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AI-based smart marketing for enhancing environmental restoration project efficiency in the mining industry

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ABSTRACT

The mining industry, due to its significant environmental impacts, requires innovative approaches to restore degraded ecosystems. Despite the considerable potential of AI-based smart marketing to enhance stakeholder engagement and optimize resource allocation, limited research has investigated the intersection of sustainable marketing, artificial intelligence, and environmental restoration projects within the mining sector. This study aims to develop a conceptual framework for the application of AI-based smart marketing to improve the effectiveness of environmental restoration projects in the mining industry. Adopting a qualitative and inductive approach, the study employed thematic analysis based on semi-structured interviews with 25 experts, including 15 university professors and 10 industry managers and consultants. The findings identified six overarching themes, comprising 144 basic codes and 24 organizing themes: data-driven analysis and resource optimization, personalization and stakeholder engagement, ethical considerations and sustainability, innovation in marketing technologies, support and participation enhancement, and project efficiency improvement. The principal innovation of this study is an integrated framework that combines artificial intelligence, smart marketing, and environmental restoration in the mining industry. The results indicate that the application of AI, through big data analytics, targeted campaign design, and real-time monitoring, can significantly enhance community participation and project efficiency, thereby.

KEYWORDS

Artificial intelligence, environmental restoration, mining, smart marketing

I. INTRODUCTION

THE mining industry plays a critical role in global economic development by supplying essential raw materials for industrial production and energy transition. However, mining activities are also among the major drivers of environmental degradation, contributing to deforestation, biodiversity loss, soil erosion, and water contamination, with long-term consequences for ecological systems (Sonter et al., 2018). Beyond ecological impacts, the failure of environmental restoration projects may also generate social conflicts, weaken stakeholder trust, and reduce the social legitimacy of mining operations (Franks et al., 2013). Therefore, developing effective and sustainable restoration strategies has become a strategic priority for the mining industry.

The application of artificial intelligence (AI) in marketing strategies offers a transformative opportunity to enhance the effectiveness of environmental restoration projects. AI-based technologies can optimize marketing efforts by providing data-driven insights, enabling organizations to engage more effectively with stakeholders and promote sustainable practices successfully (Baruno et al., 2025). AI-based marketing strategies are particularly significant in environmental restoration, as effective communication with local communities and stakeholders is essential for securing their support. By leveraging tools such as predictive analytics and machine learning, organizations can tailor messages to suit the characteristics of specific audiences, thereby increasing public awareness and participation in restoration initiatives (Noranee et al., 2023). This personalized approach fosters trust and strengthens community engagement, which is critical for the success of such projects (Marvi et al., 2025).

Moreover, AI's application in marketing can enhance the operational efficiency of restoration projects. AI can analyze vast datasets to identify optimal restoration sites and environmental risks, enabling more precise decision-making (Stević et al., 2024). This capability is particularly crucial in the mining sector, where

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environmental damage can have long-lasting impacts on ecosystems. By using AI to monitor and manage these impacts, more effective restoration strategies aligned with sustainability goals can be implemented (Vespignani et al., 2024).

Although AI has demonstrated significant potential for improving environmental decision-making and stakeholder engagement, previous studies have reported mixed findings regarding its practical implementation. While some scholars emphasize AI's ability to improve predictive accuracy, optimize resource allocation, and strengthen stakeholder communication, others highlight challenges related to algorithmic bias, data privacy, and lack of transparency that may undermine public trust and reduce adoption effectiveness (Dwivedi et al., 2021). These contradictory findings suggest that the effectiveness of AI depends not only on technological capability but also on how it is integrated into communication and stakeholder engagement strategies. Although prior studies acknowledge the importance of artificial intelligence in environmental monitoring and sustainable resource management, the literature remains fragmented. Most studies have primarily focused on technical and operational applications of AI, such as predictive maintenance, environmental monitoring, and production optimization. In contrast, studies in sustainable marketing have mainly emphasized stakeholder communication and public engagement, with limited integration of AI-driven adaptive marketing mechanisms. This indicates that technological capability, stakeholder engagement, and governance dimensions have largely been examined in isolation rather than as interdependent factors influencing restoration outcomes. Such fragmentation highlights an important unresolved gap in understanding how these dimensions interact within mining environmental restoration projects.

AI's role in promoting sustainable marketing extends beyond efficiency to encompass ethical considerations and the need for transparency. As AI adoption increases, organizations must address challenges such as data privacy and algorithmic biases to ensure that marketing strategies are both effective and responsible. Establishing an ethical framework is essential for maintaining public trust and supporting environmental initiatives, particularly in industries with a history of environmental harm.

Furthermore, integrating AI into marketing strategies can facilitate the adoption of innovative practices that support the transition to green mining. For instance, AI can optimize supply chains, reduce waste, and enhance consumer engagement with sustainable products (Nianko, 2025). Targeted marketing of these initiatives can help mining companies demonstrate their commitment to sustainability and attract environmentally conscious consumers. Additionally, AI can play a pivotal role in developing comprehensive frameworks for environmental restoration. By analyzing historical data and current trends, AI can identify best practices and propose strategies that are both economically viable and environmentally effective (Thakur et al., 2024). Such a holistic approach is essential for achieving long-term sustainability in the mining industry, balancing economic objectives with environmental responsibilities.

