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The role of artificial intelligence in shaping a sustainable future for events in Saudi: systematic review

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Abstract

This research examines the growing events environment in Saudi Arabia in the conceptual landscape of Saudi Vision 2030 and sustainability commitments. By using narrative systematic reviews for this research effort, the possible use of artificial intelligence to promote sustainability for events can be highlighted. This systematic review focuses on scientific literature concerning events in several sectors: Energy and Resource Management, Waste & Circularity Solutions, Transportation & Mobility Management, Safety & Accessibility Management Systems, and finally, Measurement & Verification Systems. The approximate results suggest more accurate predictions regarding machine learning algorithms used in association with computer vision approaches to digital twin technologies in decision-support systems. Additionally, literature indicates achievements in optimizing building energy consumption for sectors and efficiency in waste sorting performance for sectors, while other areas such as emissions via optimized mobility systems and methods for crowd protection & accessibility management systems have shown advancement. Additionally, environmental management via automated Measurement and Verification Systems has shown developments. Nevertheless, the narrative systematic analysis points out several gaps: a lack of empirical studies concerning events specifically, a dominance of studies pertaining to a temperate climatic environment, simulation-based approaches for studies, infrastructural limitations which exist only in Saudi Arabia, and a lack of focus pertaining to ethical and regulatory aspects in a Saudi Arabian environment. The literature review presents conceptual frameworks concerning events in Saudi Arabia with regard to environmental factors, social factors, economic factors, and climatic factors such as those pertaining to a temperate environment influence. Despite such technologies offering great potential for propelling sustainable events in Saudi Arabia forward, much remains to be achieved in associated research.

Keywords

Artificial intelligence, sustainable event management, machine learning, digital twins, smart mobility.

1. Introduction

1.1 Background

The events industry in Saudi Arabia has come out as a steadily progressing field in line with the vision expressed in Vision 2030 (Altouma et al., 2023). The aims of the nation towards encouraging tourism and increasing the scope and number of events further underscore the importance of this field (Altouma et al., 2023). Sustainability issues form a defining feature for large-scale events in Saudi Arabia within this broader developmental setting (Altouma et al., 2023).

Sustainability frameworks such as Saudi Green Initiatives and the Saudi sustainability standards represent Saudi Arabia's effort to address globally accepted best practices for carrying out mega-scale events. This ranges from supporting environmental stewardship with minimized carbon emissions to improving social stewardship with a focus on inclusivity in planning and executing events. In current literature regarding sustainability and AI, machine learning-based systems have shown promise as sustainability intervention strategies (Greif et al., 2024; Kar et al., 2022).

Taken together, the phenomenon of Saudi Arabian development in the event sectors and Vision 2030, the rise of sustainability mandates in both local and global frameworks, and advancements in technology affecting other sectors make the events industry a distinct arena for analyzing sustainability mandate intersection with technological evolution.

1.2 Artificial Intelligence and Sustainability in Events

Artificial intelligence (AI) refers to a class of technologies that can be used for tasks considered to belong to human intelligence. This continuum encompasses machine learning (ML), natural language processing (NLP), computer vision, digital twin simulations, and analytics for decision support (Analytics Reference, 2024). In terms of organizing events, innovations being made are using AI for personalization and enhanced security for mass events (Sailesh, 2024).

Though worldwide studies regularly stress the importance of dealing with sustainability issues using AI, practical cases can better demonstrate this importance. Greif et al. (2024) discuss techniques for dealing with sustainability using supervised learning and reinforcement learning. Kar et al. (2022) highlight integrations of AI for sustainable events with a focus on decreasing gas emissions for mass events. Though studies about transformation and sustainability in Saudi Arabia's manufacturing industry exist (Alquraish, 2025), little literature connects Saudi events with sustainability and AI. As Saudi Arabia focuses strategically on transformation, sustainability, and event development in connection with Vision 2030, this research intends to explore current trends for this purpose.

1.3 Research Problem

There is a clear gap in the current literature when it comes to evaluating or examining the role of artificial intelligence in supporting sustainability in events, whether specifically within Saudi Arabia or in a broader context. Although a substantial body of work has addressed the use of AI to support sustainability in general (e.g., Greif et al., 2024; Kar et al., 2022) and other studies have explored sustainability transformation in Saudi Arabia across different sectors (e.g., Altouma et al., 2023; Alquraish, 2025), there remains surprisingly little research that focuses on the emerging intersection between this category of AI and sustainability objectives within Saudi Arabia’s event sector.

1.4 Research Aim & Objectives

Aim: To systematically review how artificial intelligence contributes to sustainability outcomes in event planning, operations, and evaluation.

Objectives:

1. To analyze opportunities and challenges of adopting artificial intelligence in Saudi Arabia’s events sector.
2. To develop a Saudi-specific conceptual framework for sustainable, AI-enabled event management.

1.5 Significance of the Study

This study will contribute academically by filling a gap in the literature on artificial intelligence and sustainable event management, particularly within the Saudi context. Practically, the findings will offer valuable implications for policymakers, regulators (such as the Saudi Data &

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Artificial Intelligence Authority – SDAIA) and event organizers (for example, those behind major initiatives like the Riyadh Season and the broader investment in events by the national Events Investment Fund).

2. Literature Review

2.1 The Evolution of Sustainable Event Management

There has been increasing apprehension lately concerning the social and environmental repercussions linked with the business events industry. Business events require a lot of resources and lead to a massive amount of waste being produced (Dickson & Arcodia, 2013). Rising awareness about this problem has triggered the current focus on sustainability in managing business events.

Initially, studies have mainly emphasized environmental factors with a focus on how event planners could help to facilitate minimized waste creation, reduce material use, and mitigate emissions associated with transportation (Dickson & Arcodia, 2013; Allen et al., 2015). For example, a systematic literature review has revealed that Intelligent Transport Systems and Demand Responsive Services with regard to transport have shown positive results concerning neutralizing negative transport-related effects triggered by events (Ballarano et al., 2022). Following Green Procurement and Waste Management Guidelines has also been deemed critical for fulfilling environmental aims concerning event greening (Nor et al., 2014).

As time has passed within this field of research, a number of scholars have called for a more expansive focus of sustainability debates beyond environmental issues to a focus on the 'triple bottom line,' thus incorporating social and economic factors as well (Tinnish & Mangal, 2012; Kumbara et al., 2025). For instance, Kumbara et al. (2025) state that while a number of events highlight sustainability achievements, a number of those achievements often involve budget-based targets instead of targets based on environmental sustainability. This indicates that current trends in event management need to move forward beyond simple 'going green' concepts towards more expansive 'event sustainability' strategies (Dickson & Arcodia, 2013; Tinnish & Mangal, 2012). Internationally, important progress has also been made. This has been shown in a recent thematic analysis of more than 1,700 articles: sustainability has become a prominent topic in this field with a strong increase of publications in management, hospitality, and tourism literature since the beginning of 2010 (Baydeniz et al., 2024). Nevertheless, several important gaps remain: a unifying sustainability model does not exist, no consensus about sustainability definitions exists, methods for sustainability evaluation and reporting are insufficient, and a sufficient level of inter-stakeholder cooperation would be achieved more often (Ratih et al., 2025; Baydeniz et al., 2024). This would involve cases where huge events satisfy sustainability requirements but smaller events fail to build a sustainability infrastructure (Gonçalves et al., 2025).

In the field of sustainable event management, based on current scholarship and practices regarding the triple bottom line concept, one may state that:

Sustainability for the environment focuses on minimizing ecological footprints, managing resource use effectively—encompassed in energy, water, and material consumption—reducing emissions, and making sure that event management does not lead to negative outputs for the environment (Ballarano et al., 2022; Dickson & Arcodia, 2013).

Social sustainability addresses providing benefits to society via engagement with communities, supporting equity, involvement with culture retention, and protecting employee welfare (Ratih et al., 2025; Tinnish & Mangal, 2012).

As for economic sustainability: this refers to maintaining the economic viability of events with regard to factors such as cost-effectiveness and managing scarcity of resources (Dickson & Arcodia, 2013; Kumbara et al., 2025).

Over time, best practices for sustainable events developed in a more inclusive manner that attempted to address all three elements instead of looking at each one in a vacuum (Tinnish & Mangal, 2012). Guidelines such as ICLEI best practices recognize that planning and intentional execution with regard to all three elements must be a priority (ICLEI, 2022). Still, problems with regard to their use in measurements as well as in overall structures regarding these elements have been cited within literature (Ratih et al., 2025; Gonçalves et al., 2025).

2.2 AI Technologies Relevant to the Events Sector

The integration of Artificial Intelligence (AI) technology in event-related situations has grown from being driven solely by engagement values to being sufficiently aligned with sustainability values. This paper identifies some of the major technological streams being used in event-related settings today: computer vision technology, natural language processing, machine learning algorithms, digital twins, and decision support systems.

