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AI-Driven Environmental Management System: Assessing Implementation, Practitioner Involvement, and Opportunities for Continuous Improvement

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Abstract

Artificial Intelligence (AI) is increasingly recognized as a transformative technology for enhancing Environmental Management Systems (EMSs); however, successful implementation remains constrained by organizational, technological, and governance-related challenges. While the existing literature has largely examined AI adoption, environmental management, and supply chain sustainability separately, limited attention has been given to how organizational readiness, practitioner involvement, data integrity, and responsible AI governance collectively influence AI-enabled Environmental Management System (EMS) implementation and continuous improvement. This study addresses this gap through a qualitative case study involving three focus group discussions with eighteen (18) cross-functional professionals such as quality managers, SHERQ officers, supply chain analysts, sustainability managers, HSE managers, and continuous improvement specialists. Upon conducting the third focus group discussion, sampling ceased, thereby reaching thematic saturation, and data was analyzed using thematic analysis. Using reflective thematic analysis, and the Technology–Organization–Environment (TOE) framework as a theoretical lens, the study identifies two themes: challenges related to AI implementation, operational efficiency and data integrity. The findings reveal that organizational readiness, practitioner involvement, data quality, system integration, and governance mechanisms are critical enablers of successful AI implementation, while fragmented systems, manual reporting, privacy concerns, AI reliability, and resistance to change remain significant barriers. Building on these findings, the study proposes an extended AI-driven EMS Continuous Improvement Framework that integrates TOE dimensions with responsible AI governance, emphasizing human oversight, transparency, accountability, and ethical AI use. The study presents a practical implementation pathway to guide organizations from readiness assessment and data standardization to AI governance and continuous improvement. By extending the TOE framework to the context of AI-enabled EMS, the study contributes to theoretical and practical knowledge by demonstrating that sustainable AI adoption depends not only on technological capability, but also on practitioner involvement, data integrity, and governance structures that support continuous improvement.

Keywords: Artificial Intelligence (AI); Environmental Management System (EMS); practitioner involvement; implementation; continuous improvement; sustainability; Technology–Organization–Environment Framework

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1. Introduction

AI is reshaping our society in many various ways, offering both opportunities and challenges across different disciplines in organizations, including environmental management [1]. According to Edo et al. [2], there is a rapid increase in harmful human activities that damage the environment. Therefore, innovation strategies should be implemented to mitigate the environmental issues that result in ecological threat. Ogun Bukola [3] supports this by mentioning that these activities result in increasing awareness of environmental challenges, leading to increased interest within supply chain industries in terms of environmental performance.

Abuladze et al. [4] think that this rise requires us to embrace AI-enabled solutions, as they can revolutionize the approach to tackling environmental challenges. In this study, AI-enabled and AI-driven are used to describe systems that incorporate artificial intelligence technologies to support environmental management processes. While AI-driven generally implies that AI plays a primary decision-making role and AI-enabled suggests that AI supports human decision making, both terms are used in the broader literature to describe technology-enhanced management system.

As stated by Kraus [5], AI is far from being a distant forecast but is now an integral part of the current EMS. Kraus [5] further illustrates that incorporating AI into Environmental Management Systems provides considerable advantages. Konya and Nematzadeh [6] supported this by indicating that the application of AI within Environmental Management Systems has led to significant decreases in CO_2 emissions and energy consumption.

Although numerous reports advocate for AI, few studies have been conducted to comprehend the effect of AI on contemporary EMSs in the supply chain industries. Zein [7] is a notable example, as it delves into how Artificial Intelligence can contribute to EMSs by focusing on the supply chain industries. The supply chain industries are significantly transformed by AI. Companies that focus on manufacturing and logistics within the supply chain can take advantage of AI to manage the forecast shipping requirements and large-scale freight forwarding operations.

However, there is a need to pay attention to the businesses' environmental aspect, which is the Environmental Management Systems. Hens et al. [8] defines EMSs as "a set of processes and practices that enable the company to reduce its environmental impact and increase operating efficiency through consistent review, evaluation, and improvement of its environmental performance."

The study focuses on assessing AI implementation, practitioner involvement, and opportunities for continuous improvement within the EMS. Over the past few years, many organizations have increasingly adopted EMSs to promote sustainable practices, enhance regulatory compliance and improve environmental performance. In terms of the supply chain industry, there is a remarkable shift towards embracing environmental sustainability, which is driven by a growing awareness of environmental issues and the need for businesses to reduce their ecological footprint. Organizations operating within the supply chain sector have implemented a comprehensive Environmental Management System framework known as ISO 14001 [9].

The framework assists businesses in complying with regulatory requirements, reducing carbon emissions and air pollution, meeting consumer demands, and acknowledging the economic and reputational advantages of sustainable practices [10]. This ISO standard was established to efficiently incorporate environmental considerations into different product and process standards. Additionally, the significance of the supply chain has become more recognized within comprehensive environmental management approaches, which are progressively evolving towards sustainable supply chain management across various stages.

As automation continues to expand across multiple industries, a significant volume of data is produced, making the process of manually retrieving data and ensuring accurate, prompt data gathering increasingly unfeasible. Hence, industries within the supply chain still encounter numerous challenges when attempting to reduce environmental issues.

Environmental management is becoming increasingly concerned globally, which stems from issues such as global warming, air pollution, rising CO_2 emissions, land degradation, and economic exclusion [11,12]. As a result, this study assesses the implementation of AI, the involvement of environmental practitioners and the opportunities for continuous improvement for enhanced Environmental Management System.

The call for sustainable change in terms of human–environment relationships is a global concern that challenges businesses and nations to foster the best approaches to developing better Environmental Management Systems, and, most importantly, to create awareness of environmental issues stemming from human activities, which must be reduced.

According to Ravikumar [13], there is an "increased demand for environmental technologies that can help reduce greenhouse gas emissions, conserve natural resources, and minimize waste" and "an efficient framework designed to lower companies' environmental footprint, increase operating efficiency, and help integrate green improvement initiatives into business operations."

1.1. Research Problem and Gap

Based on the above, the research problem of this study is that previous research has mostly focused on supply chain sustainability and EMS implementation independently, with limited attention given to assessing AI implementation, practitioner involvement and continuous improvement opportunities to enhance the quality of Environmental Management Systems. This gap limits the ability of organizations to fully understand the advantages and disadvantages of AI implementation for better decision making, and the role of practitioners to continuously improve the quality of Environmental Management Systems. Moreover, although previous research has provided valuable insights into the benefits of AI implementation in EMSs, comprehensive studies that examine the collective impact of AI implementation, practitioner involvement and assessing continuous improvement opportunities to enhance the quality of Environmental Management Systems are lacking.

Therefore, this research intends to bridge this gap by assessing AI implementation and practitioner involvement to enhance environmental management system effectiveness. It seeks to establish a solid basis for strategic decision making in enterprises focused on enhancing Environmental Management System effectiveness. This proactive approach seeks to mitigate the risk of non-compliance and enhance health, safety, and environmental measures for both employees and the public.

1.2. Research Objectives

The following objectives guide the investigation by defining the specific actions undertaken to address the identified knowledge gaps. Each objective contributes directly to achieving the research aim.

1.2.1. Research Objective 1

To assess the involvement and influence of environmental practitioners and supply chain professionals in the implementation and success of AI-driven Environmental Management System (EMS) initiatives.

1.2.2. Research Objective 2

To identify areas within Environmental Management Systems (EMS)where AI applications remain underutilized and to explore how targeted AI deployment can enhance EMS effectiveness, operational efficiency, and continuous improvement.

To provide conceptual clarity, this study differentiates effectiveness and operational efficiency within the context of Environmental Management Systems (EMS). Effectiveness refers to the extent to which an Environmental Management System (EMS) achieves its intended environmental objectives, regulatory compliance requirements, and sustainability outcomes. This differs from operational efficiency, which focuses on optimizing the resources, costs, time, and processes used to achieve these objectives. While operational efficiency emphasizes doing things right, effectiveness emphasizes doing the right things and achieving the desired environmental outcomes. Consequently, an EMS may operate efficiently yet remain ineffective if it fails to deliver its intended environmental performance and compliance objectives.

To address these objectives, this study adopts the Technology–Organization–Environment (TOE) framework as a guiding theoretical framework. The application of TOE and its relevance to AI-enabled EMS are discussed in greater detail in the literature review chapter.

1.3. Significance of the Study

The study contributes to the existing body of knowledge by offering new insights into artificial intelligence and Environmental Management Systems. The study targeted executives, managers, and environmental specialists in the supply chain organization. It also aims to engage researchers, students, and Al specialists interested in this industry.

Supply chain industries can use this study to enhance the effectiveness of their EMSs. If studies of this nature are not conducted, South African supply chain workers might fail to continually improve their processes and compete in the global sustainability market. This would also burden supply chain industries with unknowns regarding the adoption of AI-enabled sustainable supply chain practices, such as environmental monitoring, emission management, predictive risk management or sustainable supply chain brought by Al. Qualitative methods, such as focus groups, were utilized to gather data and perspectives from individuals in South Africa's supply chain organization.

2. Literature Review

This section reviews the existing literature on Artificial Intelligence (AI) and Environmental Management Systems (EMS). It explores the key concepts, theories, empirical studies, and current trends relating to AI implementation, practitioner involvement, organizational readiness and continuous improvement.

2.1. AI-Enabled EMS

Artificial Intelligence (AI) is increasingly recognized as a transformation technology for environmental management because of its ability to process large datasets, support predictive analytics, and improve environmental decision making [14]. AI applications have been used for environmental monitoring, risk prediction, pollution control, and resource optimization, enabling organizations to respond proactively to environmental challenges. A recent study indicates that AI contributes significantly to environmental sustainability by improving monitoring capabilities and supporting evidence-based management decisions [15].

Despite these advantages and benefits, the existing literature predominantly focuses on technological capabilities and environmental performance outcomes. Previous research, such as [9,14–17], has largely emphasized the application of AI in monitoring and perdition

rather that examining how AI improves the overall quality and effectiveness of Environment Management Systems (EMSs). Furthermore, various studies, such as [18–20], investigate AI as a technological solution while providing limited consideration of organizational and human factors that influence implementation success.

Consequently, although AI-enabled EMSs have emerged as an important research area, limited empirical evidence exists regarding the organizational conditions under which AI improves EMS effectiveness.