Despite rapid advancements in artificial intelligence, digital marketing, and sustainable mining practices, a significant research gap remains in understanding how AI-based smart marketing can support environmental restoration in mining contexts. Existing studies have largely concentrated on technical AI applications in mining operations, environmental monitoring, or production optimization. In contrast, limited attention has been given to the integration of AI-driven marketing strategies with stakeholder engagement and restoration effectiveness.

This research addresses the following question: How can AI-based smart marketing enhance the effectiveness of environmental restoration projects in the mining industry? The primary objective of this study is to develop a conceptual framework that explains the mechanisms through which AI-driven smart marketing improves restoration effectiveness. The innovation of this study lies in proposing an interdisciplinary framework that integrates AI-enabled data analytics, targeted communication strategies, and stakeholder engagement mechanisms into a unified model for advancing environmental sustainability in the mining sector. This framework may also provide practical insights for other environmentally intensive industries undergoing green transformation.

This flowchart illustrates how AI-based smart marketing enhances the effectiveness of environmental restoration projects in mining. It outlines the pathways through which AI optimizes marketing efforts, leading to data-driven insights, effective stakeholder engagement, and the promotion of sustainable practices (Baruno et al., 2025; Noranee et al., 2023; Marvi et al., 2025). The diagram also shows how AI enhances operational efficiency by analyzing datasets for precise decision-making and improving environmental monitoring (Stević et al., 2024; Vespignani et al., 2024). Furthermore, it depicts AI's role in facilitating green mining practices, such as supply chain optimization and consumer engagement, and its contribution to developing comprehensive restoration frameworks (Nianko, 2025; Thakur et al., 2024). Finally, the flowchart highlights the importance of addressing ethical considerations like data privacy and algorithmic fairness to build public trust and support environmental initiatives.