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Machine learning approaches have also found adoption in event-related contexts for purposes of forecasting and optimizing resource use and waste management. For example, in managing sports events, Zhang and Yang (2023) illustrated how a combination of reinforcement learning with evolutionary optimization can predict peak demand and optimize energy use during a sudden peak demand surge. In general literature on sustainability studies, machine learning can aid in predicting models for optimizing energy, water, and material use in events to ensure effective resource use (Kar et al., 2022). Halim et al. (2023) further explicate machine learning in event management as a tool that can aid in effective decision-making using data-driven approaches for budgeting and logistics.

A great potential for improvement has emerged for computer vision in ensuring safety and sustainability during events, especially in crowd management and facility usage analysis. Although computer vision has matured in construction and industrial safety—specifically regarding developments in merging visual technology with behavioral analysis (Computer Vision Technologies for Safety Science and Management 2020)—other fields are still evolving. Methods for real-time crowd density mapping, heat map routing paths, anomaly detection for behavioral surveillance, and queue analysis software have been generated for assisting with event management and facility usage for events (Ultralytics' vision-AI for event crowd management and safety using smart vision-AI technology). This allows computer vision to apply a sustainability tool for enhanced crowd routing and facility access to reduce wait-time congestion generated from more intense safety measures. The use of computer vision technology in smart event systems has been further explained in more detail by Halim et al. (2023).

Natural Language Processing (NLP) techniques are being utilized in other sectors such as events for analyzing opinions and points of view of attendees based on social media stream analysis as well as improving chatbot-enabled communication systems. As indicated by Neuhofer, Magnus, & Celuch (2021), ‘Involvement made possible by use of such technology requires text data analysis contributed by those who participate in any number of experiences that are delivered in a given event. ‘There are several application areas available for business-related event communications where machine learning techniques based on NLP techniques are used to optimize efficiency and prepare text content for networking environments (SPIE, Use of Tools in Communication in Business Events Networks. Conference Paper).

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In the realm of business sustainability and practices, one of the most prominent potential uses of NLP would be in facilitating effective stakeholder engagement with opinion analysis in event-related business processes. Additionally, other developments involve the convergence of NLP and other AI-based applications with digital twins for simulations of event operation scenarios before and during a physical event. Literature reviews identified for this year 2024 acknowledge that comprehensive digital twin system integration is critical for prediction simulations. As identified in a literature review by Krishnakumari et al. (2023) concerning crowd management and sustainability for physical events, one approach would be to integrate a venue model in three dimensions with risk prediction methods for simulations of future events. As such, integration with digital twin systems is directly applicable for sustainability in physical events because simulations of variables such as transportation flow and peak energy use are possible before physical execution.

Decision Support Systems (DSSs) built on Artificial Intelligence are being used with increasing frequency in event management planning. Their use in this context centers on predictive analytics and real-time data processing for session scheduling, venue allocation, resource management, supply-chain analysis for events, and Sustainability Key Performance Indicators. Halim et al. (2023) explain that Decision Support Systems enable immediate resource management and informed decision-making for effective event operations. Research on DSSs tied to net-zero goals and sustainability mainly highlights applications in industrial sectors where they support decision-making processes (Alonso-Betanzos, 2024). These applications often involve optimal vendor selection, DSS-based routing for constraint optimization in power usage and management, and waste-management considerations. Such models correspond directly with sustainability objectives in event management by addressing environmental resource efficiency and associated social and financial benefits.

When viewed together, the technologies described above form a varied set of tools that support stronger sustainability practices in events. Machine learning contributes forecasting and resource optimization; computer vision enables surveillance and real-time flow analysis; natural language processing supports communication and system refinement through feedback; digital twins allow predictive modeling to anticipate resource demands; and Decision Support Systems offer essential support for decision-making. Although many uses of these technologies have been examined in sectors such as energy, manufacturing, security, and logistics, scientific studies on the

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application of Decision Support Systems for sustainability in event settings remain relatively unexplored.

2.3 AI and Sustainability Outcomes

The use of artificial intelligence (AI) in those sectors considered resource-intensive has clearly had a positive effect with regard to energy efficiency and resource management. From a sustainability-oriented perspective, empirical evidence shows that AI use ensures efficient management of consumption based on prediction models and real-time modification (Toderas, 2025). In vehicle-related sectors, for example, Intelligent Traffic Systems based on AI have influenced energy conservation along with a decline in emissions based on optimized traffic flow and minimized idling and vehicle use (Rinchi, Alsharoa & Shatnawi, 2024). For sectors similar to event management, such technologies based on AI use are anticipated to provide support for efficient energy management along with efficient use of other resources (Kar et al., 2022).

There has also been a rising trend in using artificial intelligence in waste management sectors. Intelligent classification techniques help in compacting wastes effectively, accurate separation of wastes, and integration with circular economies. A systematic literature review shows that machine learning and artificial intelligence classification techniques help in accurate separation and reduce transportation needs for waste management tasks (Fang et al., 2023). In another research dealing with circular economy systems, use of supply chain management trends and recycled material use can be forecasted effectively using AI (All Noman et al., 2022). In connection with event management tasks, various types of wastes such as food wastes, packing wastes, and material wastes have severe environmental implications; thus, predicting wastes using intelligence would be a great advantage for effective event management.

Transportation and logistics sectors could be identified as key generators of carbon emissions in events and more generally for supply chains. Artificial intelligence (AI) has shown potential in deriving efficient cuts in carbon emissions through route optimization, better management of carriers and/or payloads, mode shift analysis, and more effective use of available capacities. Taking a specific example regarding logistics optimization studies, one finds that carbon emissions associated with empty mileage can be minimized to a negligible level using generative models based on machine learning and metaheuristic approaches for logistics optimization problems (Chen et al., 2024). A literature review with a special emphasis on carbon emissions associated with transports illustrates precision in carbon emissions measured and predicted using big data and AI techniques (Jahagirdar, Jahagirdar & Apandkar, 2025). Scaled-up events such as international conferences and celebrations may thus use AI methods for managing mobility among attendees through efficient management associated with shuttle services based on optimal route planning for parks and go flow management as well as mode shift planning to reduce carbon emissions associated with transports.

Although sustainability debates often focus primarily on environmental and economic considerations, a social one continues to be of great significance. The role of AI in managing crowds pertaining to computer vision technology used for density level analysis and anomaly detection for predicting crowd flow has started showing a positive effect in uplifting event-related safety and accessibility standards. Though peer-reviewed literature available concerning a possible connection between applying AI technology to events remains scarce, research pertaining to computer vision with a focus on sustainability and safety continues to establish a positive route for crowd analysis and prevention of incidents, as observed in a 2024 Ultralytics blog.

One of the major issues associated with sustainable event management is sustainability Key Performance Indicators (KPIs) such as energy usage, waste produced, emissions associated with transports, and social responsibilities. Decision support systems and analytics with AI capabilities help in automating data processing and analysis. This makes fast reporting and anomaly detection easier. The literature available regarding sustainability and AI focuses primarily on using analytics and simulations via digital twins for supporting measurements and verification of sustainability reports (Toderas, 2025; Kar et al., 2022). Such aspects help event managers apply AI for sustainability verification and assessment for future as well as existing events.

Gaps in Existing Research

There appears to be a growing nexus between research literature on Artificial Intelligence (AI) and sustainability studies; however, a number of gaps exist when considering their convergence and interaction. Firstly, most of the literature studies relating to ‘AI for sustainability’ primarily focus on sectors such as manufacturing, logistics, and smart cities. This means that any uniqueness inherent within events—temporarily based, densely populated with crowds, multi-stakeholder involvement, and logistically demanding—have still not received sufficient focus in studies relating to sustainability and AI. Secondly, most of the existing literature studies relating to AI and sustainability studies focus primarily on economies based in developed countries. Saudi Arabia and other Middle East countries remain understudied regarding other mentions being made but insufficient focus directly in Saudi Arabia. Thirdly, though most studies relating to sustainability studies mention ‘green debates,’ most studies regarding sustainability primarily focus on environmental factors such as consumption levels, emissions levels, and levels of wastage. Few studies focus on sustainability based within its triple-bottom line approach—eco-friendly (logical environmental factors), social responsibilities, and economic factors when assessing roles relating to Artificial Intelligence within event management. Fourthly, sustainability assessment and verification regarding current methods and practices relating to event management appear far less studied when assessing empirical research relating to a role of Artificial Intelligence towards instant monitoring and assessment verification. Fifthly, critical assessments relating to roles of Artificial Intelligence towards roles of accountability and stakeholder equity assessment appear unexplored.