2.2. AI Adoption in Supply Chains

AI adoption has become a major driver of digital transformation in the supply chain. Organizations increasingly deploy AI technologies for demand forecasting, inventory optimization [21], transportation planning [22], supplier management [23], and sustainability performance improvement [24]. Studies indicate that AI can enhance operational efficiency while reducing environmental impacts through improved resource utilization and waste reduction.

Literature further suggest that AI supports sustainable supply chain management by improving decision making and enabling organizations to balance economic and environmental objectives [25–28]. However, findings across these studies remain largely focused on operational performance and sustainability outcomes rather than management system effectiveness.

Moreover, while existing studies establish a positive association between AI adoption and sustainability performance, little is explored on how AI specifically contributes to enhanced EMS effectiveness in supply chain environments. This limitation highlights a significant empirical gap concerning the integration of AI-enabled technologies and Environmental Management Systems.

2.3. Practitioner Involvement in Digital Transformation

Practitioner involvement has consistently been identified as a key success factor in digital transformation initiatives [29]. According to Dugstad et al. [30], employee participation facilitates knowledge sharing, technological acceptance, organizational learning, and effective implementation of digital innovations. The previous literature also suggests that active practitioner engagement increases the likelihood of successful transformation outcomes by improving employee commitment and reducing resistance to change [31].

Moreover, the literature also reveals conflicting findings regarding the extent of practitioner influence: while some studies argue that employee participation is a critical determination of digital transformation success [32,33], others suggest that the quality of implementation and organizational support mechanisms are more important than the degree of employee involvement itself [34].

These inconsistencies indicate that the role of the practitioner involvement remains insufficiently understood, particularly in the context of AI-enabled EMS implementation.

2.4. Organizational Readiness

Organization readiness refers to the extent to which an organization possesses the technological infrastructure, human competencies, management support, and financial resources required for successful technology adoption [35,36]. Hence, AI implementation often demands substantial organizational commitment, making readiness an important determinant of successful adoption.

Previous studies consistently identify technological capability, leadership support, data quality, organizational culture, and resource availability as essential readiness dimensions [37,38]. However, studies differ regarding the relative importance of these fac-

tors. Some researchers emphasize technological infrastructure as the primary driver of AI adoption, while others argue that organizational competencies and cultural readiness are equally important.

Although organizational readiness has been widely studied as a predictor of AI adoption, limited research has examined its influence on Environmental Management System effectiveness. Consequently, the relations between readiness and AI-enabled EMSs remain insufficiently explored.

2.5. Continuous Improvement

Continuous improvement constitutes a fundamental principle of Environmental Management Systems within ISO 14001 through the Plan–Do–Check–Act (PDCA) cycle. Through monitoring, auditing, corrective action and management review processes, organizations continually enhance environmental performance and system effectiveness [39].

Previous studies demonstrate that continuous improvement contributes to improved compliance, environmental performance, operational efficiency, and organizational learning [40–42]. Nevertheless, most existing research examines continuous improvement within traditional EMS frameworks rather than AI-enabled environments.

As organizations increasingly adopt AI technologies, understating how continuous improvement interacts with AI-enabled systems remains an important research challenge. The existing literature provides limited empirical evidence regarding the combined effect of AI and continuous improvement on EMS effectiveness.

2.6. Technology-Organization-Environment (TOE) Framework

The Technology–Organization–Environment (TOE) Framework developed by [43] explains the adoption of technological innovations through three contextual dimensions: technological, organizational, and environmental factors. The technological context refers to the availability and suitability of technologies; the organizational context includes organizational readiness, management support, and human capabilities; while the environmental context encompasses external pressures and regulatory requirements [43].

The TOE framework has been widely used to explain digital transformation initiatives, artificial intelligence adoption, and sustainability-related technologies because it captures the multiple organizational conditions required for successful innovation implementation [44]. Within the context of Environmental Management Systems (EMSs), TOE provides a suitable theoretical lens for examining how organizations integrate AI-driven technologies while balancing technological capabilities, practitioner involvement, and organizational preparedness.

2.7. Research Gap and Theoretical Contribution

Previous literature demonstrated that AI technologies can improve environmental management activities, practitioner involvement can facilitate successful technology implementation, and continuous improvement can strengthen Environmental Management System effectiveness. However, these streams of studies have largely evolved independently. Existing studies also predominantly focus on environmental performance, technology adoption, or operational outcomes, with limited attention given to EMS effectiveness as a distinct outcome variable.

Furthermore, insufficient empirical evidence exists regarding how AI implementation, practitioner involvement, and opportunities for continuous improvement collectively contribute to the effectiveness of AI-enabled Environmental Management Systems. This fragmentation represents both a theoretical and empirical gap in literature. Therefore, this study develops empirically tests an integrated framework that examines the influence of AI

implementation, practitioner involvement, and opportunities for continuous improvement of EMS effectiveness. Based on the gaps identified in the literature, an AI-driven EMS Continuous Improvement Framework was developed below to provide a conceptual foundation for this study and to show the relationships among the key research variables. The following figure shows the AI-driven EMS Continuous Improvement Framework developed.

As illustrated in Figure 1, the current body of knowledge is characterized by separate streams of research focusing on AI implementation, practitioner involvement, and continuous improvement. Although valuable insights have been generated within each stream, the literature provides limited evidence regarding how these factors collectively contribute to the effectiveness of AI-driven Environmental Management Systems. The figure therefore highlights the theoretical and empirical gap that underpins this study and justifies the development of an integrated framework for examining the combined influence of these constructs on EMS effectiveness.

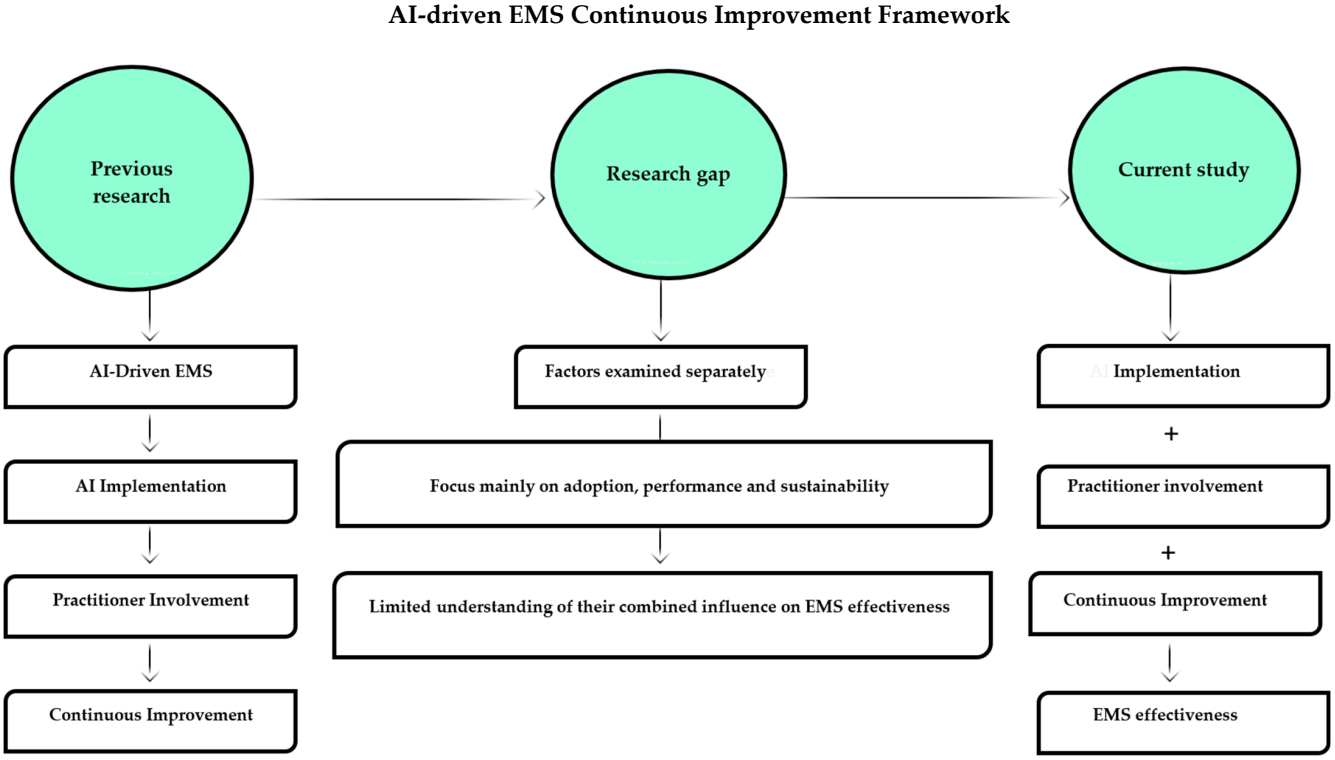


Figure 1. Conceptual framework for AI-driven Environmental Management System Continuous Improvement (Authors' own work).

3. Materials and Methods

This study adopts a qualitative case study research design to examine how environmental and supply chain practitioners contribute to the implementation of an AI-driven Environmental Management System (EMS) and to identify opportunities for leveraging artificial intelligence to strengthen EMS effectiveness, support continuous improvement, and promote sustainable operational performance. This case study approach is appropriate as it allows the researcher to explore complex organizational processes within a natural setting [45]. It also enables a detailed understanding of interactions between EMS practices and AI technologies through the focus group. This design supports the contexture; factors by influencing the system's performance and quality.

3.1. Organizational Profile

The study was conducted within the South African operations of the global supply chain and logistics organization. The company was explicitly identified from the most recent industry reports on South Africa's supply chain sector. The organization operates across multiple countries and provides integrated logistics, transportation, warehousing, distribution, and supply chain management services. Due to the nature of its operations, the organization manages significant environmental aspects associated with transportation, fuel consumption, emissions, waste management, and regulatory compliance.

This study focused specifically on five operational depots located within the Gauteng region of South Africa. These depots were selected because they play an important role in organization supply chain activities and Environmental Management System (EMS) implementation. Participants were drawn from the five depots and represented various functional areas, including environmental management, SHERQ, quality management, operations, sustainability, supply chain management, and continuous improvement.

The organization maintains an Environmental Management System certified to ISO 14001, reflecting its commitment to environmental compliance, risk management, sustainability, and continuous improvement. Environmental responsibilities within the organization include environmental performance monitoring, regulatory compliance, waste management, environmental emission management, resource efficiency, and the promotion of sustainable supply chain practices.