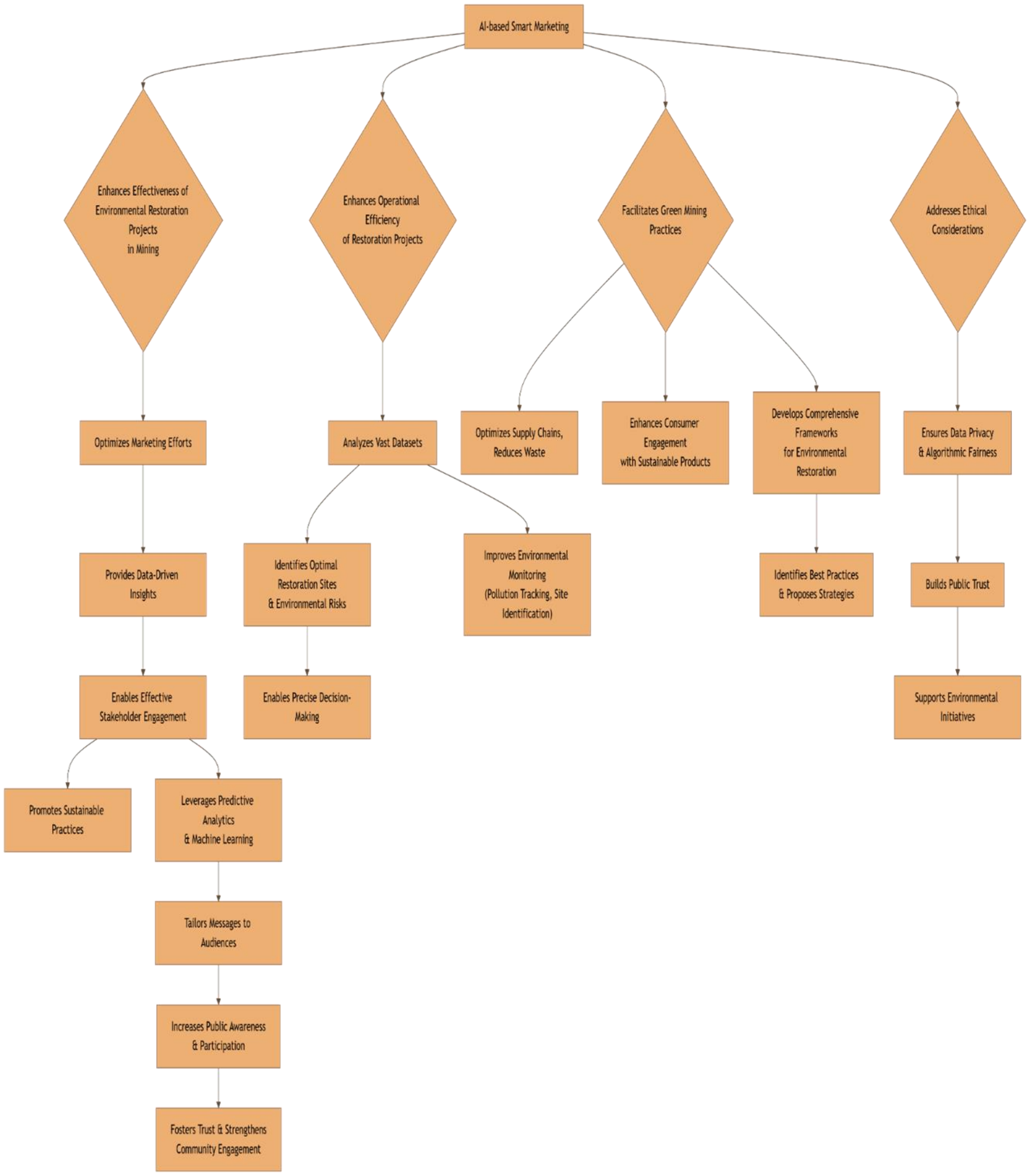

Fig. 1. The impact of intelligent marketing based on artificial intelligence on the effectiveness of environmental restoration in mining. (Source: Taken from research literature)

II. THEORETICAL BACKGROUND

AI-based smart marketing refers to the integration of artificial intelligence technologies, machine learning, advanced analytics, and automated decision-making systems into marketing processes to improve targeting, personalization, stakeholder communication, and decision quality. In the context of this study, environmental restoration projects refer to planned interventions aimed at rehabilitating degraded ecosystems, restoring ecological functions, and mitigating environmental damage caused by mining activities. Project effectiveness refers to the extent to which restoration initiatives achieve environmental, social, and operational objectives. These concepts constitute the core constructs of this study and provide the conceptual basis for examining the role of AI-driven marketing in environmental sustainability (Dwivedi et al., 2021).

Mining activities, due to extensive resource extraction, result in severe environmental impacts, such as ecosystem degradation, soil and water pollution, and biodiversity loss, necessitating innovative restoration strategies (Yue et al., 2024). AI-based smart marketing has emerged as a transformative approach to enhance the effectiveness of environmental restoration projects in the mining sector by leveraging advanced data analytics and targeted stakeholder engagement. By utilizing tools like machine learning and predictive analytics, AI enables the processing of large-scale environmental and social data, allowing organizations to design targeted marketing campaigns that enhance local community participation in restoration initiatives

(Baruno et al., 2025). By analyzing behavioral patterns and community needs, AI tailors marketing messages to not only raise public awareness but also foster a sense of ownership and responsibility toward restoring ecosystems degraded by mining activities.

From a theoretical perspective, this study is grounded in Stakeholder Theory, which emphasizes that organizational success depends on effectively managing relationships with stakeholders, including local communities, regulators, and environmental groups. This perspective suggests that environmental restoration projects are more likely to succeed when stakeholders actively participate and trust organizational initiatives. Furthermore, the Resource-Based View explains how technological capabilities such as artificial intelligence can function as strategic organizational resources that improve performance and generate sustainable competitive advantages (Barney, 1991). These theoretical foundations help explain how AI-based smart marketing may strengthen stakeholder engagement and improve restoration effectiveness.

AI technologies, particularly machine learning and predictive analytics, have fundamentally transformed organizational approaches to marketing in environmental restoration projects. These technologies enable the processing of geographic, demographic, and environmental data to identify communities or areas most affected by mining activities or those with high potential for restoration participation (Stević et al., 2024; Nagina et al., 2024). For example, AI algorithms can analyze soil or water quality data in mining regions and design marketing campaigns that emphasize the benefits of restoration for local communities, such as improved access to clean water or enhanced agricultural productivity. This capability allows organizations to strategically allocate limited resources, preventing budget waste on non-targeted campaigns (Xie et al., 2022; Nalini et al., 2021). Additionally, AI automates processes such as marketing content creation, message scheduling, and stakeholder feedback analysis, enhancing operational efficiency and enabling organizations to respond swiftly to community needs. These features are particularly critical in restoration projects, which often face time and budget constraints.

One of the key advantages of AI-based smart marketing is its ability to enhance stakeholder engagement through personalized communication. By analyzing behavioral data and community preferences, organizations can produce messages aligned with local values, cultures, and needs (Rathod, 2023; Lakshmipriyanka et al., 2023). For instance, in projects aimed at restoring mining-degraded lands, AI can design messages highlighting economic benefits, such as job creation for local youth, or environmental benefits, such as pollution reduction. This approach not only increases campaign effectiveness but also fosters deeper trust and connection between organizations and local communities, which is critical for active participation in restoration projects (Todorova et al., 2023; Young et al., 2022). In regions where communities are skeptical due to mining's negative impacts, AI can reduce resistance by analyzing social data and delivering transparent, evidence-based messages. AI also enables the development of educational programs or interactive digital platforms that engage communities in the restoration process, fostering a sense of responsibility.