Additionally, another critical gap with regard to a lack of empirical research pertains to the insufficiency of studies that empirically examine the role of AI regarding effective management and capability building at a state level. While this gap has been identified and discussed in contemporary literature concerning the use of AI in sustainability problems, empirical research regarding this particular gap remains a concern. This current study aims to fill this research gap.

The other gap that exists relates to a lack of empirical research regarding the efficiency of AI in managing systems and capability building, especially where more than one efficiency challenge co-exists. As indicated in the previous point, this gap also exists in literature concerning the broader topic of AI and sustainability. This particular research seeks to address this. Finally, a related research gap with regard to this study pertains to a lack of empirical research concerning AI's role in enabling efficient system management and capability enhancement regarding efficiency. This portion of AI's role within sustainability studies today remains unexplored. This research study aims to address this lack.

3. Methodology

3.1 Research Design

This research uses a narrative literature review to examine the application of artificial intelligence in sustainability in the events industry. The use of a narrative literature review appears fitting for this literature because sustainability and artificial intelligence represent a wide range of studies. This literature review form also allows for a wide range of literature across a number of themes and fields of study.

3.2 Literature Search Strategy

The literature search was conducted using major academic databases, including **Scopus, Web of Science, ScienceDirect, SpringerLink**, and **Google Scholar**. Searches covered the period from **2010 to 2025** to reflect contemporary technological developments. Keyword combinations included:

- "artificial intelligence" AND "sustainability"
- "AI" AND "event management"
- "machine learning" AND "resource optimisation"
- "digital twins" AND "events"
- "crowd management" AND "AI"
- "AI" AND "Saudi Arabia"

Only peer-reviewed journal articles and academic conference papers were considered.

3.3 Inclusion and Exclusion Criteria

3.3.1 Inclusion Criteria:

- Peer-reviewed academic publications
- Studies addressing AI technologies with relevance to sustainability
- Research focusing on environmental, social, or economic sustainability dimensions
- Literature applicable to event management or transferable to event contexts

3.3.2 Exclusion Criteria:

- Non-academic sources (e.g., websites, blogs, white papers)
- Studies unrelated to AI or sustainability
- Publications outside the defined timeframe unless conceptually foundational

3.4 Screening and Selection Procedure

The screening process involved reviewing article titles and abstracts to identify potentially relevant studies. Full-text screening was then conducted for selected articles. Duplicate records and studies lacking conceptual connection to the research objectives were removed. The resulting body of literature was sufficiently broad to support thematic synthesis while maintaining scholarly relevance.

3.5 Data Extraction and Analysis

A structured extraction process was used to gather key information from each study, including:

- AI technologies examined
- Sustainability outcomes targeted
- Sectoral and contextual application
- Methodological approaches
- Key findings and limitations

A **thematic narrative synthesis** was conducted to organise the literature into coherent thematic categories reflecting sustainability outcomes:

1. energy and resource optimisation,
2. waste reduction and circularity,
3. transport and emissions reduction,
4. crowd management and accessibility, and
5. measurement, reporting, and verification (MRV).

This method allowed the integration of insights across diverse contexts and supported the development of a conceptual understanding relevant to the events sector.

3.6 Quality Considerations

This quality appraisal was done informally but with a focus on peer-reviewed literature available in reputable scientific journals and a special emphasis on literature indexed in Scopus and Web of Science. This quality appraisal especially focused on rigor in methodology and relevancy of concepts relating to sustainability as well as Artificial Intelligence.

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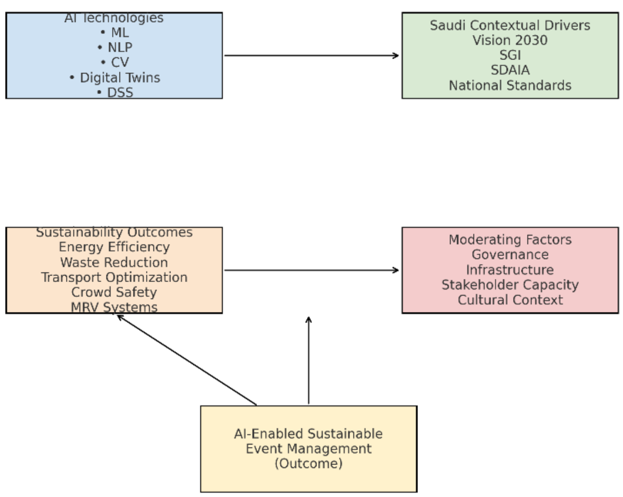
Conceptual Framework

To integrate the results of this narrative literature review and explore how sustainability in Saudi Arabia's events industry might be enhanced by artificial intelligence, a conceptual model has thus been created. This conceptual model identifies how the main types of artificial intelligence-related technologies affect sustainability out comes. A graphical representation of this conceptual model specific to Saudi Arabia appears as Figure 1.



4. Findings

This section presents the results of a narrative literature review using a thematic synthesis of peer-reviewed literature. Five major themes were identified for the integration of artificial intelligence for sustainability achievements in event management. The themes identified include energy and resource optimization, waste reduction and circular economy practices, transportation optimization and emissions management, crowd management and accessibility strategies, and sustainability measurements and verification. This thematic structure serves as a basis for organizing this thematic synthesis. The cross-theme synthesis forms a premise for a conceptual framework for Saudi Arabia.

4.1 Data Gathering and Synthesis Approach

The findings are derived from qualitative synthesis of peer-reviewed articles selected through the narrative review process. Each study was analysed for its contributions to AI applications, sustainability dimensions, and relevance to event operations. Extracted patterns were compared across studies, coded into preliminary categories, and refined into the five thematic areas presented below. The synthesis emphasises convergences in the literature, identifies recurring mechanisms, and highlights gaps requiring further investigation.

4.2 Energy Efficiency and Resource Optimization

A review of peer-reviewed studies shows an increasing use of artificial intelligence (AI)—including machine learning (ML), deep learning models, hybrid techniques, and adaptive control methods—in managing building energy use. This body of research demonstrates substantial improvements in efficiency and resource optimization. Although most of this work centers on smart building systems rather than event-specific contexts, it still serves as a strong foundation for potential applications within event infrastructure.

Several reviews and meta-analyses report measurable energy reductions when AI is applied to building control. A meta-analysis covering 126 studies from 2010 to 2024 found that hybrid AI methods and reinforcement learning achieved the highest energy savings at 28.1% and 22.3%, while supervised approaches delivered moderate savings of about 14.7% (Gunasena et al., 2025). Similarly, recent summaries of research on machine learning and deep learning for HVAC and building automation systems show that AI-based control allows for energy reductions while maintaining acceptable indoor environmental quality (Tien et al., 2022).

More targeted analysis appears in the work of Spanos et al. (2024), who examined how ML can support energy-efficient “smart” residential and commercial buildings. They argue that ML-driven demand forecasting, occupancy prediction, and building control can outperform traditional rule-based systems by striking a more precise balance between efficiency and comfort. They also point out that buildings consume large amounts of energy worldwide and contribute significantly to greenhouse gas emissions, making them critical targets for decarbonization—and highlighting the potential impact of ML in this area. Additional evidence comes from focused reviews on AI-enabled smart building management. For instance, one review examining ML applications for energy forecasting, non-intrusive current load monitoring, predictive maintenance, and system optimization reports savings ranging from 15% to 40%, depending on building category, climate, and system complexity (Noura, Salman & Chahine 2025; Gracia et al., 2023). Another review assessing building management automation using AI combined with Internet of Things (IoT) sensors concludes that integrating these technologies improves energy management, increases energy efficiency, and reduces energy loss (Farzaneh et al., 2021).

As far as energy conservation aside from the aforementioned savings available in this current research study, available literature regarding energy conservation points out that one of the factors contributing to this goal of energy savings and energy conservation as a whole is based on the use of artificial intelligence. This technology may help avoid wastages in heating, ventilation, and cooling and lighting systems based on occupation and environmental parameters and can adapt to changes in variables in a real-time manner for energy savings and reduction of emissions (Woldegiyorgis et al., 2025).

Nevertheless, a uniform literature does not exist. Certain limitations concerning structures and contexts appear:

Firstly, most research focuses primarily on conventional building types such as offices, residential buildings, and commercial buildings. Gunasena et al. (2025) state that a meta-analysis shows that about 78% of research relates to office buildings. This generated a query regarding whether this energy optimization using AI would be applicable for event facilities because of the stark contrast in usage profiles.

Secondly, climatic/geographic bias emerges. Indeed, a large amount of such studies has taken place in temperate zones. This hinders the application of those results to warmer environments with larger variations in temperatures. This would include Middle East countries such as Saudi Arabia. As pointed out by Gunasena et al. (2025), only 33% of those studies have taken place in climatic conditions other than temperate zones. This means that energy performance may be overstated in warmer environments where cooling dominates.