The organization was selected due to its active engagement in supply chain operations and its interests in leveraging artificial intelligence (AI) to enhance environmental management performance and operational efficiency. To preserve confidentiality, the name of the organization is not disclosed in this study.

Building on the organizational profile for the study, the focus now shifts to sampling and the method used to select participants. This section will outline the recruitment process and participants who participated in the focus group discussions that were used to generate rich and detailed data for this study.

3.2. Participants Selection and Sampling

The study population consisted of sustainability executives, heads of departments, SHERQ managers, warehouse/operations managers, HSE practitioners, quality managers, business excellence specialists, supply chain analysts, and a continuous improvement team.

Purposive sampling was employed to select participants with relevant knowledge of and experience with Environmental Management Systems (EMSs), Artificial Intelligence (AI), sustainability initiatives, quality management, and supply chain operations. Purposive sampling is widely used in qualitative research because it enables researchers to obtain information-rich insights from individuals who possess expertise related to the phenomenon under investigation.

Participants were selected based on predefined inclusion criteria, including their involvement in environmental management practices, operational decision making, sustainability initiatives, quality management system or their involvement in AI-related activities within the organization. The sampling approach was therefore intended to obtain diverse professional perspectives relevant to AI-enabled EMS implementation rather than to achieve statical representativeness.

A total of eighteen participants participated in three focus group discussions, representing functional areas including sustainability, SHERQ, quality, operations, the supply chain and continuous improvement.

Table 1 presents an overview of the participants to show who participated in the study, including their years of experience, roles, and the focus group in which they participated.

Table 1. Participant overview based on 3 focus groups. (Authors' own work).

Focus Group	Number of Participants	Years of Organization Experience	Years of Experience in AI and EMS	Fields Represented
1	7	Five participants have more than Five years of experience Two participants have less than Five years of experience	AI: 5 EMS: 4	Senior Sustainability SSA, Supply chain analyst, Quality Manager; Operations Manager; Operational excellence analyst, Safety, Environment, Risk, and Quality (SHERQ) officer
2	6	Three participants have more than Five years of experience Three participants have less than Five years of experience	AI: 4 EMS: 3	Two Safety, Health, Environment, Risk, Quality (SHERQ) officers; Business development analyst; Quality and compliance manager; Operations manager; and Continuous improvement specialist
3	5	Three participants have more than Five years of experience Two participants have less than Five years of experience	AI: 3 EMS: 2	Safety, Health, Environment, Risk, Quality (SHERQ) specialist; Business Development analyst; Quality and compliance manager; Supply chain analyst; and Continuous improvement specialist

Table 1 above shows the demographic and professional characteristics of the participants involved in this study. The diverse range of roles, experience levels, and functional backgrounds provided rich insights into AI-enabled Environmental Management System (EMS) implementation and continuous improvement in the supply chain context. Furthermore, the participants' relevant expertise supports the appropriateness of the purposive sampling approach adopted in this study. The following section outlines the research reflexivity for the study.

3.3. Researcher Reflexivity

The researcher had familiarity with the organization, which facilitated access to participants and provided contextual understanding of the organizational environment. To minimize potential bias, a structural discussion guide was used, discussions were facilitated in a neutral manner, and findings were derived from participant responses rather than researcher's assumptions. Furthermore, all participants were encouraged to express their view openly and independently throughout the focus group discussions.

3.4. Pilot Focus Group

Prior to the main data collection process, a pilot focus group was conducted to evaluate the clarity, relevance, and sequencing of the discussion questions. Feedback obtained during the pilot session was used to refine the discussion guide and improve the facilitation process.

The pilot focus group served exclusively as an instrument refinement exercise, and the data generated during the pilot session were not included in the final analysis. Only data collected from the three formal focus group discussions were used in the development of the themes and findings in this study.

3.5. Data Collection Procedure

Data was collected through three focus group discussions involving eighteen participants. Each session was guided by a semi-structured discussion protocols developed from the study objectives. The facilitator used follow-up and probing questions where necessary to obtain clarification and deeper insights into participant experience and perceptions.

Each session lasted approximately 60 to 90 min and was conducted online through Microsoft teams. With the participants' consent, all discussions were audio recorded to ensure the accurate capture of responses. The recordings were subsequently transcribed verbatim and reviewed for accuracy prior to analysis.

To ensure the credibility of the findings, participants were provided opportunities to clarify statements during the discussions, and the analysis process involved repeated review and comparison of the transcripts to ensure consistency in theme development. Furthermore, to enhance transparency and replicability, the proceedings of the focus group, including the discussion guide and key procedural steps, are presented in Appendix A.

3.6. Data Analysis

This study uses thematic analysis, especially reflexive thematic analysis by Braun and Clarke [16]. Reflective thematic analysis is a popular data analysis method that focuses on the identification, explanation, description, linkages, and substantiation of themes [17]. This method offers a structured and flexible framework for distinguishing, analyzing, and interpreting patterns of meaning within qualitative data.

The coding and analysis were conducted by the researcher. An inductive coding approach was adopted, allowing patterns and themes to emerge from the data rather than being imposed from predetermined theoretical categories. Following transcription, the researcher repeatedly reviewed the focus group transcripts to achieve familiarity with the data set and develop an understanding of the participants' experience and perspectives regarding AI-enabled Environmental Management Systems (EMSs).

During the initial coding phase, meaningful segments of texts were identified and assigned descriptive codes representing key ideas, perceptions, challenges, and opportunities discussed by participants. Similar codes were subsequently grouped together to form candidate themes. These themes were reviewed iteratively against the original transcripts to ensure that they accurately reflected participant perspectives and adequately captured the underlying patterns within the data.

Thematic analysis was conducted using Microsoft Excel for (Microsoft Corporation, Redmond, WA, USA) to support theme development and data categorization.

Through an interpretive process, candidate themes were refined, merged, separated, or redefined where necessary. The final themes were determined based on their relevance to the research objectives, their consistency across participant discussions, and their ability to provide meaningful insights into AI implementation, practitioner involvement, and continuous improvement within EMSs.

Consistent with the principles of reflexive thematic analysis, the researcher played an active role throughout the analysis process with regard to interpretations. Rather than treating themes as automatically emerging from the data, the analysis involved ongoing reflection and engagement with participant accounts to construct meaningful interpretations of the data in relation to the study objectives.

Development of Codes into Themes

A thematic map was developed to provide an overview of the participants' quotes, axial quotes and the two themes that emerged from them. Figure 2 shows how these themes were developed from the participants' quotes. The coding table (Appendix B) presented earlier sets out the thematic analysis in detail, providing transparency on how the themes were created.

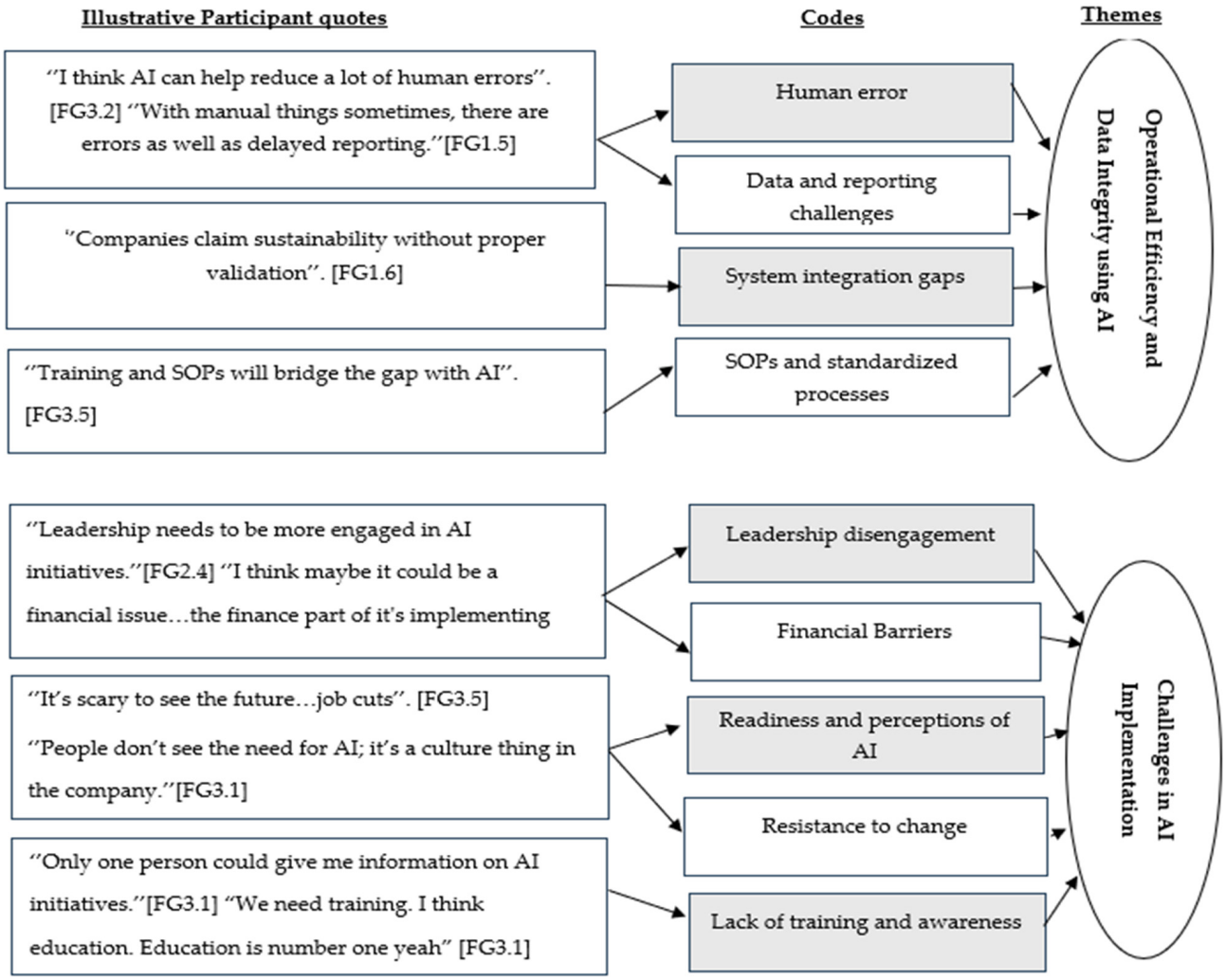


Figure 2. Thematic map diagram (Authors' own work).