The use of AI in marketing environmental restoration projects presents several ethical challenges that must be carefully managed to maintain stakeholder trust. A primary concern is protecting the privacy of data collected from local communities and stakeholders. Analyzing personal data, such as online behavior or demographic information, can raise privacy concerns. Organizations must establish transparent policies for data collection and use, ensuring that data is collected with full stakeholder consent and stored securely. Additionally, algorithmic biases can lead to inequities in access to information or resources, such as excluding marginalized groups from marketing campaigns (Davenport et al., 2020). To address this, organizations should regularly evaluate algorithms and ensure diverse input data to produce equitable outcomes. Recent studies also highlight contradictory findings regarding AI implementation, indicating that while AI can improve predictive accuracy and stakeholder responsiveness, challenges related to algorithmic opacity, privacy risks, and biased decision-making may reduce trust and limit adoption effectiveness (Dwivedi et al., 2021). Adhering to ethical principles, such as transparency in data use and regular reporting on algorithm performance, can enhance community trust and organizational credibility in restoration projects.

AI also enables real-time assessment of marketing campaign impacts, which is invaluable for enhancing the effectiveness of restoration projects in mining. AI-driven data analytics tools can monitor key metrics, such as community participation rates, the number of new supporters, or public awareness levels (Rathod, 2023; Zhang, 2025). These insights allow organizations to identify campaign strengths and weaknesses and dynamically adjust marketing strategies. For example, if analytics reveal that a campaign fails to engage a specific group, such as local farmers, organizations can use AI to redesign messages or communication channels, shifting focus from traditional advertising to social media. This data-driven approach not only enhances marketing efficiency but also ensures alignment with the environmental goals of restoration projects, maximizing their impact.

The success of AI-based smart marketing in restoration projects depends on interdisciplinary collaboration among marketing experts, ecologists, and data scientists. Such collaborations enable the development of innovative solutions to address the complex challenges of environmental restoration in mining (Mohammadian, 2024; Sajili et al., 2024). For instance, combining ecologists' knowledge of degraded ecosystems with data scientists' expertise in big data analysis can produce algorithms that accurately predict mining's environmental impacts and link these insights to marketing strategies.

Moreover, successful projects demonstrate that AI-driven community engagement can significantly increase participation. Projects using digital platforms to educate communities about restoration benefits have successfully enhanced public awareness and support (Festin et al., 2019; McRae et al., 2012). These experiences can serve as models for organizations, promoting innovative approaches such as incentive programs or local workshops. As AI technology advances, its applications in marketing restoration projects are expanding. Emerging tools, such as sentiment analysis on social media, enable organizations to understand better local communities' views and concerns regarding mining and restoration activities (Weinmann et al., 2016). This information can refine marketing messages to address public concerns and garner greater support. Policymakers can also play a critical role by developing frameworks that encourage AI innovation while ensuring ethical standards (Thakur et al., 2024; Davenport et al., 2020). For example, policies mandating transparent data use reports can enhance public trust and facilitate the adoption of AI-based smart marketing in restoration projects.

The ultimate goal of AI-based smart marketing is to achieve long-term sustainability in environmental restoration projects. By enhancing community engagement, promoting responsible practices, and improving project efficiency, AI contributes to the restoration of ecosystems degraded by mining activities (Nagina et al., 2024; Xie et al., 2022). For instance, marketing campaigns using AI to educate communities about the importance of restoring mined lands can promote sustainable behaviors, such as recycling or resource conservation. This holistic approach not only ensures the short-term effectiveness of restoration projects but also fosters long-term sustainability by cultivating a sense of ownership among local communities.

Based on the theoretical foundations of this study, the relationship among the core constructs can be explained as follows: AI-based smart marketing improves data analysis, communication precision, and resource allocation; these capabilities strengthen stakeholder engagement and community participation, which in turn enhance the effectiveness of environmental restoration projects and ultimately contribute to long-term environmental sustainability in the mining industry. This causal relationship provides the conceptual foundation for the present study.

In conclusion, AI-based smart marketing offers a unique opportunity to enhance the effectiveness of environmental restoration projects in the mining sector. By improving personalization, optimizing resources, and strengthening stakeholder engagement, AI mitigates the environmental impacts of mining activities. However, its success depends on addressing ethical challenges, such as data privacy and algorithmic biases, and fostering interdisciplinary collaboration. As technology and research in this field progress, AI-based smart marketing can serve as a key tool in promoting environmental sustainability and responsible resource management in the mining industry.