A third limitation would be that most of the current studies are still only simulations and/or experiments. Large-scale studies in realistic environments are still relatively rare. As pointed out by

Tien et al. (2022), most studies of machine learning and deep learning have promise for experiments but typically involve no form of post-occupancy evaluation, leaving a degree of uncertainty about sustainability benefits being maintained in real-world settings.

Fourthly, there appears to be a continued emphasis towards optimizing single systems individually instead of optimizing more than one type of resource. As indicated in the results shown in the findings of Gunasena et al. in 2025, 76 percent of literature reviews retained a focus on single building systems. This particular issue becomes more prominent when considering large-scale events with complex relationships in energy, water, waste, and HVAC.

Fifth, trade-offs with regard to indoor environmental quality are still open to debate. While most studies focus on energy efficiency benefits, few focus on comfort conditions for building occupants when optimal control solutions are used, which would be particularly pertinent where a large number of people are brought together, significantly exceeding typical office room population levels. On the other hand, several potential limitations exist for successful execution: for effective AI-related energy management solutions, a strong sensor infrastructure for energy control purposes, accurate data, and qualified staff may be absent in existing buildings.

Taking into account such factors, optimizing energy and resource usage with help from AI remains a prominent path forward in making event space environments more sustainable. This would be applicable for existing event space structures equipped with the right infrastructure such as convention centers, sports stadiums, and exhibition halls. In regions such as Saudi Arabia with similar climatic conditions, climate-responsive performance gaps confirm that region-responsive adjustments are a critical factor.

Furthermore, temporary event infrastructure used for festivals and pop-up events may face unbalanced usage distributions that may worsen existing problems because such infrastructure does not use automation technology that would help in optimizing. Therefore, in spite of the strong theoretical and empirical basis underlying contemporary research in building energy studies today, a critical and pressing need exists for empirical research relating to event facilities being conducted in a hot and arid climate with regard to using AI optimization for energy. This would include studies relating to resource management, comfort studies, and Indoor Environmental Quality.

The peer-reviewed literature supports the potential of AI — particularly through machine learning, adaptive control, hybrid models, and real-time sensing — to deliver meaningful energy and resource efficiency gains in buildings. Yet, important limitations and contextual gaps (building type bias, climate bias, limited real-world deployment, narrow subsystem focus, IEQ tradeoffs, deployment barriers) constrain the generalizability of these results to event venues, especially in hot climates such as Saudi Arabia. This assessment underscores both the promise and the critical need for contextualized empirical research in AI-enabled sustainable event management.

4.2 Waste Reduction and Circularity — Literature Synthesis

Current empirical studies have shown that one of the major drivers for waste reduction and a circular economy would be a catalyst role played by artificial intelligence. Thus, when coupled with sensor technology and data systems, the application of artificial intelligence in urban waste management has shown a great potential in waste classification and separation, logistics of waste management, and recycle operations with the end goal of decreasing landfill dependence and increasing material recovery (Fang et al., 2023; Dao et al., 2025; Idrissi et al., 2025).

There appears to be a uniform consensus in literature concerning automated waste sorting that machine learning and deep learning techniques outperform human sorting. A systematic review of one hundred studies indexed regarding AI-assisted waste sorting reveals that convolutional neural networks using transfer learning are the most effective methods in this regard with a number of systems capable of reaching a high classification rate in a controlled environment (Fotovvatikhah et al., 2025). Also, in a study regarding a smart bin system using visual recognition technology with a robotic arm and a VGG16 neural network, a total accuracy of 98 percent was achieved for classifying Wet Waste, Sorted Trash, and E-Waste (Ruparel, Chaudhary & Rathod, 2024).

Besides classification tasks, AI serves as a means for enhanced optimization within waste management. A recent literature examination regarding smart city adoption of AI illustrates that smart waste management systems using AI technology—ranging from smart garbage bins, garbage-sorting robots, models for forecasting garbage generation, logistics optimization for garbage management, and optimizing waste-to-energy processes—can potentially lower garbage collection distances by 36.8%, reduce garbage collection expenses by 13.35%, and accelerate garbage collection processes by 28.2%, with only a slight compromise in classification levels among 72.8%

to 99.95% depending on conditions (Fang et al., 2023). In addition, a 2025 systematic literature acquisition among 152 literature studies utilizing AI and ICT published between 2018 and 2023 identifies valid improvements regarding waste forecast precision, garbage collection route optimization, garbage sorting efficiency, and total garbage recycle quality for optimal circular economy practical management outputs (Idrissi, Benabbou, & Elhaji, 2025).

Scientific studies have confirmed the efficiency of such integrated methods. Thus, for example, in a mixed waste environment with a complex sorting process, a machine learning model for waste recycle (AMLWRF) outperformed other methods for material separation and produced more accurate classification when compared with other approaches (Abed Mohammed et al., 2022). Examples such as this clearly demonstrate how AI can help shift a waste management system based on a linear disposal model to a cyclical model based on a systematic segregation of waste.

In general, existing literature suggests a gradual transition where conventional waste management approaches are being replaced with more AI-based approaches for a circular economy. Researchers who have contributed to this literature recently (Dao et al., 2025; Fang et al., 2023; Idrissi et al., 2025; Abed Mohammed et al., 2022) clearly establish that because of the automation capability of AI and machine learning algorithms' potential for data analysis for more complex waste generation trends typical of modern consumption patterns, AI can be considered a relevant technology for effective waste management.

In a number of studies, a number of themes appear. Firstly, a number of themes are associated with innovations based on AI for classifying and sorting waste for a circular economy. Whether based on vision algorithms using CNNs, smart bins with sensors, or robotic sorting systems, using AI has resulted in a cleaner sorted fraction with lower levels of contamination compared to manual sorting (Fotovvatikhah et al., 2025; Ruparel et al., 2024; Abed Mohammed et al., 2022).

Secondly, integration of AI with logistics and collection systems also emerges as a major trend. Smart waste management platforms using AI often involve classification systems together with route optimization systems that use fill level sensors to develop dynamic routing schedules based on projected quantities of waste. This thus cuts down distances and number of trips as well as environmental and operation costs associated with waste collection (Fang et al., 2023; Idrissi et al., 2025).

Thirdly, a lot of effort has been put towards ensuring that the solutions developed are indeed scalable. This has ranged from small-scale environments such as bin level to municipal level municipal waste management. Applications of AI have been classified depending on the level of adoption. This includes micro level adoption for smart bins and managing domestic waste, meso level for municipal logistics and waste management, and macro level for managing industrial waste and energy-from-waste (Snoun et al., 2025; Fang et al., 2023).

Fourth, a consensus appears to be emerging with regard to the application of AI throughout a total circularity cycle, ranging from sorting and re-cycling to waste energy conversion (Fang et al., 2023; Snoun et al., 2025). This tends to confirm that even more extensive uses of AI may be made for purposes of waste management other than for efficiency enhancement. Nevertheless, in spite of a promising body of evidence, several critical gaps and limitations continue to exist that preclude confidence with regard to a total applicability of AI for this particular end.

One of the key concerns identified in this literature is that most studies have dealt with municipal or urban waste management systems in general. The significance of event-related waste generation with a large volume of waste produced in a small interval of time and represented by heterogeneous waste such as kitchen waste, packaging material waste, single-use item waste, plastics, organic waste, and electronic waste.

The other gap identified would be those concerning infrastructure dependencies. The viability of AI-based waste management solutions relies heavily on factors such as data acquisition infrastructure, technology supporting smart bins and robotics for sorting, among others. This particular issue has come up several times as a barrier to the generalizability of research results (Idrissi et al., 2025; Dao et al., 2025). Another gap would be that with little research being conducted using real-world performance evaluations. Although various AI waste classifiers perform well when put to real-world evaluations with several rounds of waste processing, little research has been conducted to establish their robustness.

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The current state of problems includes diversity and contamination in waste. In cases where diverse waste types contain a mixture of organic waste, dirty containers, liquids, and composite material wastes, classification efficiency tends to be hampered. The current state of classification systems tends to be efficient for cleaner and better-arranged inputs. However, when a classification system encounters more disorganized inputs associated with real-world waste types, efficiency tends to decline. This occurs because training a classification model for unbalanced data across varying types might be challenging (Fotovvatikhah et al., 2025; Dao et al., 2025). Additionally, more general factors related to systemic and governance aspects have received little attention. Although the importance of technical feasibility has come more to the fore, far fewer studies have focused on other factors such as social acceptance, regulatory frameworks, economic interests, and organizational preparedness for a successful transformation towards a circular economy.