Figure 2 above illustrates the analytical process used to develop themes from the focus group data. Initial codes were generated from participants' responses and subsequently grouped into broader categories based on conceptual similarities. Through iterative review and interpretation, these categories were refined into the final themes that guided the study findings.

3.7. Research Ethics, Consent, and Data Handling

This study was conducted following the institutional ethical guidelines which govern research involving humans. Prior to data collection, ethical approval was obtained from the Institutional Review Board (IBR). The participants in this research were given a letter of consent before the focus group proceedings, which highlighted that they are allowed to withdraw their involvement in this study at any given time. To ensure privacy and confidentiality, all data were anonymized, stored, and managed in accordance with the research protocols. The data collected from this study will be retained for a period of five years following the completion of the study and will be securely destroyed in line with the approved data management and institutional requirements.

4. Results

This chapter presents the study findings based on the data collected from participants. The results are organized according to the research objectives and key themes that emerged during the analysis.

4.1. Overview of Findings

The thematic analysis identified two key themes that describe the role of environmental and supply chain practitioners in AI deployment and pinpoint the opportunities for enhancing Environmental Management Systems (EMSs) through AI applications:

> Operational efficiency and data integrity using AI and Challenges in AI implementation

These themes tackle the objectives of the study by exploring practitioner engagement in AI projects and identifying areas where AI can improve EMS effectiveness.

4.2. Challenges in AI Implementation

The findings reveal that environmental and supply chain practitioners recognize the potential value of AI in improving environmental monitoring, decision making and operational performance. However, practitioner involvement in AI initiatives remains limited across many operational companies.

Participants consistently pointed to several challenges that hinder full and effective implementation. These challenges reflect gaps in financial resources, organizational readiness, leadership engagement, cultural attitudes, and awareness. Together, they explain why AI remains underutilized in EMS processes and why opportunities for improvement are realized unevenly across business units. The sub-themes that emerged for this theme, along with their descriptions, are presented in Table 2.

Table 2. Challenges in AI implementation subthemes and descriptions. (Authors' own work).

Sub-Themes	Description
Readiness and perceptions of AI	Mixed perception and perception of integrating AI technologies
Financial barriers	High implementation costs to deploy AI initiatives in Environmental Management System
Resistance to change	Fear of being replaced by AI and cultural resistance

The participants highlighted several challenges experienced by the case study organization during the implementation of AI within its Environmental Management System. When asked about these challenges, participants such as FG1.2, FG3.1, FG3.3, FG2.3, FG3.2, FG3.4, FG3.5, FG2.1, FG2.4, FG2.4, and FG1.1 identified the lack of top management involvement as the major obstacle to integrating AI in the EMSs of the supply chain organization.

4.2.1. Practitioner Involvement

The participants repeatedly highlighted the lack of leadership involvement in AI initiatives, especially regarding environmental management applications. While some innovations are led by global offices or certain technical teams, local leaders—including SHERQ/environmental specialists—were not fully engaged with strategic discussions about AI.

> *"I think the most important issues that have been identified regarding the quality in the EMS system is lack of top management commitment."* [FG2.4]

> "*Only a very small portion of people are involved in AI initiatives… most information I got was from head office*." [FG2.3]

Another participant demonstrated the disconnection between what leadership endorses and what is done practically.

> "*I don't think I've personally seen many people involved with AI projects, maybe people don't think it's necessary*." [FG3.3]

The participants suggested that practitioners play a vital role in stimulating the adoption of AI by allocating resources, sponsoring implementation, ensuring cross functional collaboration, and enforcing organizational commitments. This suggests that AI adoption risks becoming fragmented and inconsistent without strong practitioner engagement and strategic guidance, hindering the overall impact of EMS output. This finding agrees with the literature that shows that leadership commitment is the hindrance for adopting AI in environmental management [40] lack of leadership engagement results in poor resource allocation and implementation monitoring.

4.2.2. Lack of Awareness

The core barrier noted across the focus groups was low organizational awareness of existing AI capabilities, the coming initiatives and the possible advantages of the application of Artificial Intelligence within Environmental Management Systems. Participants mentioned that while AI is widely used in daily life, several employees do not recognize AI systems and hence underestimate their simplicity and practicality in the workplace.

> "*AI is in out TV, phones, Facebook cars, and many people don't know they are already using it*." [FG2.4]

One participant was convinced that without awareness, AI cannot be successfully implemented at the site level:

> "*I don't think people see how it could be beneficiary… maybe they just don't think it's necessary*."

Numerous participants endorsed awareness workshops and discussions with IT and operational excellence teams to clarify AI's environmental use-case.

> "*We need a workshop on AI use-cases for EMS, to find out what exists, what's coming and how we can use it*." [FG2.2]

> "*We need training and awareness to integrate AI effectively*." [FG2.3]

These findings suggest that poor awareness and slow adoption result in lags in AI adoption as teams cannot advocate for technologies and tools, they do not fully understand. Without a clear discussion and toolbox talks with teams and internal education, SAI remains underutilized.

4.2.3. Financial Barriers

Across all groups, participants identified financial barriers as a major obstacle to AI implementation. Most Environmental Management Systems—such as integrated camera analytics, advanced telematics, and automated environmental monitoring—require upfront investment, which participants believe the organization is not always willing to invest to support AI technologies.

A participant noted that the customers wanted to absorb the additional costs associated with environmentally advanced AI systems.

> "*Customers don't price environmental improvement into the service; only blue-chip clients will pay.*" [FG1.4]

Financial barriers also affect maintenance and upgrades because depots cannot always acquire the latest technology needed to support real-time monitoring or predictive risk identification.

> "*You can achieve anything if the money is available.*" [FG1.4]

> "*I think maybe it could be a financial issue… the finance part of it's implementing this AI into the whole business.*" [FG3.4]

With reference to participants FG1.4 and FG3.4, the quotes highlight that AI implementation remains fragmented due to financial constraints and lack of training. These insights align with the literature suggesting that lack of training and implementation costs hinder AI implementation.

The long-term benefits of AI are recognized; however, budget limitations heavily influence whether those technologies are deployed or sustained across sites. Therefore, Environmental Management System enhancements are uneven, depending on affordability and customer willingness to assist with funding.

4.2.4. AI Readiness and Perceptions

Participants showed mixed perceptions regarding readiness to adopt ASI. While several participants expressed curiosity and willingness to explore AI tools, they highlighted that overall organizational readiness is inconsistent. Some sites employ AI in specific operational areas (such as temperature or fatigue monitoring), while others rely heavily on manual, spreadsheets, or paper-based processes.

Some participants described AI as a tool that needs continuous learning, where employees must adapt to the job, such as how they previously learned Excel or Power B.

> "*We learned Excel and Power BI as we used them, AI will be the same.*" [FG2.4]

However, readiness was described as uneven, with some workers perceiving AI as overly complex or irrelevant to their role. Some participants mentioned concerns about the reliability of AI and the need for human verification.

> "*Has it been tested long enough? Will people still monitor what AI picks up?*" [FG2.5]

Both confidence and familiarity influence readiness. Where exposure is limited, AI perceptions remain uncertain, slowing its adoption in EMSs.

4.2.5. Resistance to Change

Participants observed that certain workplaces display resistance to AI technologies, often because staff are accustomed to manual methods or because automated tools are perceived as intrusive or surveillance.

For example, warehouse staff sometimes override scanner instructions, believing that the traditional method is quicker.

> "*People override the scanners because they think their way is faster.*" [FG3.2]

Similarly, initial resistance to camera-based monitoring stemmed from concerns about privacy and being watched.

> "*If people think its surveillance, they resist, only when they see it prevents close calls do they accept it.*" [Common sentiment across groups]

The participants explained that resistance is stimulated by individuals who are not familiar with AI technologies and lack of training. The participants further suggested that uncertainty about whether AI is replacing jobs, as well as concerns on accuracy over-alerting, causes resistance in AI adoption.

Furthermore, participants pointed out that organizational culture such as resistance to change and fear of job replacement further hinders AI implementation.

"*It's scary to see the future… job cuts.*" [FG3.5]

"*Just the whole business adapting to change could be the issue.*" [FG3.1]

These quotes are in alignment with the study by [46], which stated the importance of organizational readiness as a critical factor for adopting AI. This is because of the organizational culture towards change, which shows the need for organizational change management strategies.

Moreover, some participants showed mixed perceptions and voiced concerns regarding AI reliability and ethical implications. This mirrors the broader global debates on AI implementation and underlines the significance of leadership engagement and honest communication.

Overall, the findings suggest that while practitioners are receptive to AI adoption, organizational readiness remains a major determinant of successful implementation.

4.3. Operational Efficiency and Data Integrity Using AI

Theme 2 relates to the limitations of current EMS processes and the opportunities for AI-enabled improvement.

Participants emphasized that AI can significantly strengthen data integrity and streamline operations within the EMS. However, a few operational pinpoints emerged consistently across all focus groups, especially those associated with manual reporting errors, system integration gaps, data quality challenges, and the need to standardize processes and SOPs. These limitations were identified as significant sources of inefficiency and inconsistent environmental management performance. The sub-themes that emerged for this theme, together with their descriptions, are set out in Table 3.

Table 3. Operational efficiency and data integrity using artificial intelligence subthemes and descriptions. (Authors' own work).

Sub-Themes	Description
AI Errors in manual reporting	AI helps reduce human errors and enhances proactive data reporting
Challenges in data and reporting	Lack of validation and standardized record keeping
Gaps in system integration	Misinformation in sustainability reporting and greenwashing
SOPs and standardized processes	Lack of SOPs and standardization bridge the AI integration gap

The major theme that emerged from the participants was a strong emphasis on addressing the operational and data challenges that hinder the effectiveness of Environmental Management System in supply chain organization. Participants, such as FG3.1, FG3.5, FG1.6, FG3.2, FG1.5, FG1.2, and FG3.2, revealed some challenges related to the lack of validation and standardized record keeping, training and awareness of AI, system integration gaps, manual reporting errors, Standard Operating Procedures and standardization. These challenges compromise the quality of the EMS within the supply chain organization.

4.3.1. Manual Reporting Errors

The participants highlighted that manual reporting is associated with operational weakness, explaining that it brings delays, errors, and inconsistencies. Some sites still use spreadsheets and human-defendant logging, which results in discrepancies when employees are upsent, tired, or even replaced. Participants on challenges associated with manual handovers:

For instance, participant FG3.2 revealed that AI can help with manual labor and human error, which were identified as some quality issues in EMS.