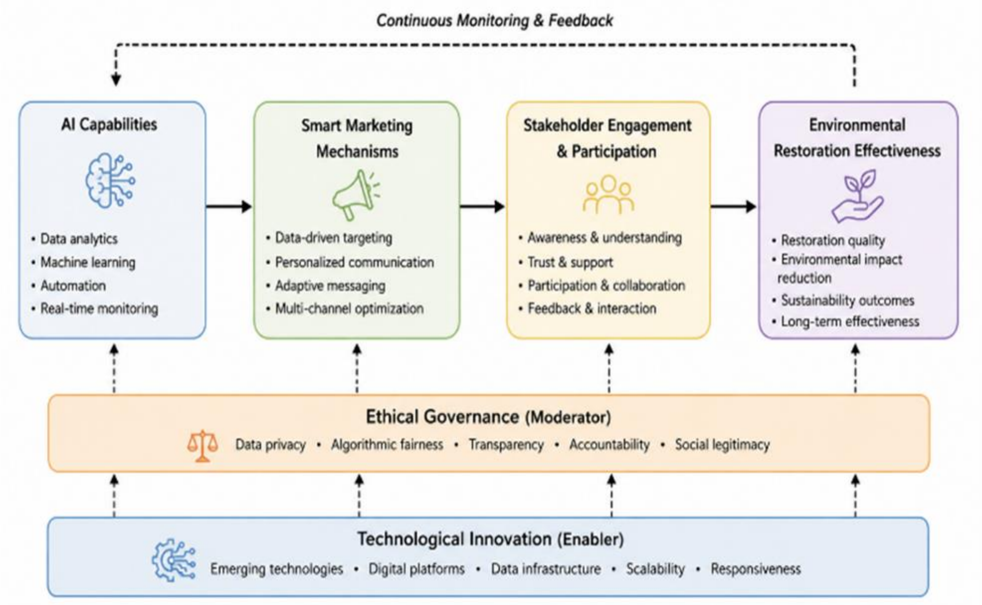

Fig. 1. Conceptual model

III. RESEARCH METHODOLOGY

This study is an exploratory, applied qualitative research utilizing thematic analysis to analyze data. Conducted with an inductive approach based on an interpretive philosophy, the research targeted two main groups of experts: first, university professors specializing in marketing and business management from universities in Tehran, Mazandaran, Semnan, Ilam, and Qom, with academic publications or research experience related to the study topic and at least three years of scientific or practical experience in modern marketing, smart marketing, or AI technologies; second, industry experts, including managers, consultants, and senior specialists in mining, environmental, and digital marketing organizations, with practical experience in implementing technology- and data-driven environmental restoration projects. Selection criteria included relevant scientific or practical expertise, over three years of managerial or consulting experience, and familiarity with technology-based marketing concepts. Snowball sampling was used, resulting in a sample of 25 participants. Snowball sampling was selected because the study addressed a highly specialized interdisciplinary topic at the intersection of artificial intelligence, smart marketing, mining, and environmental restoration, making it difficult to identify sufficiently qualified participants through conventional sampling approaches. This method enabled the researchers to access experts through professional referral networks and ensured the inclusion of participants with highly relevant academic and practical expertise.

Despite its suitability for accessing highly specialized experts, snowball sampling may introduce selection bias because participants are often recruited through interconnected professional networks, potentially increasing the likelihood of homogeneous perspectives. This may limit the representation of alternative or dissenting viewpoints related to AI adoption, marketing practices, or environmental restoration strategies. To reduce this limitation, deliberate efforts were made to recruit participants from diverse academic institutions, industrial sectors, and professional roles across different geographical locations, thereby enhancing the heterogeneity of perspectives included in the study. Nevertheless, the findings should be interpreted with consideration of this sampling limitation.

The selected participants possessed complementary expertise directly related to the research problem. Academic participants contributed theoretical knowledge in marketing strategy, business analytics, artificial intelligence applications, and digital transformation. In contrast, industry participants provided practical insights from mining operations, environmental rehabilitation, sustainability management, and technology-driven restoration projects. This combination ensured both theoretical depth and practical relevance in addressing the study objectives.

Theoretical saturation was achieved after the 16th interview, but interviews continued until the 25th to enhance data credibility and diversity of perspectives.

The determination of theoretical saturation was based on continuous comparative analysis of interview transcripts, initial codes, and emerging themes throughout the data analysis process. Saturation was considered achieved when three consecutive interviews (interviews 14–16) produced no substantially new codes, categories, or higher-order themes, indicating that the collected data had become largely repetitive. Interviews were nevertheless continued until the 25th participant to confirm saturation across different participant subgroups, particularly academic and industry experts, and to enhance the credibility, robustness, and diversity of perspectives in the findings. The additional interviews did not generate new themes; however, they provided richer supporting evidence and strengthened confidence in the stability of the thematic structure.

Semi-structured interviews, conducted in-person or virtually, lasted 45 to 60 minutes. All interviews were recorded with participants' informed consent, transcribed verbatim, and returned to participants for validation. Interview questions were designed to be clear and comprehensible to ensure tool reliability. The main research questions included:

1. How does AI-based smart marketing impact the effectiveness of environmental restoration projects in mining?
2. Which AI technologies and tools are most effective in marketing environmental restoration projects in mining?
3. What factors facilitate or hinder the successful use of smart marketing in mining restoration?
4. How do stakeholders' (investors, local communities, government institutions) perceptions and reactions influence the effectiveness of this marketing?
5. What ethical, technical, or cultural challenges arise in applying smart marketing to environmental projects?
6. What strategies are recommended to enhance the effectiveness of smart marketing in mining environmental restoration?