In view of this, the potential for waste reduction and circularity using AI technology appears to be strong for event-related settings such as mass gatherings and exhibitions. There appears to be evidence supporting the use of smart bins and sorting robots in municipal waste management systems for a possible reduction in waste generation for events such as those mentioned. However, a number of gaps still exist. This highlights a key role for empirical pilots in environments where waste composition and amount are much more variable. This needs to examine degrees of classification error, levels of contamination in separated waste, infrastructural needs, cost comparison, and user acceptance. Additionally, adaptive positioning based on a certain context might be very important in a climate and geography such as that of Saudi Arabia. This would help adapt to differences in waste composition and usage levels that exist between Saudi Arabia and other countries.

4.3 Transportation and Mobility Optimization — Literature Synthesis

During recent years, a marked increase has been observed in literature regarding the use of artificial intelligence (AI) and machine learning (ML) methods for mobility and traffic systems with emphasis on optimizing traffic flow efficiency, congestion reduction, routing improvement, and sustainability. Analysis of current literature reveals that traffic management using AI can significantly increase traffic efficiency and decrease congestion along with addressing environmental sustainability via lower emissions and associated benefits (Jain & Pandey, 2025; Gheorghe & Soica, 2025; Zhang & Yang, 2017).

A systematic review conducted in 2025 analyzed 46 studies published between 2019 and 2024. Jain and Pandey highlight that only sophisticated approaches using deep NNs, GANs, and hybrid optimization methods were found to outpace traditional methods based on simple ML algorithms for tasks such as traffic flow prediction and traffic density classification. Their results indicated that traffic classification problems using RNNs achieved 95 percent accuracy and 98 percent using GANs for traffic density classification. Hybrid models combining optimization methods with neural networks achieved values for R^2 of 0.999 for traffic flow prediction tasks, which indicate a strong fit to the data (Jain & Pandey, 2025).

Additionally, aside from prediction capability, other benefits include those obtained by combining ML with Internet of Things (IoT) technology and adaptive traffic management systems. For example, recent literature has shown that average congestion delay can be reduced by as much as 30% with adaptive traffic systems using AI and IoT. New models for congestion management in real time have also recently developed; for example, a hybrid model called DTS-GRU uses GRU neural networks along with methods for optimizing congestion prediction and management for smart cities. This model uses traffic data such as flow, speed, and volume to adapt management policies for intelligent systems and yield congestion relief compared with traditional traffic management methods.

Another series of studies focuses on traffic optimization using AI technology in the scope of autonomous vehicles (AVs). The studies argue that coupling AVs with predictive routing and infrastructure analytics via AI can help reduce traffic congestion and optimize vehicle-to-everything (V2X) communication. The potential sustainability gains for such AI-related mobility optimization methods are quite prominent. Optimized traffic conditions, minimized stop-and-go cycles, and reduced idling time would help reduce emissions of fuel emissions and thus add towards urban sustainability (Gheorghe & Soica, 2025; Zhang & Yang, 2017; Nosratabadi et al., 2020).

A literature review indicates a number of trends existing. Firstly, a lot of researchers emphasize that a combination of deep learning techniques with optimization approaches and real-time traffic information leads to a more effective traffic prediction and flow optimization using a hybrid AI approach than other methods (Jain & Pandey, 2025; Gheorghe & Soica, 2025).

A visible trend towards the integration of Internet of Things (IoT) technology concepts with Artificial Intelligence approaches and adaptive control systems emerges. This integration allows current traffic signal infrastructure and overall urban infrastructure to evolve from static schedule-dependent operation to a dynamic operation that requires real-time adjustments. This adaptability allows for responsiveness towards changing traffic conditions and irregular traffic demands such as those witnessed during weekends (Gheorghe & Soica, 2025; Chaudhary et al., 2025).

A number of studies emphasize scalability and transferability with regard to diverse environments, ranging from small urban areas to a city-wide network that includes autonomous vehicles, public transit, and personal cars (Nosratabadi et al., 2020; Zhang & Yang, 2017). This refers to the far-reaching uses of mobility optimization using AI.

Sustainability performance might be directly associated with particular targets such as a decrease in traveling time, waiting time, idling time, and emissions. Some research studies recognize environmental gains realized via traffic optimization. This makes mobility systems using AI helpful for environmental sustainability in urban areas (Gheorghe & Soica, 2025; Zhang & Yang, 2017; Nosratabadi et al., 2020).

Nevertheless, several questions and gaps exist with regard to the current state of advancement as indicated in literature. Firstly, much of this operational work has only taken place in simulations and pilots. Large-scale evaluations have only remained limited. This means that little can be said regarding its effectiveness in dealing with certain unexpected incidents in traffic.

Questions of safety, ethics, privacy, and equity appear relatively less frequently. While most studies focus on efficiency and optimizing traffic flow, fewer explore how such smart systems use AI to address questions of protecting data (geolocation and vehicle data), equity with regard to user types (public and private traffic), among others.

Little data exists with regard to using AI technology for mobility optimization in terms of event-related peak periods. This type of scenario encompasses those areas in which routing forecast techniques and integrated crowd & vehicle flow analysis would produce maximum applicable benefits. This stems from the fact that a mass event generates a distinct congestion form.

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The connection between traffic management using AI and multimodal mobility infrastructures such as public transport systems, pedestrian movements, chauffeur-driven services, and micro-mobility has received little examination. Current models primarily emphasize road traffic without considering how AI might interact with numerous mobility ecosystems.

Nevertheless, while studies often focus on figures of merit regarding prediction accuracy, elimination of delays, or relief from congestion, very few studies examine environmental impacts such as total emissions savings and/or social aspects such as equality with regard to mobility.

4.4 Safety, Monitoring & Social Well-Being — Literature Synthesis

Artificial intelligence (AI), with a focus on computer vision, finds increasing use in improving public security and accessibility. Within environments where crowd regulation and accessibility are of importance, AI finds great potential in density prediction and anomaly detection. Also, AI would help with accessibility for disabled individuals, leading to overall social welfare improvement.

Literature studies about crowd surveillance with AI technology have shown that computer vision and deep learning algorithms have a capability to measure crowd density effectively, identify unusual behavioral patterns accurately, and handle dynamic flow management effectively. For example, a study proposing a 'Crowd Monitoring and Localization' system used deep convolutional neural networks to examine CCTV and video content in a wide range of settings such as parks, airports, sports stadiums, and public sites. This particular system effectively addressed conventional issues regarding crowd surveillance—density changes, occlusion problems, and unbalanced density distributions—and illustrated its potential use as a replacement for manual human observation in a security surveillance system (Khan et al., 2020). A major achievement observed in this regard regards a crowd counting and density map localization algorithm called 'Composition Loss,' tested for extremely dense scene conditions using the challenging UCF-QNRF dataset containing more than one million annotated head points accurately. This achieved state-of-the art results in such extremely dense real-world setups, thus effectively emphasizing the potential use of computer vision algorithms even in extremely challenging environments (Idrees et al., 2018).

In regard to events and massive gatherings, several studies have observed that there exist AI-based crowd analytics solutions appropriate for large gatherings and dense crowds. A particular

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example would be a computer vision solution created for crowd mobility analysis in a religious pilgrimage event, with the capability to approximate crowd density and guide crowd management via data analysis (Khan et al., 2017).

The algorithms used in machine learning have also been utilized for purposes such as crowd counting and density calculation. During the COVID-19 period, a computer vision and deep learning model combining object detection (YOLOv4), Inverse Perspective Mapping (IPM), and SORT (Simple Online and Real-time Tracking) was used for social distancing surveillance in indoor and outdoor settings. This model had a very high level of accuracy (Mean Average Precision: 99.8%) even with occlusion and changing lighting conditions, showing that crowd and safety surveillance using AI remains accurate under varying conditions (Rezaei & Azarmi, 2020). This further highlight that SWWB requirements can be met using AI for density and safety analysis.

Increasingly, the use of AI for improving accessibility receives recognition as a very important aspect of social well-being. Accessibility for individuals with disabilities in navigating and making sense of their environment has received recent coverage regarding computer vision technology and speech-to-text functionality (Ferebee, 2025; CPWD, 2025). Examples of AI-related accessibility include visual description for images, speech-to-text captions, mobility routing assistants, and content creation design (Gibson, 2024).

There are several prominent trends apparent in the literature reviewed. One such prominent trend has to do with developments in computer vision methods for dealing with dense crowds. This has always been a challenging task because of occlusion problems, scale changes, and continuous flow. Methods such as density map learning, composition loss learning, and convolution neural networks trained for massive datasets such as UCF-QNRF indicate that superior performance levels can be achieved with AI (Appl. Sci. 2020, 10, 4781; Idrees et al., 2018). This technology means that large-scale events such as a pilgrimage or concert can be efficiently tracked using AI.