> "*I think AI can help reduce a lot of human errors, right? So, in operations, like I said before, there's a lot of manual labor, there's a lot of things that are done manually. There are a lot of reports that are compiled manually, right? We have TAT reports*." [FG3.2]

Another participant highlighted the consequences of oversight or incorrect logging:

> "*If someone misses the gate-in-time, it messes up the entire turnaround time report*." [FG3.1]

Participants described manual reporting as slow, prone to human errors, and difficult to validate, increasing non-compliance risks during audits and customer reviews. Several participants also linked manual processes to rework because incomplete or inaccurate data had to be corrected and validated retroactively. Finally, the participants see manual reporting as a fundamental and vital source of inefficiency. Without AI integration, EMS data remains inconsistent and vulnerable to errors across supply chain processes.

4.3.2. Data and Reporting Challenges

The analysis shows how AI can significantly improve operational efficiency across EMSs in the supply chain industry. Participants provided examples of operational challenges that can be avoided using AI technologies. They mentioned data and reporting challenges that create difficulties in operational efficiency.

> "*You guys showed me your dashboard for reporting… not just environment, the compliance, yeah, the compliance and it was in spreadsheets like I could not believe that a company as big as this is still using spreadsheets and someone else was sitting somewhere would get all those reports and they need to put it onto the system*." [FG1.5]

This quote implies that a gap exists between the size of the organization and advancement in technology in terms of environmental data. Reporting data using spreadsheets shows poor automation, manual processes, and fragmented systems. This is consistent with the literature, emphasizing the role of AI in driving operational efficiency [41]. Hence, this quote emphasizes how manual reporting results in increased data inconsistency, human error, and delayed data reporting.

Apart from manual errors, the participants emphasized broader data quality and reporting limitations, such as the following:

- Delays in receiving data from stakeholders and suppliers;
- Missing or inconsistent report formats;
- Difficulty in co-leading large volumes of driver behavior and operational alerts;
- Lack of real-time data visibility across sites.

For example, one participant noted the following regarding overload in systems:

> "*We have the information-but it's too much and difficult to collate. Someone still must decide that matters*." [FG3.5]

Participants also expressed concern about inconsistent data validation, which makes it difficult to confirm the legitimacy of sustainability claims:

> "*Some companies present misinformation about being environmentally sustainable because there's no proper validation*" [FG1.3]

Data challenges hinder the ability of the organization to make informed decisions, meet compliance obligations, and maintain EMS credibility. Participants view AI as a potential solution if data inputs are accurate and standardized.

4.3.3. Gaps in System Integration

One of the strongest threats across all three groups was the lack of unified systems within the supply chain organization. Participants explained a landscape of platforms that are not connected, business units, and different by site or function. As a result, environmental processes and operations are manually consolidated, leading to poor or slow decision-making and creating avoidable administrative burdens.

A participant summarized the following issue:

> "*Different sites use different systems; if we want AI to work, everyone must be on the same page*." [FG2.6]

Another participant showed disbelief at the extent of spreadsheet dependence:

> "*I count believe a company as big as this is still using spreadsheets for compliance reporting*." [FG1.3]

The reliability of AI-enabled tools can also be affected by system gaps. For example, route optimization and driver behavior analytics are weakened when subcontracted fleets do not provide telematics data.

> "*If subcontractors don't have telemetry, the system won't give accurate route suggestion*." [FG3.3]

The findings indicate that system fragmentation is a structural barrier to operational efficiency. Participants think that without a shared data spine, AI cannot effectively scale across sites or support EMS improvement.

4.3.4. SOPs and Standardized Processes

In terms of SOPs and standardized processes, the participants showed that AI will increase the quality of training and SOPs, enhancing operational efficiency.

> "*Training and SOPs will bridge the gap with AI*." [FG3.5]

Looking at participant FG3.5's quote, it agrees with the theme of AI enhancing operational efficiency and data integrity. This quote reveals that SOPs are important for an effective integration of EMSs, as they bring guidelines and a structured workflow that helps improve operational efficiency and foster consistency and accuracy. SOPs will be a building block of AI and EMS integrations by ensuring that AI technologies are ethically and procedurally handled to enhance EMS effectiveness.

The participants noted that most inefficiencies arise due to the lack of process clarity and not necessarily lack of technology. This results in inconsistencies, workarounds, and resistance. For example, the warehouse team overrides the scanner instructions, despite the scanner being designed to optimize the movement due to no clear SOP, which reinforces adherence:

"*People override the scanners because they think their way is faster.*" [FG3.2]

Similarly, participants argued that standardized processes would ensure consistency across business sites, especially regarding FE initiatives, hazard-respond actions and CEM.

These findings suggest that participants view SOPs as important for embedding AI in daily work. Standardization ensures consistency and provides behavior pillars that convert SAI insights into reliable operational actions.

5. Discussion

This chapter presents and discusses the study findings in relation to the research objectives and the existing literature. It focuses on organizational readiness, the involvement of environmental and supply chain practitioners in AI-enabled initiatives and identified opportunities for improving Environmental Management System (EMS) effectiveness through targeted AI applications.

5.1. Finding in Relation to the TOE Framework

This study adopted the Technological–Organization–Environment (TOE) framework as a theoretical lens for understanding factors influencing AI-enabled EMS implementation. The findings indicate that organizational readiness and practitioner involvement align with the organizational dimension of TOE while data integrity and system integration challenges align with the technology dimension. Regulatory and sustainability requirements reflect the environmental dimension as shown below.

Table 4 shows how the findings of this study align with the dimensions of the Technology–Organization–Environment (TOE) framework. The results indicate that the successful implementation of AI-enabled Environmental Management Systems (EMSs) is influenced by a combination of organizational, technological, and environmental factors. Organizational readiness, practitioner involvement, and resistance to change were identified as critical organization considerations, while data integrity, AI deployment, and system integration emerged as key technological requirements. Furthermore, compliance requirements and sustainability pressures reflected the environmental context in which AI-enabled Environmental Management Systems operate. Together, these factors contribute to the achievement of continuous improvement, highlighting the interconnected nature of technological capabilities, organizational preparedness, and environmental demands.

Table 4. Dimensions of the Technology–Organization–Environment (TOE) framework and study findings. (Authors' own work).

TOE Dimension	Findings
Organizational	Organizational readiness, practitioner involvement and resistance to change
Technological	Data integrity, AI deployment and system integration
Environmental	Compliance requirements and sustainability pressures
Outcome	Continuous improvement

5.2. Practitioner Involvement in AI-Driven EMS

The findings reveal that environmental and supply chain practitioners recognize the potential of AI to improve Environmental Management System (EMS) effectiveness; however, their involvement in AI initiatives remains limited. Participants reported that AI-related activities are often driven at high organizational levels, with limited engagement at operational levels. Training emerged as a critical requirement, with participants emphasizing that employee competence and awareness are important for successful implementation.

Resistance to change, financial constraints and lack of skills were the key barriers to adoption. These findings suggest that practitioner involvement extends beyond system use and should include active participation in AI planning, implementation and continuous improvement.

The findings are consistent with previous studies that identity human capital and organizational readiness as critical enablers of digital transformation. Ref. [47] found that successful AI adoption in supply chain operations depends on employee competencies, stakeholder engagement and organizational support. Similarly, Ref. [48] revealed that AI implementation requires organizations to develop both technological infrastructure and workforce readiness to realize its full potential. The limited practitioner participation observed in this study is therefore constraining the effective deployment of AI within EMS processes.

The findings further highlight the importance of leadership support in adopting AI. Previous research has shown that management commitment influences technology acceptance, organizational changes and resource allocation initiatives [14]. Participants concerned regarding financial constraints and limited AI awareness support the view that organizations must invest not only in technology infrastructure but also in employee development and management of change programs. Consequently, environmental and supply chain practitioners should be viewed as strategic contributors to AI-enabled sustainability initiatives rather than merely end-users of technology.

5.3. Opportunities for AI-Enabled Continuous Improvement

Participants identified reporting, fragmented information systems, and spreadsheet-based processes as key limitations within current EMS practice. These challenges were associated with reporting inefficiencies, data quality issues and difficulties in converting large volumes of data into actionable insights. Similar challenges were reported in studies highlighting the importance of reliable data and system integration for AI-enabled environmental management [49,50].

The findings further suggest that the effectiveness of AI-enabled Environmental Management Systems (EMSs) depends heavily on the accessibility, quality, and integration of organizational data. This observation reflects the well-established garbage out (GIGA) principle, whereby the inaccurate, incomplete, or inconsistent input of data can lead to unreliable AI-generated outputs and decision making. Consequently, the potential benefits of AI are likely to be constrained in organizations characterized by fragmented systems, manual reporting processes, and poor data management practices.

Furthermore, the findings indicate several districts, but interrelated data-related factors influence the successful implementation of AI-enabled EMSs. Data quality refers to the accuracy, completeness, consistency, and reliability of environmental data. Data governance involves policies, procedures, and responsibilities established to ensure data integrity and accountability. Data interoperability relates to the ability of different systems to exchange and utilize information effectively. Data standardization refers to the use of consistent data formats and reporting procedures across organizational functions, while data availability concerns the accessibility and timeliness of information required for decision making. Weaknesses in any of these dimensions may limit the ability of AI systems to generate meaningful insights and support continuous improvement.

The findings also reveal opportunities for AI application in real-time environmental monitoring, automated compliance reporting, predictive risk management, fleet optimization and carbon emissions monitoring. These findings are consistent with previous research that reveals that these applications can strengthen decision making, improve environmental performance and support continuous improvement initiatives [51]. This suggests that AI can transform EMSs from being a reactive compliance tool into a proactive and predictable management system.

5.4. Integration of Findings into the AI-Driven EMS Continuous Improvement Framework

The AI-driven EMS Continuous Improvement Framework, as developed in chapter two, provides an integrated representation of the factors influencing AI adoption and EMS effectiveness. However, participants expressed concerns regarding employee surveillance, potential job displacement, AI reliability, and data privacy. While these concerns represent barriers to AI adoption, they also highlight the importance of responsible AI governance within Environmental Management Systems (EMSs). The findings suggest that successful AI implementation should not be evaluated critically in terms of operational efficiency and environmental performance, but should also consider ethical, social, and governance implications.