To ensure the study's validity, triangulation was employed. Data were collected from three independent sources: university professors, industry managers and consultants, and technology-based marketing specialists. Additionally, analysis results were shared with some participants for feedback, and necessary revisions were made. This approach provided comprehensive insights from various perspectives, identifying components, challenges, and functions of AI-based smart marketing in enhancing the effectiveness of mining restoration projects. Collecting data from diverse sources, including academics, industry managers, and marketing experts, increased the depth and variety of data, facilitating a more precise and multidimensional analysis. Furthermore, a literature review of digital marketing, AI, and environmental projects was used as a complementary resource. To ensure data quality, a quality control process was implemented, where initial analysis results were summarized and sent to some interviewees for verification of alignment with their intended meanings. Feedback led to revisions, enhancing the alignment of the analysis with participants' experiences and ensuring acceptable validity. To ensure the reliability of data collection tools, particularly semi-structured interviews, various approaches were used to confirm the tools' ability to produce valid and repeatable results. Key concepts were defined clearly to avoid ambiguity, and questions were revised and pre-tested for clarity. Participants were asked to confirm whether their interpretations aligned with the researcher's intent. The interview structure was designed to encourage participation through appropriate wording, logical question sequencing, and a conducive dialogue environment. To verify data stability, initial findings were shared with some participants for feedback on accuracy and alignment, which was used to refine the analysis and enhance the quality of the findings.

To ensure transparency in the coding process, the development of themes followed a systematic multi-stage coding procedure. First, all interview transcripts were reviewed repeatedly to achieve deep familiarization with the data. During this stage, meaningful statements, repeated expressions, and conceptually relevant observations were highlighted. In the open coding stage, raw interview excerpts were segmented into meaningful analytical units, resulting in an initial pool of 312 raw codes. These raw codes were generated inductively without imposing predefined theoretical categories.

In the second stage, similar or conceptually overlapping raw codes were merged through constant comparative analysis, redundancy was removed, and semantically related codes were consolidated into 144 basic codes. During axial coding, relationships among these basic codes were examined to identify shared conceptual patterns, causal connections, and recurring dimensions. This process led to the formation of 17 constituent themes representing broader conceptual categories.

In the final selective coding stage, the constituent themes were further abstracted and integrated into 4 overarching themes: Data-Driven Optimization and Project Effectiveness; Stakeholder Engagement, Support, and Participation; Ethical Governance and Sustainability; and Technological Innovation in Smart Marketing. The coding structure was reviewed iteratively through multiple rounds of comparison between codes, themes, and original transcripts to ensure internal consistency and conceptual distinctiveness. To enhance reliability, parts of the coding process were independently reviewed by academic peers familiar with qualitative research, and selected participants were asked to validate whether the extracted themes accurately reflected their perspectives.

The matic Analysis Process (Braun et al., 2006):

1. Data Familiarization: The researcher actively reviews the data multiple times to gain a deep understanding, noting initial concepts and patterns for later use.

2. Initial Coding: Relevant data segments are identified and coded based on the research focus, either data-driven or theory-driven, depending on the research objectives.

3. Theme Searching: Initial codes are organized and grouped into potential themes, with some forming main themes, other sub-themes, and irrelevant codes discarded.

4. Theme Reviewing: Identified themes are refined at two levels: reviewing themes against coded data and evaluating themes against the entire dataset, with recoding or re-theming as needed.

5. Theme Definition and Naming: Themes are defined, named, and analyzed, specifying the details of data within each theme.

6. Report Writing: The final analysis is conducted, and the research report is prepared, presenting refined themes and their analyses.

This structured, flexible process enables systematic data analysis and reliable results.

IV. DATA ANALYSIS AND FINDINGS

To identify the components, drivers, barriers, and outcomes of applying AI-based smart marketing to enhance the effectiveness of environmental restoration projects in mining, semi-structured interviews were conducted with 25 academic and industry experts. Participants included 15 university faculty members (in marketing management, technology management, strategic management, and information systems) and 10 managers, specialists, and consultants in mining, environmental, and digital marketing fields. Selection criteria included expertise in smart marketing, AI, environmental issues, or mining, with at least three years of professional experience. All participants were male, with 24% under 40 years, 52% aged 40–50, and 24% over 50. Regarding professional experience (educational, research, or managerial), 24% had less than 10 years, 48% had 10–15 years, and 28% had over 15 years. Theoretical saturation was achieved after the 16th interview, but interviews continued until the 25th to enhance credibility and diversity.