Additionally apparent in literature is the trend towards more proactive management systems for crowds instead of reactive surveillance. This evolution requires using intelligence technology with a view to automating the assessment of crowd density and behavior instead of manual surveillance using CCTV cameras. This approach leads to better management of crowds with a

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possible reduction in dangers posed by a mass assembly of individuals (Khan et al., 2017; Rezaei & Azarmi, 2020).

In terms of accessibility research and development studies, there appears to be a shift towards utilizing AI in promoting inclusivity beyond efficiency. As opposed to conventional studies that often-viewed accessibility as a secondary issue when considering technological innovation, current studies relocate focus to assistive technology based on inclusive design for those with disabilities, as well as older individuals and those with mobility and information needs (Ferebee 2025; Gibson 2024; CPWD 2025). This supersedes previous definitions that focus solely on safety.

Another trend that has been identified is the increasing use of multimodal approaches for AI. Modern crowd surveillance solutions often involve a combination of computer vision techniques, sensor data processing, track analysis, and behavioral analysis models. This multi-disciplinary design boosts precision levels and facilitates decisions being made instantaneously for tasks that may be demanded in event-scale settings and/or in a more urban environment (Appl. Sci., 2020, 10, 4781; Khan et al., 2017; Rezaei & Azarmi, 2020).

Nevertheless, in spite of such achievements, a number of gaps and uncertainties exist regarding large-scale events, heterogeneous social environments, and/or distinct geographical regions with tropical climatic conditions and multicultural settings. Though computer vision techniques are successful when used in a controlled environment, there is a scarcity of empirical evidence regarding their effectiveness in a wide range of practical environments such as festival events, concerts, religious gatherings, and/or temporary event structures. This particular work aims at deriving inferences based on available literature regarding crowd analysis.

Secondly, privacy, ethics, and social acceptance are also insufficiently explored. Issues surrounding data privacy and consent with regard to the use of AI-based surveillance systems and crowd analytics were considered; however, to a great extent, the current mainstream literature accessible to researchers does not primarily examine such issues. Compared with other fields, this one has attracted relatively little critical inquiry.

Thirdly, in the context of accessible AI, a clear scarcity of scientific literature exists which continues to address empirical studies associated with extended effects and adoption among individuals with disabilities. A large portion of existing scientific literature appears in conceptual form and/or literature reviews. This further leads to a low level of confidence in practical implications of such technologies.

Lastly, physical and environmental factors such as the need for a high-resolution camera and a stable power source may reduce viability. Mass events in distant and challenging environments may be unable to facilitate sensor and data networking infrastructure for effective crowd surveillance with a sophisticated AI system.

Finally, research remains unexplored for other types of social well-being factors such as comfort levels for users, levels of stress generated because of crowding effects, inclusion of vulnerable populations such as seniors and the disabled, equity of access, along with broader social implications for using AI-related crowd management and accessibility solutions.

4.5 Measurement, Reporting, and Verification (MRV) — AI-Enabled Environmental Monitoring & Sustainability Governance

Artificial intelligence (AI) has recently taken a prominent role in shaping a new paradigm for collecting, processing, and reporting environmental data. This foretells a future where Monitoring, Reporting, and Verification (MRV) occurs in a constant and automated mode without human observation. By coupling AI with environmental sectors of remote sensing and Internet of Things (IoT) environmental sensing networks and big data processing, the scope of environmental-related Monitoring, Reporting, and Verification has widened to include atmospheric environments and quality data, emissions data, land use and biodiversity evaluation data, waste management and pollution data, and climate variables data (Alotaibi & Nassif, 2024; Miller et al., 2025; Janga et al., 2023). This seems to unveil a future where sustainability and environmental regulatory requirements are demanded with a focus on transparency and sustainability.

A bibliometric analysis of 4,762 publications sourced between 1991 and 2024 shows a steadily increasing number of publications using AI and machine learning for environmental observation dating back to 2010 with a focus on ambient quality, land use dynamics, biodiversity assessment, and climate studies (Alotaibi & Nassif, 2024). This observation can be attributed to a recognition that conventional approaches such as manual sampling, auditing, and low-resolution observation methods are no longer effective for environmental observation and management. The use of AI in remote sensing and data analysis closes this gap with better resolution and coverage (Miller et al., 2025; Bhargavi et al., 2023).

There appears to be evidence of practical benefits for environmental surveillance. Machine learning and deep learning models have been used for the evaluation of multispectral and hyperspectral satellite imagery and ground station measurements to determine carbon emissions source regions for emissions reduction verification purposes in industrial and urban areas. Additionally, environmental changes have also been observed via machine learning and deep learning models using UAV data for emissions reduction purposes (Ojadu et al., 2025; Bhargavi et al., 2023). In most cases, machine learning and deep learning techniques have shown faster processing speeds compared to other methods of environmental surveillance (Arowolo et al., 2024; Janga et al., 2023).

Besides environmental observation, another importance of artificial intelligence systems for verification and reporting purposes lies in automating data aggregation, quality assurance, anomaly detection, analysis of trends, and report generation capable of supporting regulatory requirements. Also, combining diverse data inputs such as satellite data, Internet of Things data, meteorology data, existing baselines, and even social data makes environmental dashboards more accessible. Thus, one more role of artificial intelligence systems serves regulatory requirements for environmental observation, environmental aspect of ESG reports, sustainability goal achievement observation, and decision-making for event planners and other parties involved (Miller et al., 2025; Arowolo et al., 2024).

Taken together, these developments promise a shift towards environmental management with a focus on using AI for measurement, reporting, and verification (MRV) that ensures environmental management becomes a constant and verifiable process. As such, instead of using audits or manual methods of measurement for environmental management, this process can be made adaptive with changes based on near-real-time measurements of environmental factors such as emissions and usage.

Despite this background information, there appear to be certain deficiencies outlined in existing literature. Firstly, data quality and data availability seem to be foremost among such deficiencies. A number of studies utilizing AI-MRV involve high resolution satellite data, extensive sensor networks, as well as sophisticated Internet of Things (IoT) networks. As a result, their

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adoption in countries with poor sensor networks for data coverage and poor data management and technological infrastructure may be a concern (Bhargavi et al., 2023; Arowolo et al., 2024). Additionally, satellite data acquisition may be affected by cloud interference, poor resolution of satellite data used in observation purposes, revisit cycle time for satellites, as well as a lack of ground truth data (Bhargavi et al., 2023; Popescu et al., 2024). A concern stems from the fact that most existing models are opaque—termed “black-box” models—which may adversely affect transparency and accountability. Without a mechanism to employ explainable AI (XAI) techniques and traces to back environmental indicator outputs produced using such black-box models, one may rightfully be left wondering about their credibility regarding environmental indicators produced with such outputs (Alotaibi & Nassif, 2024).

Scalability beyond pilots and research settings remains a challenge. There are only a few cases showing that Monitoring, Reporting, and Verification (MRV) systems with AI are maintained for a prolonged period of time beyond a specific region and industrial sector. As a consequence, there is little empirical data available and no consistency (Bhargavi et al., 2023; Miller et al., 2025). A new concern emerges regarding the environmental impact generated by AI. Several studies have shown that training huge models, processing huge RS datasets, as well as maintaining data centers, require a lot of energy. Consequently, this casts a shadow of a doubt on whether "green" benefits achieved using AI-based MRV are overshadowed by energy needs associated with this technology (Himeur et al., 2022).

Finally, issues regarding governance and equity have received little focus. In fact, for AI-MRV systems, transparency and institutional capability with regard to data are critical. Without such capability, potential problems such as data misuse and inequitable use of surveillance practices exist. They have received little explicit attention in existing empirical studies (Alotaibi & Nassif, 2024; Arowolo et al., 2024).

Taken collectively, there appears to be a great potential in the literature for a transformation of sustainability governance based on AI-supported MRV. However, this potential remains conditional with regard to overcoming data infrastructure bottlenecks and other associated costs.

4.6 Integrative Summary of Findings

On each of the five themes identified in this literature review—energy efficiency/resource optimization, waste reduction and circular economy strategies, transportation/mobility optimization, safety/surveillance and social welfare provisions, and verification of measurement and reporting—there appears to be a potential role for using artificial intelligence as a management tool with a focus on sustainability and social responsibility.

In the field of energy and resource management, the use of AI, when integrated with building automation systems, sensor networks, and/or digital twin technology, shows promise for producing a marked amount of energy savings as well as efficiency gains for resource use in buildings. Modern systematic reviews and empirical research converge in finding that energy savings and reduction of wastages produced using building automation systems controlled with AI represent a strong case for sustainable infrastructure (Bibri & Huang, 2025; systematic reviews of AI use in smart buildings).