Therefore, human oversight remains essential to ensuring that AI-generated recommendations are reviewed, validated, and appropriately applied within organizational contexts. Furthermore, transparency regarding how AI systems generate output can help strengthen employee trust and facilitate the acceptance of AI-assisted decision making. Accountability mechanisms are similarly important to ensure that organizational responsibility remains with human decisionmakers rather than being transferred entirely to automated systems. Privacy considerations also require careful attention, especially were AI systems process employees, operational, or environmental performance data.

These findings indicate that responsible AI governance should be viewed as an integral component of AI-enabled EMS implementation and continuous improvement. Consequently, organizations should establish governance structures that promote ethical AI use, transparency, accountability, and human overside alongside technological adoption initiatives.

Based on the findings and the Technology–Organization–Environment (TOE) framework, an extended AI-driven EMS Continuous Improvement Framework was developed. The framework shows how organizational, technological, and environmental factors interact with responsible AI governance mechanisms to support effective AI-enabled EMS implementation and continuous improvement.

Figure 3 shows how the extended AI-driven EMS Continuous Improvement Framework was developed from the study findings and informed by the TOE framework. The framework highlights the interaction between organizational readiness, practitioner involvement, technological capabilities, and environmental requirements in supporting AI-enabled EMS implementation. With regard to participants' concerns regarding privacy, job displacement, AI reliability, and surveillance, the framework incorporates responsible AI governance through human oversight, transparency, accountability, ethical AI use, and privacy protection. Collectively, these elements contribute to improved environmental performance, enhanced compliance management, data-driven decision making, and continuous improvement.

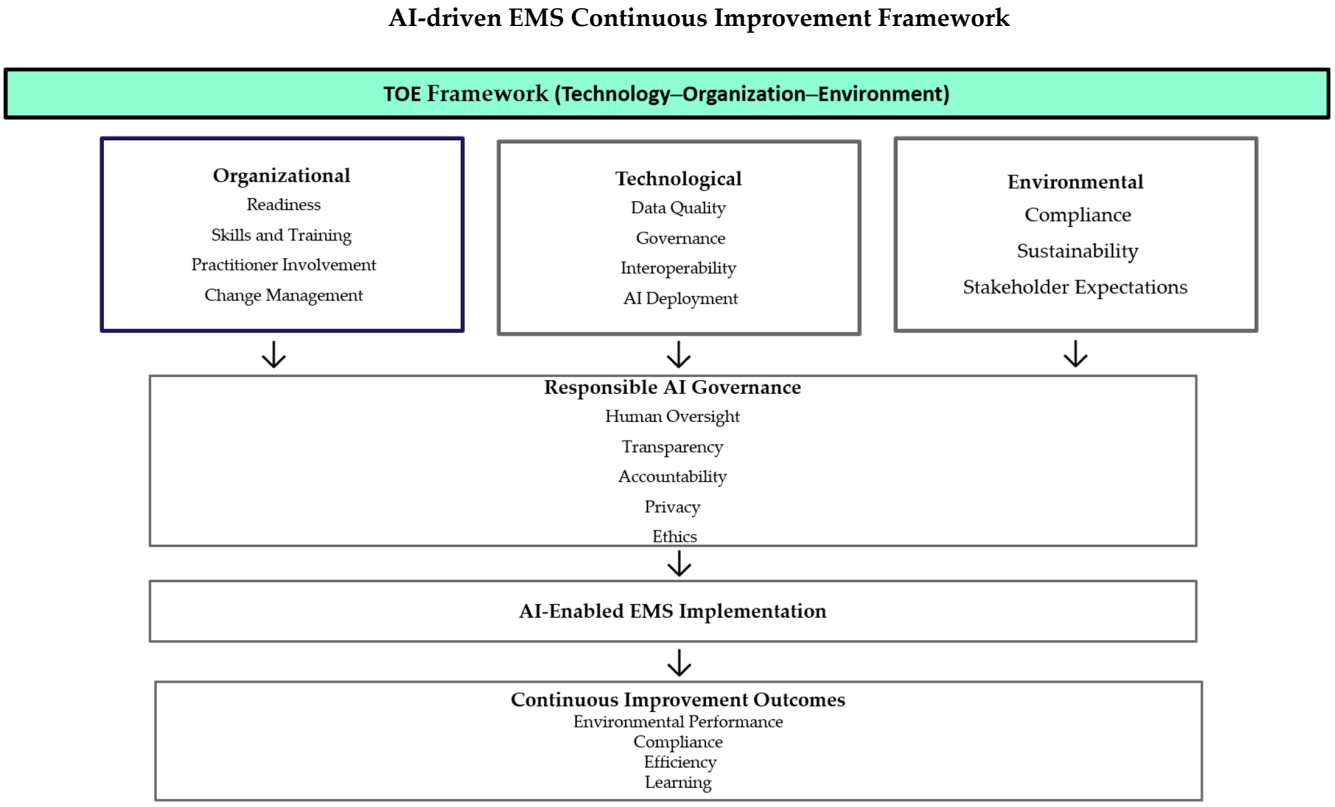


Figure 3. AI-driven EMS Continuous Improvement Framework (Authors' own work).

5.5. Implications for Theory and Practice

The findings of this study contribute to the body of knowledge on AI-enabled Environmental Management Systems by showing that technological capability alone is insufficient for successful implementation. Organizational readiness, data integrity and keeping humans in the loop remain the critical determinants of success. Based on the study findings, several recommendations are proposed for enhancing the successful integration of Artificial Intelligence within Environmental Management Systems to strengthen continuous improvement efforts in supply chain environments.

Practical perspective: Organizations should prioritize the following:

5.5.1. Government Frameworks and Developing AI-Focused SOPs

Organizations should establish AI-focused Standard Operating Procedures (SOPs) that align with existing environmental regulations and emerging AI governance framework. The findings in alignment with the literature by Harshita & Hastier [52] reveal that uncertainly regarding AI use, limited training, and inconsistent implementation practices limit the effective integration of AI within Environmental Management Systems (EMSs). The study recommends that developing clear SOPs would provide guidance on data collection, data validation, decision-making processes, system monitoring and accountability when AI technologies are used in environmental management activities. Furthermore, governments and regulatory bodies should develop frameworks that promote responsible AI adoption while ensuring compliance with environmental legislation, data protection requirements, and ethical principles. Such frameworks can support organizations in implementing AI consistently and transparently, while also reducing risks associated with algorithm errors, data quality issues, and poor governance. By using regulatory guidance with properly defined SOPs together, practitioners can better understand their responsibilities and effectively utilize AI to enhance EMS performance and support continuous improvement objectives.

5.5.2. Standardization of Environmental Reporting Systems

This study recommends that organizations prioritize the standardization of environmental reporting systems to improve consistency, data quality and inter-operability across supply chain operations. The study found that fragmented reporting processes, reliance on spreadsheets, and inconsistent data management practices limit the effectiveness of EMSs and reduce the value derived from AI applications. A standardized reporting framework would enable the collection of reliable and comparable environmental data across different sites, departments, and business units [53]. This would enhance the ability of AI technologies to generate accurate insights, facilitate real-time environmental monitoring, and support predictive analytics. Standardization can also reduce manual reporting errors, improve regulatory compliance, and strengthen decision-making processes by providing a source of accurate environmental information [54]. As organizations increasingly adopt AI-enabled solutions, standardized reporting systems will serve as a critical foundation for improving environmental performance, supporting sustainability objectives, and enabling data-driven continuous improvement within EMSs.

5.5.3. Establish Cross-Functional AI Governance and Innovation Teams

The study reveals that AI initiatives within EMSs are often fragmented, with limited practitioner involvement and a lack of collaboration between the environmental, supply chain and information technology disciplines. This finding aligns with the study by [14], who argued cross-disciplinary cooperation is central, linking AI strategies to regulations, sustainability and ethical practices. To address this gap, organizations can establish cross-functional AI governance and innovation teams responsible for identifying, implementing, prioritizing, and monitoring AI opportunities within EMSs. These teams should unite environmental practitioners, supply chain professionals, data analytics, information technology, continuous improvement analysts and senior management professionals to ensure that AI initiatives align with the realities of the operations, environmental objectives, and strategic goals. Such governance structures would promote knowledge sharing, improve stakeholder engagement, and ensure that AI applications are developed in response to actual environmental challenges rather than technology-driven trends [55]. Furthermore, cross-functional teams will oversee pilot projects, evaluate AI performance, control risks, and identify opportunities for continuous improvement. By putting in place collaboration and accountability, organizations can strengthen practitioner participation, accelerate AI adoption, enhance system integration, and improve the overall effectiveness of Environmental Management Systems. These interventions may increase practitioner participation, enhance EMS data quality and maximize the value derived from AI technologies.

5.5.4. Practical Implementation Pathway for AI-Enabled EMS

The findings suggest that organizations seeking to implement AI-enabled Environmental Management Systems (EMSs) should adopt a structured and phased approach rather than pursuing isolated technology initiatives. Based on the study findings, a practical implementation pathway is proposed to support successful adoption and continuous improvement. Figure 4 shows the seven key steps that organizations may follow to successfully integrate AI technologies into Environmental Management Systems.

Figure 4 presents the proposed implementation pathway for an AI-enabled EMSs. The framework integrates the technological, organizational, environmental and human dimensions necessary for effective EMS improvement. The following discussions examine each of the seven steps and demonstrate the responsibilities of practitioners in each step.

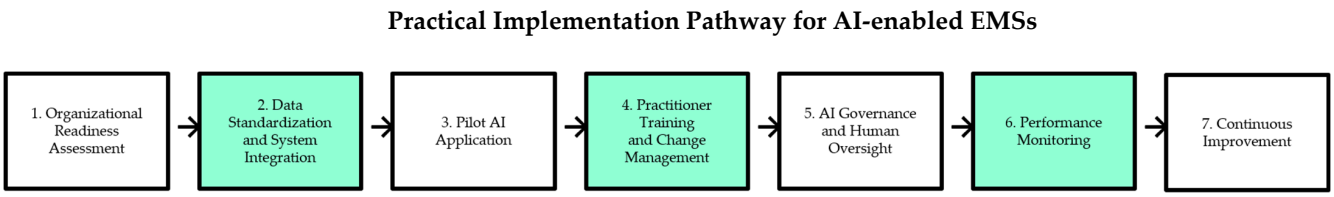


Figure 4. Practical Implementation Pathway for AI-enabled EMSs (Authors' own work).