Table 1. Descriptive statistics of experts

Variable	Category	Number (Persons) (%)	Percentage (%)
Gender	Male	25	100
Age Group	Under 40 years	6	24
40 to 50 years	13	52	
Over 50 years	6	24	
Professional Experience	Less than 10 years	6	24
10 to 15 years	12	48	
More than 15 years	7	28	
Participant Type	Faculty Members	15	60
Industry Experts and Consultants	10	40	
Number of Interviews Until Theoretical Saturation	-	16	-
Total Number of Interviews	-	25	-

Table 2. Sample interview transcript

Interview No.	Participant Details	Interview Text	Extracted Codes
1	University Professor, 45 years, Digital Marketing Specialist, 12 years of experiences	"AI in marketing can be a game-changer. For example, we can use big data to understand which areas need environmental restoration the most. It's like having a precise map of where to focus. Then, you can send messages that resonate with people, like telling someone that restoring the land will provide cleaner water for their farm. You can also automate content creation, so you don't need a hundred people writing texts. But you have to be careful that people's data doesn't leak, because if they lose trust, it's over!"	Predicting community needs - Identifying priority restoration areas - Analyzing environmental data - Producing personalized content - Automated content production - Protecting personal data - Trust-building messaging
2	Mining Project Manager, 50 years, 15 years in mining industry	"In mining projects, we deal a lot with the environment. AI can tell us where soil or water is most damaged, so that we can focus restoration there. Alternatively, you can use an app to show locals what the project is about, making them partners in the process. I've seen a case where an educational program got young people to help restore land. The only issue is that algorithms sometimes make mistakes, so you need to ensure no group is overlooked."	Monitoring soil quality - Monitoring water quality - Developing interactive educational programs - Encouraging voluntary participation - Fostering community ownership - Monitoring algorithmic biases - Ensuring diverse input data
3	Marketing Consultant, 38 years, 10 years in technology-based marketing	"With AI, you can understand what people want and give it to them. For example, in a village ruined by mining, you can send a message saying what the project will bring, like jobs or cleaner air. Alternatively, on social media, you can see what people are saying—if they're angry, you adjust your approach. However, you need to handle people's data carefully, or it'll cause trouble."	Needs-based messaging - Behavior-based targeting - Social media sentiment analysis - Producing motivational content - Enhancing digital communication - Secure data storage - Adhering to ethical standards

V. DISCUSSION AND CONCLUSION

AI-based smart marketing presents a transformative approach with significant potential to enhance the effectiveness of environmental restoration projects in the mining industry. This study, through thematic analysis, identified 4 overarching themes and 17 constituent themes encompassing 144 basic codes. The revised thematic structure provides a more integrated conceptual framework by reducing overlap among themes and clarifying the causal relationships between technological, social, and governance dimensions of AI-based smart marketing. Rather than functioning independently, these themes interact dynamically and collectively shape restoration outcomes. Below, each main theme and its constituent themes are discussed and supported by credible academic sources.

Table 3. Extracted codes from expert interviews: role of AI-based smart marketing in mining environmental restoration

Main Overarching Themes	Constituent Themes	Basic Codes
Data-Driven Optimization and Project Effectiveness	Predictive Analysis	Predicting community needs; identifying priority restoration areas; analyzing environmental data; predicting environmental impacts; optimizing resource allocation; analyzing stakeholder behavior; assessing environmental risks; predicting campaign feedback; analyzing geographic data; identifying environmental trends; predicting ecosystem changes; analyzing social data; predicting resource demand; analyzing economic restoration impacts; monitoring sustainability indicators; analyzing soil and water data; identifying critical restoration points; analyzing historical data; predicting long-term impacts; analyzing multidimensional data; predicting investor behavior; analyzing meteorological data; assessing social impacts; real-time feedback analysis
	Process Automation	Automated content production; scheduling message releases; managing digital campaigns; automated feedback analysis; optimizing communication channels; automated reporting; managing stakeholder data; optimizing digital advertising; automated sentiment analysis; managing automated interactions; optimizing marketing processes; automated campaign monitoring; producing analytical reports; automated stakeholder responses; automated content management; optimizing workflows; automated competitor analysis; automated budget management; multilingual content production; automated performance evaluation; managing digital platforms; optimizing campaign scheduling; automated environmental data analysis; producing interactive content
	Resource Optimization	Reducing supply chain waste; managing resources efficiently; analyzing supply chain data; optimizing transportation; predicting logistical needs; sustainable inventory management; analyzing supply chain costs; optimizing distribution processes; using real-time data; managing sustainable supply; analyzing supply chain environmental impacts; optimizing energy consumption; managing suppliers; analyzing supply data; predicting raw material demand; managing recycled resources; analyzing supply chain risks; optimizing recycling processes; analyzing production data; managing sustainable raw materials; optimizing procurement processes; analyzing supply chain social impacts; monitoring supplier sustainability; optimizing logistical routes.
	Environmental Monitoring and Management	Monitoring environmental pollution; identifying suitable restoration sites; assessing long-term impacts; monitoring soil quality; monitoring water quality; analyzing environmental data; monitoring biodiversity; assessing mining impacts; monitoring greenhouse gas emissions; analyzing ecosystem data; monitoring climate changes; assessing project social impacts; monitoring natural resources; analyzing atmospheric data; monitoring ecosystem health; assessing environmental risks; monitoring mining activity impacts; analyzing geological data; monitoring ecosystem sustainability; analyzing restoration social impacts; monitoring air quality; assessing restoration economic impacts; monitoring water resources; analyzing multisource environmental data
	Campaign Effectiveness Evaluation	Evaluating community participation rates; evaluating new supporter numbers; evaluating public awareness levels; evaluating campaign feedback; evaluating advertising effectiveness; evaluating digital interactions; evaluating message effectiveness; evaluating investor participation; evaluating social feedback; evaluating communication channel effectiveness; evaluating online interaction rates; evaluating digital content effectiveness; evaluating government institution participation; evaluating environmental feedback; evaluating platform effectiveness; evaluating local group participation; evaluating educational content effectiveness; evaluating multimedia feedback; evaluating voluntary participation; evaluating incentive program effectiveness; evaluating social interactions; evaluating sustainable content effectiveness; evaluating indigenous group participation; evaluating two-way communication effectiveness
	Continuous Monitoring and Framework Development	Monitoring project progress; monitoring environmental impacts; monitoring stakeholder participation; monitoring project feedback; monitoring campaign performance; monitoring social impacts; monitoring project sustainability; monitoring economic impacts; monitoring restoration quality; monitoring digital interactions; monitoring long-term impacts; monitoring community participation; developing restoration frameworks; developing sustainability frameworks; developing data-driven frameworks; developing collaborative frameworks; developing long-term sustainability frameworks