Waste management practices and circular economy strategies map similar uses of AI. In waste management systems, using AI for sorting, optimizing waste-to-energy, logistics optimization, and smart bins boosts the effectiveness of trash classification. Literature studies have identified potential uses of AI for optimizing distances and associated expenditures for waste logistics while making efficient uses of waste-to-energy and environmentally responsible practices for recycling (Fang et al. 2023; Alsabt, Alkhaldi & Adenle et al. 2024).

In mobility and transport, using AI for traffic prediction, routing algorithms, and system optimization opens opportunities for easing congestion and emissions. In conjunction with urban design and logistics for events, such technology can facilitate sustainable mobility strategies aligned with sustainable building design and waste management practices in a sustainability agenda (empirical studies showing lower emissions and energy use when using AI for mobility and transport systems). The scope of safety, surveillance, and welfare may be smaller in comparison but clearly highlights that research areas such as real-time surveillance systems, crowd surveillance systems based on sensors, and simulations using digital twins are applicable and of importance in public safety and management. This also clearly indicates that sustainability encompasses factors such as social welfare. This coupled with themes such as resource and waste clearly indicates that sustainability with regard to social welfare for safe events and buildings can be achieved with the use of AI.

Within the field of measurement, reporting, and verification (MRV), artificial intelligence (AI) functioned as a strong enabler for continuous and more resolved monitoring, steadily replacing conventional interval audit processes. The use of sophisticated AI technology in MRV has great potential to provide real-time information about energy use, wastage, emissions, resource use, and other sustainability parameters. This would help in operational sustainability as well as sustainability standard requirements being maintained within a pre-defined management structure (Toderas, 2025).

Taken together, this body of evidence points to one inference: integrated AI technologies have the potential to unlock and leverage environmental efficiency, recirculation of resources, mobility optimization, social welfare, and good governance. While being a distinct and standalone measure for sustainability improvement, integrated AI technologies may be a foundational component for a more systems-focused approach to sustainability for a complex and resource-heavy site such as a mass event.

Despite this, a comparison of existing literature also brings out certain gaps and limitations. A major one among those is that the best possible empirical results always come out of studies based on conventional structures, waste management systems running in a state of constant equilibrium, and conventional mobility settings. There does exist a relatively lower number of scientific studies available in peer-reviewed literature with a focus solely on specific events and/or settings influenced by climatic factors. A major portion of existing literature has remained somewhat unorganized with a focus solely either on energy or solely on waste management.

This particular research points out that while AI may increase efficiency and optimization for purposes of sustainability goals, various studies have indicated possible paradoxes. Indeed, energy use and resource requirements concerning operating infrastructure for such processes may limit sustainability gains unless effectively managed in accordance with Green AI best practices (Toderas, 2025).

Of particular concern in this regard would be those factors that rely upon data inputs, sensors, Internet of Things technology, stable connectivity, and existing capacities. This would be a concern with regard to equity and feasibility—particularly within those areas that would be considered less developed. This may inhibit broader adoption of those sustainability projects that use AI.

In conclusion, while a cautious notion of optimism with regard to existing capabilities and developments might be appropriate, a more profound transformation with regard to sustainability and a general level of social well-being might be more realistically considered in a comprehensive integrated application regarding energy management and sustainability approaches integrated with waste management systems, mobility concepts, inclusion-oriented approaches, and appropriate usage of AI towards better governance. This potential has to be tapped with regard to further research for environments where major developments with a possible large-scale population significance might be involved.

5. Discussion

5.1 Interpretation of Findings

The thematic synthesis draws attention to the fact that this level of flexibility for supporting sustainability has become possible only recently using artificial intelligence. However, this study brings to light those limitations that exist despite being strengthened by such technologies while trying to put such intelligence to use for sustainability in Saudi Arabia. In the field of energy and resource optimization using machine learning algorithms along with deep learning and hybrid control methods for optimizing energy efficiency in buildings and similar structures with enhanced energy efficiency levels, a marked level of energy savings has always been identified in various empirical studies. A similar level of energy savings has also been identified when such intelligence associated with integrated heating and ventilation and HVAC systems along with lighting and automation for buildings has come into use (Gunasena et al., 2025; Tien et al., 2022; Spanos et al., 2024). Such studies have always indicated a marked level of success concerning smart buildings and transformation while confirming that optimization using artificial intelligence has strengthened sustainability transitions for smart buildings (Noura et al., 2025; Farzaneh et al., 2021; Rodríguez-Gracia et al., 2023).

A similar body of evidence can be observed in waste management with regard to reduction and circularity processes. The studies made in urban and industrial waste management systems have observed that classification using AI technology, route optimization techniques using AI technology, and dynamic scheduling for recycling purposes lead to a marked enhancement in waste management efficiency. Deep learning types of algorithms outpace manual sorting approaches. Additionally, logistics systems integrated with AI technology reduce waste collection distances and quantities (Fang et al., 2023; Idrissi et al., 2025; Ruparel et al., 2024). Taken together, these studies make one thing clear: this technology makes a more efficient and smoother transition toward a more

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circular economy possible for recycled matter (Abed Mohammed et al., 2022; All Noman et al., 2022). In the mobility and transport arena, existing literature today affirms that sustainability-oriented event-related AI solutions function satisfactorily. Sophisticated traffic prediction algorithms, along with smart traffic management systems managed using IoT technology, reduce traffic congestion and emissions associated with traffic congestion (Jain & Pandey, 2025; Gheorghe & Soica, 2025; Chaudhary et al., 2025). Though little literature might exist for application within event-related research studies today, existing studies describing congestion, idling, and energy-related benefits for major events provide insight into a successful usability level for mobility intelligence systems for such events (Nosratabadi et al., 2020; Zhang & Yang, 2017).

Social welfare: The results for safety, surveillance, and social welfare highlight a rising use of artificial intelligence in the social aspect of sustainability. Modern computer vision systems enable accurate crowd density estimation and anomaly analysis for real-time surveillance in dense environments such as airports, sports stadiums, and religious pilgrimage sites (Khan et al., 2020; Idrees et al., 2018; Khan et al., 2017). The current breakthroughs in accessibility solutions based on artificial intelligence reiterate its importance in the social sustainability pillar with enhanced opportunities for better access for disabled individuals (Ferebee, 2025; Gibson, 2024; CPWD, 2025).

Monitoring, reporting, and verification (MRV) studies underscore the integrational role of AI. Emerging literature points out how environmental observation with a degree of detail unfeasible before has become possible with remote sensing using machine learning analytics based on Internet of Things (IoT) networks (Alotaibi & Nassif, 2024; Miller et al., 2025; Bhargavi et al., 2023). Additionally, AI-based MRV for sustainability management brings more precision and confidence to verification. Thus, automated systems for MRV have become a vital part of any sustainability structure for events that come with certification/validation/suitability requirements (Toderas, 2025; Arowolo et al., 2024; Ojadu et al., 2025).

Taken together, the five themes demonstrate a discernible pattern: AI offers a distinct but interlinked series of benefits pertaining to efficiency in the environment, circularity of resources, mobility optimization, social welfare benefits, and sustainability. While several of the empirical studies outlined above extend well beyond their original event-centric contexts, their underlying mechanics are clearly applicable within a manner responsive to the needs expressed within the events industry in Saudi Arabia..

5.2 Practical Implications

The results have several notable implications for policymakers, event professionals, and technology designers in Saudi Arabia. Within the energy management context, for example, AI-based energy management solution designs promise to ease the operational transformation of event sites such as large exhibition grounds, sports complexes, and event zones being developed under Vision 2030. By seamlessly combining adaptive management techniques with predictive analysis and real-time operational management capabilities, for example, event site owners might be able to lower energy use when peak demand occurs, maximize cooling efficiency in tropical environments, and extend resource life. The strong empirical support for energy optimization using AI identified in contemporary literature indicates that such systems would be successful in optimizing operational expenses while living up to sustainability requirements underlying Saudi Green Initiative commitments, for example, Gunasena et al. (2025) and Tien et al. (2022).

Likewise, using AI technology in waste management offers efficient solutions for events producing large amounts of mixed waste in a short period of time. Smart bins, AI-based sorting stations, predictive models for forecasting waste quantities, and route optimization for waste collection would go a long way in maximizing the recycle quantities and decreasing landfill use for large-scale events such as Riyadh Season, MDLBEAST Soundstorm, and corporate meetings (Fang et al. 2023; Idrissi et al. 2025). Though such technologies depict best practices worldwide, their use in Saudi Arabia requires modification according to Saudi consumption habits and environmental regulations.