Stage 1: Organizational Readiness Assessment

The implementation process should start with an assessment to measure organizational readiness. Organizational leaders, senior management, environmental practitioners, Quality managers, HSE Managers, IT practitioners, data experts and sustainability professionals should evaluate existing technological capabilities, workforce competencies, data management practices, and the culture of the organization. Resources required at this stage include leadership commitment; stakeholder engagement; and readiness assessment tools such as structured checklists, scorecards, and other diagnostic assessments that assist with implementation strategy, governance and understanding of the data.

Stage 2: Data Standardization and System Integration

The organizations can establish standardized environmental reporting procedures and improve interoperability among existing systems. Information technology teams, operations managers and environmental practitioners should collaborate to improve data quality, data governance, and system integration. Success indicators may include reduced data inconsistencies, improved data accessibility, and increased reporting accuracy.

Stage 3: Pilot AI Implementation

Organizations can implement AI in selected high-impact areas, instead of implementing sustainability across EMSs. For instance, they can implement in areas such as environmental monitoring, compliance reporting, risk prediction or carbon emissions tracking. The pilot projects should be led by multidisciplinary teams such as environmental practitioners, operational managers, IT specialists and continuous improvement analysts. Success can be measured through improvements in reporting efficiency, accuracy, and decision making.

Stage 4: Practitioner training and Change Management

At this stage, employee training initiatives and programs should be implemented to enhance AI literacy and reduce resistance to technological change. Environmental Management practitioners, human resources departments, learning and development departments, and organizational leaders should collaborate to develop training initiatives focused on AI utilization, the interpretation of AI-generated insights, and responsible AI practice. The operations team should also be involved to ensure that delegates attend training as planned and not disrupt daily operational planning. Success indicators may include user acceptance, practitioner participation, and training completion rates.

Stage 5: AI Governance and Risk Management

Organizations should establish cross-functional AI governance structures responsible for overseeing ethical AI use, data privacy, transparency, accountability, and human oversight. Governance teams should include representatives from environmental management, operations, quality management, information technology, and senior leadership; the success of the implementation can be evaluated through compliance performance, stakeholder trust, and governance effectiveness.

Stage 6: Performance Monitoring and Continuous Improvement

Continuous monitoring should be conducted to evaluate the impact of AI-enabled EMS initiatives on environmental performance, operational efficiency, compliance management, and sustainability objectives. Performance indicators should be reviewed regularly

to identify opportunities for refinement and continuous improvement. Lessons learned implementation should inform future AI deployment strategies and organizational learning.

5.6. Limitations and Directions for Future Research

This study has several limitations that should be considered when interpreting the findings. Although participants were drawn from multiple depots and operational sites across the organization, the study was conducted within a single organizational context. In addition, the study relied on a relatively small purposively selected sample and self-reported perceptions obtained through the focus group discussions, which may have been influenced by selection bias, group conformity effects, organizational hierarchy, and confidentiality considerations.

While measures were implemented to minimize bias, researcher familiarity with the organization context may have influenced data collection and interpretation. Furthermore, the study did not include objective EMS performance indicators and focused primarily on perceptions regarding AI implementation rather than evaluating fully implemented AI-enabled EMS solutions. Moreover, the exploratory qualitative design does not permit casual inferences regarding the relationships among organizational readiness, practitioner involvement, data integrity, AI deployment, and continuous improvement outcomes. These limitations suggest that the proposed AI-driven EMS Continuous Improvement Framework should be viewed as contextually informed framework requiring further validation.

Future research should validate the framework in different industrial settings and examine the long-term impact of AI adoption on environmental and operational performance. Researchers are also encouraged to adopt mixed-methods or longitudinal approaches to examine the long-term impact of AI adoption on environmental performance, operational efficiency, and practitioner engagement within Environmental Management Systems.

6. Study Contribution

The study contributes to the literature on AI-enabled Environmental Management Systems (EMSs) by highlighting the role of environmental and supply chain practitioners in AI adoption and continuous improvement. The findings demonstrate that practitioner involvement, organizational readiness, and data integrity are critical to enabling effective AI implementation. The study also identifies underlined AI application areas, including environmental reporting, compliance monitoring, and predictive risk management. Furthermore, it offers the AI-driven EMS Continuous Improvement Framework. The framework integrates four interrelated elements: organizational readiness, practitioner involvement, data integrity and targeted AI deployment. This framework extends the existing literature by presenting a practitioner-centered approach to AI adoption in EMS and provides a foundation for future research and implementation strategies.

Theoretical Contribution

While the TOE framework identifies organizational, environmental and technological factors as important determinants of technology adoption, this study extends the framework by demonstrating that practitioner involvement is not merely an organizational factor, but a critical mechanism through which an AI-enabled Environmental Management System achieves continuous improvement. Furthermore, the findings highlight data integrity as a functional technological requirement that directly affects the effectiveness of AI applications within EMSs.

7. Conclusions

This study addressed the critical research problem of assessing the role of environmental and supply chain practitioners in AI-enabled Environmental Management Systems (EMSs) and identified opportunities for enhancing EMS effectiveness through targeted AI applications. The findings revealed that practitioner involvement in AI initiatives remains limited despite widespread recognition of AI's potential to improve environmental monitoring, decision making and compliance management standardized procedures emerged as critical factors for improving organizational readiness and practitioner participation. The study also highlights the importance of practitioner involvement and organizational support in ensuring successful AI adoption.

Based on the findings, an AI-driven EMS Continuous Improvement Framework was developed to guide organizations in integrating AI within EMS processes. The study contributes to the growing body of knowledge on AI-enabled environmental management and provides practical insights for organizations seeking to improve environmental performance and sustainability. Moreover, the effective integration of AI and human expertise has the potential to transform EMSs into a proactive and continuous improving system that supports sustainable development.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding author.

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Conflicts of Interest: The authors declare no conflicts of interest. The study was conducted in the absence of any commercial or financial relationships, hence no potential conflict of interest.

Abbreviations

The following abbreviations are used in this manuscript:

IoT	Internet of Things
FG1	Focus Group 1
FG2	Focus Group 2
FG3	Focus Group 3
AI	Artificial Intelligence
SCM	Supply Chain Management
EMS	Environmental Management System
SOP	Standard Operating Procedure
CO_2	Carbon Dioxide
SHERQ	Safety Health Environment Risk Quality
HSE	Health Safety Environment
TOE	Technology–Organization–Environment framework

Appendix A

Appendix A.1. Proceeding of the Focus Group

Appendix A.1.1. Welcome

Participants were welcomed and appreciated for joining the focus group.

Appendix A.1.2. Introducing the Topical

The topic of the study titled Enhancing the quality of Environmental Management System using Artificial Intelligence: The supply chain case, was introduced by the facilitator. The facilitator discussed that the results from the focus group will be used for research purposes.

The participants were also told that they were selected because of their expertise and knowledge regarding AI, the supply chain and Environmental Management Systems.

Appendix A.1.3. Participants Guidelines

The participants were told that there is no wrong or right answer, but different perspectives. The pilot study was tape recorded with the permission from the participants. A rule was implemented where only one person would speak at a time. They were also told that they do not have to agree with other participants but rather encouraged to share their own view and listen to others respectfully as they share their views. Rules on using a cell phone or any device while attending the focus group were discussed, and the participants were encouraged to turn off their phones. Furthermore, if there was any emergency, they were encouraged to exit the teams meeting quietly and rejoin again as quickly as they could.

The moderator explained his role as a guide to the focus group discussion to all the participants.

Appendix A.1.4. Opening Question: The Beginning of the Focus Group

The researcher created a thoughtful, permissive atmosphere and gave ground rules to set a tone for the proceeding. This is because the first few minutes of focus group proceedings are critical.

The pattern below was used for introducing the group discussion:

Welcome to participants
Study Overview
Setting ground rules
First Question

The below is how the group discussion was introduced:

"Good day all, welcome to the pilot study of our focus group discussion. Thank you very much for taking your time in your busiest schedule to join us today. As most of you know me, my name is Lehlogonolo Moroasehla. I am an MPhil in Quality Engineering at the University of Johannesburg. We are here to discuss the study titled: Enhancing the quality of Environmental Management System using A: A supply chain case study. You were chosen and invited to this discussion because you have background and experience of either AI, EMS or supply chain industries.

Please note that there is no wrong or right answer and be free to bring your different perspectives on the subject matter. All answers are correct answers, whether negative or positive answers, because negative answers are as useful as the positive ones. This meeting is recorded. This is because we do not want to miss any important comments from our discussion. Feel free to discuss with us and note that we will not use any of your names in the reports, as it will be kept confidential.

Now, let's start. Please introduce yourself and which filed are you from."

Appendix A.1.5. Asking Research Questions

The below questions were used during the focus group discussion:

What is the role of Al on Environmental Management System in Supply chain industries?
How to integrate Al with EMS in supply chain industries?
What quality issues exist in the Environmental Management System of supply chain?
How are Environmental and supply chain practitioners engaged in AI initiatives, and what role do they play?
Where in the EMS processes are AI techniques underutilized and how to use these technologies to enhance the effectiveness of EMS?

Questions to be asked during the focus group

How and when do you use AI in your day-to-day activities?
What are the benefits of using AI?
Do you think AI can improve the quality of EMS?
What is the role of Environmental and supply chain practitioners with AI initiative?
How are Environmental and supply chain practitioners engaged in AI initiatives?
What are challenges associated with adopting AI?
Do environmental practitioners have the necessary skills to work with AI technology?

Appendix A.1.6. Closing Questions

The below questions were posed to the participants to reflect on the focus group engagement:

Question 1
If you had a minute to talk to the organization Vice President today, on the topic that we discussed, what will you say?
Question 2
Reflecting on all things we discussed today about AI, what stoop up for you?
Question 3
The facilitator/moderator reviewed the objectives of the study with the question: Have we covered everything

Appendix B

Table A1. Presentation of themes and sub-themes-Coding Table.

