi.org/10.1108/AGJSR-04-2023-0140

Ranasinghe, R., Gangananda, N., Bandara, A., & Perera, P. (2021). Role of Tourism in the Global Economy: The Past, Present and Future. *Journal of Management and Tourism Research*, *4*(1), vi–xxii.

Rasit, Z. A., Bahari, N. A. M., Urus, S. T. & Ismail, A. H. (2022). Technology Industry Revolution 4.0 and Environmental Performance: The Mediating Role of Environmental Management Accounting. *GATR Accounting and Finance Review*, *7*(1), 62–78. https://doi.org/10.35609/afr.2022.7.1(3)

Stevens-King, N. & Bello, F. G. (2023). Drivers and Barriers of Corporate Social Responsibility Engagement Within Small, Medium and Micro Hospitality Enterprises: The Case of the Hospitality Sector in South Africa. *Journal of Tourism & Development*, *42*, 225–242. https://doi.org/10.34624/RTD.V42I0.32694

Thomas, A. (2024). Digitally Transforming the Organization Through Knowledge Management: A Socio-Technical System (STS) Perspective. *European Journal of Innovation Management, 27*(9), 437–460. https://doi.org/10.1108/ejim-02-2024-0114

Velaoras, K., Menegaki, A. N., Polyzos, S. & Gotzamani, K. (2025). The Role of Environmental Certification in the Hospitality Industry: Assessing Sustainability, Consumer Preferences, and the Economic Impact. *Sustainability*, *17*(2), 650. https://doi.org/10.3390/su17020650

Zafar, F., Sabri, R., Siddiqui, H. M. A. & Masood, I. (2024). Emerging Issues in Management Accounting: Digital Technologies, Governance, and Sustainability. *Bulletin of Business and Economics (BBE)*, *13*(1), 363–371. https://doi.org/10.61506/01.00214

Zatini, G., Della Porta, A. & Za, S. (2025). Deciphering Barriers and Strategies in Environmental Management Accounting (EMA) Adoption: A Comprehensive Two-Decade Analysis. *Corporate Social Responsibility and Environmental Management*, csr.3130. https://doi.org/10.1002/csr.3130

Zhang, X., Nutakor, F., Minlah, M. K. & Li, J. (2023). Can Digital Transformation Drive Green Transformation in Manufacturing Companies?—Based on Socio-Technical Systems Theory Perspective. *Sustainability*, *15*(3), 2840. https://doi.org/10.3390/su15032840