As far as mobility and transportation are concerned, traffic prediction and routing using AI can lead to better accessibility and reduce congestion. Smart mobility solutions using sensor networks and analytics platforms can help in modal coordination and shuttle planning for more efficient last-mile mobility. This focus is in line with smart city initiative developments in the nation vision for 2030 (Jain & Pandey 2025; Gheorghe & Soica 2025).

The implications for safety and surveillance purposes as well as social welfare are also significant. Crowd analytics using AI can form a basis for risk analysis and prevention in real time, efficient evacuation strategies, density level surveillance, and prevention of crowd crush incidents

(Khan et al. 2017; Idrees et al. 2018). Accessibility-related AI technology for dense crowds can help in making crowds more inclusive as a means of supporting inclusive involvement in culture (Ferebee 2025; CPWD 2025). Additionally, AI-based Monitoring, Reporting, and Verification systems constitute a basic mechanism for addressing domestic and foreign requirements for sustainability reporting. A one-stop platform combining energy, waste management, emissions, and mobility would make possible sustainability compliance and sustainability assessment for events by their organizers (Alotaibi & Nassif 2024; Miller et al. 2025; Toderas 2025). Despite this integration challenge, a wide range of benefits for the use of AI technology in sustainable event management has been indicated within existing literature.

5.3 Development of a Saudi-Specific Framework

Aggregation of evidence. The current debate emphasizes the importance of creating a conceptual approach specific to Saudi Arabia. This appears to be a novel combination of opportunities and challenges for Saudi Arabia that includes fast infrastructural development, a state-defined digitization strategy, a climatically challenging environment, a risk profile shaped based on Saudi culture and religion, and a regulatory regime aligned with sustainability and data management.

Recent literature points towards such a model being based on three pillars. Firstly, technological enablers such as machine learning approaches, computer vision techniques, digital twins, and decision support systems integrated with artificial intelligence form a basis for sustainability intervention. Sustainability intervention in energy management, waste management, management of transport systems, and management of safety can be made possible with predictive analytics and automation using such technological enablers (Kar et al., 2022; Halim et al., 2023; Greif et al., 2024).

Secondly, for sustainability results to be achieved, consideration must be given to the environmental, social, and economic pillars. This is because artificial intelligence benefits these pillars through energy savings, closing the loop in terms of circularity, inclusive event creation, mobility systems enhancement, and ensuring transparency in governance. As indicated in sustainability literature studies, a sustainability strategy must consider a comprehensive approach that looks beyond more than one pillar without focusing only on environmental, social, or economic sustainability (Dickson & Arcodia, 2013; Tinnish & Mangal, 2012; Kumbara et al., 2025).

Thirdly, some design parameters for frameworks rely on data that are specific to Saudi Arabia. This data includes energy requirements based on climate conditions, sustainability policies in Saudi Arabia, current levels of infrastructure maturity, scale of mega-projects being developed in Saudi Arabia, event trends in Saudi Arabia, and technology transformation levels in Saudi Arabia (Altouma et al., 2023; Alquraish, 2025).

Therefore, this tool needs to offer a combination of worldwide best practices for AI use in sustainability and local aspects. This tool should be capable of being used for a wide array of events, such as temporary outdoor events and fixed convention event sites. There needs to be integration with verification for measurements and reporting for transparency. All of this needs to be compatible with a future-ready environment for events designed in line with Vision 2030.

5.4 Risks and Challenges

Despite the fact that a great number of opportunities for sustainable event management using AI exist, a number of risks and limitations associated with this technology have also been put forward by existing studies. A major risk associated with this technology lies in the adaptability of this technology because most of its sustainability-related applications were designed for conditions that feature stable buildings and favorable climatic conditions (Spanos et al. 2024; Gunasena et al. 2025). This stands contrary to outdoor facilities in Saudi Arabia.

A second challenge concerns infrastructure and data needs. For effective use of AI, a sensor density infrastructure needs to exist. This infrastructure would be a challenge for temporary event environments. The issue then arises as to whether such environments can be scaled using AI. This challenge has been identified for 2025 by Idrissi et al. and Dao et al.

Ethical concerns regarding privacy and social acceptance also continue to be insufficiently addressed. Particularly with regard to computer vision-based applications used for crowd surveillance, several questions have popped up with regard to data protection and social acceptance that are insufficiently addressed in recent studies (Khan et al. 2020; Rezaei & Azarmi 2020). A data regulation-compliant approach also gains prominence in Saudi Arabia because of ongoing developments in data regulation policies.

Issues and considerations regarding environment and use of AI must also be acknowledged. Certain reviews pointed out that a great amount of computing power is currently being used by current models of AI for real-time processing of videos and satellite imagery (Toderas 2025;

Himeur et al. 2022). This factor may moderate any sustainability benefits being advocated by use of AI. Finally, the literature indicates a scarcity of empirical studies that directly examine AI within event-related and/or hot climate settings. Almost all studies today use simulations and/or come from other sectors to address this issue because this would impede any predictive evaluations about how effectively AI would function in the Saudi Arabian event environment (Dickson & Arcodia 2013; Ballarano et al. 2022). Taken together with previous points, this indicates a number of factors which make a delicate and responsive approach to implementing sustainable event management and AI a realistic requirement. By addressing this gap, Saudi Arabia would be fully capable of using AI for sustainability purposes and living up to its sustainability ideals.

6. Conclusion and Recommendations

This review makes it clear that a new level of sustainability improvement in managing events can be introduced through artificial intelligence. Through a compilation of peer-reviewed studies in energy optimization techniques, waste management, environmentally responsible mobility systems for events, as well as specific event-related factors concerning security and social welfare along with sophisticated verification methods for sustainability assessment, this literature clearly reveals that a major capability pertaining to managing energy-intensive as well as complex social factors associated with current events management exists with artificial intelligence. Though most of the empirical data available pertains to other conventional smart processes such as smart buildings, smart waste management systems, smart mobility systems for urban environments, and environmental surveillance.

Throughout previous research, a clear trend indicates that AI has always had the potential to augment prediction capacities for real-time decision-making. Whether in energy and resource management, where adaptive forecasting via AI leads to reduced consumption and emissions; waste management, where prediction capabilities via AI lead to efficient sorting; traffic management, where AI leads to efficient routing; environmental sustainability and accessibility management, where AI enhances crowd management; and finally emissions calculation and reporting systems, where AI leads to a level of specificity beyond current capacities, this capability highlights the overall potential of this technology to facilitate a shift towards a culture of safe and environmentally responsible event management in Saudi Arabia.

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At the same time, the need to adapt these approaches to fit local needs is emphasized. The imperfections of today's state of evidence—marked by a preponderance of simulations, a geographical focus in temperate zones for a great number of studies, and a focus for most studies conducted in existing buildings instead of event locations—make a simple transfer of current AI application themes in other fields directly to Saudi Arabia impossible. Local conditions such as intense temperatures, a fast pace of infrastructural development, usage types, and a level of events associated with Vision 2030 require locally adapted solutions. The Saudi Arabian model used in this research takes this into account with a focus on aligning technology enablers and sustainability pillars with a local/national environment.

Literature identifies two major conclusions. Firstly, current literature reaches a level of quality that allows a conclusion about Saudi Arabia being a region with great potential for realizing a more sustainable events environment via the use of artificial intelligence. Secondly, for this potential to be realized, Saudi Arabia needs a responsible use of AI in a manner informed about data management and ethics involved in organizing. Additionally, for this potential to be realized, one needs collaboration between event promoters and SDAIA.

Taken together, this review presents a comprehensive array of insights and a conceptual model informed by a particular context for applying strategy using AI for sustainable event management in Saudi Arabia. This current study has synthesized a wide array of evidence to inform opportunities and limitations for making use of AI as a catalyst for sustainability. This study forms groundwork for future studies regarding Saudi Arabian events with a focus on testing this strategy using AI for sustainability.

6.1 Recommendations for Future Research

Below are some statements defining possible research directions with a focus on the Saudi Arabian environment to measure the performance of artificial intelligence in various types of events.

- Engaging in empirical research focusing on incidents within Saudi Arabia to evaluate how effectively AI performs in practical settings such as festival events, exhibitions, sports games, religious meetings, and similar events.

- Longitudinal studies should be conducted to establish whether sustainable outcomes regarding effectiveness and sustainability are achieved when AI systems are deployed.
- Assessing the performance of AI in challenging climatic conditions with a focus on high temperatures and its effects concerning energy requirements for crowds and event infrastructure in Saudi Arabia.
- Evaluating data governance, ethics, and privacy policies regarding the use of AI-based crowd monitoring systems and Monitoring, Reporting, and Verification (MRV) systems. This ensures responsible use of such technology in a manner compatible with culture.
- Assessing the environmental impact of AI in terms of energy use, hardware needs, and carbon emissions to determine the total sustainability factor contributed by AI-based systems.

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