Participants	Participants Quote	Initial Code	Axial Code	Theme
FG3.1	"The role that artificial plays in in our industry is maybe just promoting agility in identifying hazards."	Promoting agility in identifying hazards	Agility in hazard identification and efficiency	Enhancing safety and efficiency
FG1.1	"It could also enable us to mitigate some of the risks that we could potentially bring about with our production or emissions... also enable us to mitigate some of the risks."	Promoting agility in identifying hazards	Agility in hazard identification and efficiency	Enhancing safety and efficiency
FG1.3	"With this type of business, one of the things that people like to emphasize is speed, like efficiency, you know, and I think AI can help with that."	Promoting agility in identifying hazards	Agility in hazard identification and efficiency	Enhancing safety and efficiency

Table A1. *Cont.*

Participants	Participants Quote	Initial Code	Axial Code	Theme
FG3.4	"AI can actually help us to find routes that are shorter."	AI helps shorten routes	Route optimization	Enhancing safety and efficiency
FG3.3	"Because we can't waste time as well, especially when you're giving stuff to clients."	AI helps shorten routes	Route optimization	Enhancing safety and efficiency
FG3.1	"My understanding of AI is agility… identifying things a bit quicker."	AI helps shorten routes	Route optimization	Enhancing safety and efficiency
FG2.1	"We won't be able to identify a truck that is leaking somewhere, maybe a car accident… we are unable to identify those areas just as human beings. But AI will help us identify and react to new information. To react quick to situations that are harmful to the environment"	AI helps shorten routes	Route optimization	Enhancing safety and efficiency
FG3.4	"which will then save on fuel and yeah, minimize the consumption of CO_2."	Minimize the consumption of CO_2	Fuel and CO_2 reduction	Enhancing safety and efficiency
FG2.1	"From a perspective of maybe fuel consumption and driver behavior… AI can assists."	Minimize the consumption of CO2	Fuel and CO2 reduction	Enhancing safety and efficiency
FG1.5	"Vehicle usage to reduce fuel consumption because a lot of the things that i notice is our fuel consumption… we have the most impact on the environment, our carbon emission is very, very high"	Minimize the consumption of CO2	Fuel and CO2 reduction	Enhancing safety and efficiency
FG2.4	"I don't think we're using it to the full capabilities… AI techniques are underutilized example, in waste reduction emissions and fuel emissions."	Minimize the consumption of CO2	Fuel and CO2 reduction	Enhancing safety and efficiency
FG1.2	"Systems can detect temperature deviations and trigger corrective actions."	AI helps with temperature control and compliance monitoring	Enhanced temperature control and compliance monitoring	Enhancing safety and efficiency
FG1.2	"I know that group internal audit and I'm talking about the highest level based in Dubai. I think they already have an AI based platform with which they're utilizing for internal audits. So, it would provide you with real time data."	AI helps with temperature control and compliance monitoring	Enhanced temperature control and compliance monitoring	Enhancing safety and efficiency

Table A1. *Cont.*

Participants	Participants Quote	Initial Code	Axial Code	Theme
FG1.4	"There's a lot of AI applications that have been created for cameras… could do the same thing on environmental monitoring. you can also use these things for, let's say compliance monitoring for any license conditions or spill leak detection".	AI helps with temperature control and compliance monitoring	Enhanced temperature control and compliance monitoring	Enhancing safety and efficiency
FG1.5	"AI is underutilized in areas like real time monitoring and predictive."	AI helps with temperature control and compliance monitoring	Enhanced temperature control and compliance monitoring	Enhancing safety and efficiency
FG3.1	"I think last week, and I got so anxious with the men and machine in the warehouse...and I thought to myself, surely there is a way where we can utilize AI to create or separate the two."	Improved man–machine separation	AI can improve safety in warehouses	Enhancing safety and efficiency
		Lack of AI training and awareness	Training and awareness of AI	Operational efficiency and data integrity
FG3.5	"Training and SOPs will bridge the gap with AI"	Need for SOPs and standardized processes	Standardized process for AI integration	Operational efficiency and data integrity
FG3.1	"For or us to eliminate the usage of vehicles that use diesel or maybe to mitigate how the diesel is used to maybe reduce our carbon emissions… but we can maybe try and find systems like Vantage that will even if not an SOP but a standardized way."	Need for SOPs and standardized processes	Standardized process for AI integration	Operational efficiency and data integrity
FG1.6	"Companies claim sustainability without proper validation"	Misinformation in sustainability reporting and greenwashing	System integration gaps	Operational efficiency and data integrity
FG3.2	"I think AI can help reduce a lot of human errors, right? So, in operations, like I said before, there's a lot of manual labor, there's a lot of things that are done manually. There are a lot of reports that are compiled manually, right? We have TAT reports."	AI helps reduce human errors	Errors in manual reporting	Operational efficiency and data integrity

Table A1. *Cont.*

Participants	Participants Quote	Initial Code	Axial Code	Theme
FG1.5	"I wanted to also add and agree with what Participant 1 was saying in regard to the manual that it's not fully automated… so often there will be errors because we know that with manual things sometimes there are errors as well as delayed reporting."	AI helps reduce human errors	Errors in manual reporting	Operational efficiency and data integrity
FG3.1	"You guys showed me your dashboard for reporting… not just environment, the compliance, yeah, the compliance and it was in spreadsheets like I could not believe that a company as big as this is still using spreadsheets and someone else was sitting somewhere would get all those reports and they need to put it onto the system."	AI helps reduce human errors	Errors in manual reporting	Operational efficiency and data integrity
FG1.2	"We might be lacking in terms of record keeping… it's quite manual and it's dependent on someone"	AI helps reduce human errors	Errors in manual reporting	Operational efficiency and data integrity
FG3.2	"We're in an industry where there's a lot of manual labor… Manual labor that poses a risk in terms of safety and environment."	AI helps reduce human errors	Errors in manual reporting	Operational efficiency and data integrity
FG3.5	The challenge in collating AI generated data… its overwhelming.	Lack of validation and standardized record keeping.	Data and reporting challenges	Operational efficiency and data integrity
FG3.2	"In our reporting… AI could assist lot in reducing human errors, you know."	Lack of validation and standardized record keeping.	Data and reporting challenges	Operational efficiency and data integrity
FG1.5	"With manual things sometimes, there are errors as well as delayed reporting."	Lack of validation and standardized record keeping.	Data and reporting challenges	Operational efficiency and data integrity
FG3.1	"People must see the need for this technology… I think it's a culture thing in the company. So once maybe people see the need for this AI or systems, then yeah."	Mixed perception and cultural barriers	Readiness and perceptions of AI	Challenges in AI implementation

Table A1. *Cont.*

Participants	Participants Quote	Initial Code	Axial Code	Theme
FG3.3	"People don't see the need for AI; it's a culture thing in the company."	Mixed perception and cultural barriers	Readiness and perceptions of AI	Challenges in AI implementation
	"I think I'm having a bit of a positive outlook on AI."	Mixed perception and cultural barriers	Readiness and perceptions of AI	Challenges in AI implementation
FG2.3	"The finances AI can be very expensive and especially when you got to put in money for training and things… we need the finances, infrastructure, you know, all of that."	Costs of implementing AI	Financial barriers	Challenges in AI implementation
FG3.1	"If you go on to something that's AI driven, you'd also have to validate that data, you know, so there's a whole lot of things that go behind data validation and it's quite costly sometimes."	Costs of implementing AI	Financial barriers	Challenges in AI implementation
FG3.2	"You can achieve anything if the money is available. So, one of the big challenges is we cannot pass cost on successfully to customers. It does not seem customers are fully embedded in wanting to achieve, you know to price in environmental improvement."	Costs of implementing AI	Financial barriers	Challenges in AI implementation
FG3.4	"I think maybe it could be a financial issue… the finance part of it's implementing this AI into the whole business."	Costs of implementing AI	Financial barriers	Challenges in AI implementation
FG2.4	"Leadership needs to be more engaged in AI initiatives."	Lack of top management commitment.	Leadership disengagement	Challenges in AI implementation
FG1.1	"I think the most important issues that have been identified regarding the quality in the EMS system is lack of top management commitment."	Lack of top management commitment.	Leadership disengagement	Challenges in AI implementation
FG2.3	"I think as a whole, um, we need management involved."	Lack of top management commitment.	Leadership disengagement	Challenges in AI implementation
FG3.5	"It's scary to see the future… job cuts."	Fear of being replaced by AI and cultural resistance	Resistance to change	Challenges in AI implementation

Table A1. *Cont.*

Participants	Participants Quote	Initial Code	Axial Code	Theme
FG3.1	"Just the whole business adapting to change could be the issue."	Fear of being replaced by AI and cultural resistance	Resistance to change	Challenges in AI implementation
FG2.3	"We need training and awareness to integrate AI effectively."	Lack of AI training and awareness	Training and awareness of AI	Challenges in AI implementation
FG2.1	"I think not a lot of drivers are being trained on it and it could basically save a company a lot of money when it comes to diesel and reduce our carbon emission."	Lack of AI training and awareness	Training and awareness of AI	Challenges in AI implementation
FG3.1	"We need training. I think education. Education is number one yeah"	Lack of AI training and awareness	Training and awareness of AI	Challenges in AI implementation
	"The priorities would be on safety and health and the environment part of those lacks attention… there's not a lot of training."	Lack of AI training and awareness	Training and awareness of AI	Challenges in AI implementation
FG2.5	"I would say exactly what I think participant G2,3 or participant G2,4 referred to earlier is just to create a department that basically focuses on AI It's fine. I agree with we need training."	Lack of AI training and awareness	Training and awareness of AI	Challenges in AI implementation
FG3.1	"Only one person could give me information on AI initiatives."	Few individuals involved in AI initiatives	Lack of awareness	Challenges in AI implementation
FG2.5	"It is engaged, but other departments are blocked from using AI tools"	Few individuals involved in AI initiatives	Lack of awareness	Challenges in AI implementation
FG3.1	"I think not a lot of drivers are being trained on it and it could basically save a company a lot of money when it comes to diesel and reduce our carbon emission. But I think it's not being given enough attention."	Few individuals involved in AI initiatives	Lack of awareness	Challenges in AI implementation
FG3.3	"That's the first time I've heard about such, and I think within my team, especially where I'm based, I don't really get to hear about such."	Few individuals involved in AI initiatives	Lack of awareness	Challenges in AI implementation

Table A1. *Cont.*

Participants	Participants Quote	Initial Code	Axial Code	Theme
FG1.4	"There should be a next step out of this discussion to talk to the custodians of our AI techniques and maybe I'll even go talk to our OPS excellence team about... so all of you on the field, whether we're in quality, security, safety, health and well-being because there's you know and fatigue management and all of those things are really using some AI tools as well as environment. But what are the cases you know we need that conversation to even think about."	Few individuals involved in AI initiatives	Lack of awareness	Challenges in AI implementation

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