Table 3. (*Continued*)

Stakeholder Engagement, Support, and Participation	Targeted Marketing	Tailoring messages for local communities; designing culturally relevant messages; targeting specific groups; needs-based messaging; producing personalized content; targeting investors; messaging for government institutions; designing environmental messages; targeting age groups; value-based messaging; behavior-based targeting; producing regional content; messaging to reduce resistance; targeting key stakeholders; producing motivational content; data-based messaging; demographic-based targeting; producing visual content; trust-building messaging; preference-based targeting; multimedia content; emotion-based messaging; geographic-based targeting; interactive digital content
	Ownership and Participation Building	Fostering responsibility; creating community ownership; promoting active participation; building project trust; enhancing social interactions; encouraging sustainable behaviors; creating local incentives; enhancing two-way communication; promoting project transparency; encouraging voluntary participation; fostering local identity; encouraging community feedback; promoting environmental values; fostering ecosystem belonging
	Sentiment Analysis	Analyzing social media sentiments; identifying community concerns; analyzing stakeholder feedback; monitoring public perceptions; analyzing investor reactions; identifying stakeholder needs; analyzing local sentiments; monitoring digital feedback; identifying cultural barriers; analyzing emotional data; identifying community priorities; identifying emotional patterns; stakeholder preferences.
	Educational and Incentive Programs	Designing digital educational programs; educating local communities; developing interactive educational content; environmental workshops; sustainability education; online educational programs; education on mining impacts; multilingual educational content; restoration benefit education; AI education; local incentive programs; financial incentives; social incentives; environmental incentives; youth-focused incentives; women-focused incentives
Ethical Governance and Sustainability	Data Privacy Management	Protecting personal data; obtaining informed consent; transparency in data collection; secure data storage; managing data risks; developing transparent policies; preventing privacy breaches; creating security protocols; regulatory compliance; encryption systems; transparency reports; ethical guidelines
	Reducing Algorithmic Bias	Regularly evaluating algorithms; ensuring diverse input data; reducing access inequities; monitoring algorithmic biases; developing fair algorithms; ensuring equitable access; analyzing cultural biases; algorithm transparency; inclusive algorithms; monitoring gender biases.
	Long-Term Sustainability	Promoting sustainable behaviors; reducing environmental impacts; promoting recycling; green projects; responsible consumption; reducing carbon emissions; green technologies; promoting green economy; reducing waste; ecosystem protection; sustainability policies
	Interdisciplinary Collaboration	Collaborating with ecologists; collaborating with data scientists; collaborating with marketing experts; collaborating with government institutions; collaborating with local communities; collaborating with technology experts; collaborating with environmental organizations; collaborating with policymakers; collaborating with universities
Technological Innovation in Smart Marketing	Emerging AI Technologies	Real-time analytics; generative AI; augmented reality; blockchain; cloud technologies; IoT; virtual reality; predictive analytical tools; AI in advertising; environmental data analytics
	Digital Platforms and Analytics	Interactive digital platforms; mobile applications; interactive websites; social media platforms; data analytics platforms; digital communication platforms; feedback platforms; multilingual platforms; sentiment analytics platforms; real-time analytics platforms
	Innovative Content Production	Interactive content; multimedia content; visual content; multilingual content; sustainable digital content; motivational content; environmental content; AR content; VR content; emotion-based content; green digital content

Fig. 2. Schematic model of AI-based smart marketing framework

A. Data-Driven Optimization and Project Effectiveness

(Predictive Analysis, Process Automation, Resource Optimization, Environmental Monitoring and Management, Campaign Effectiveness Evaluation, Continuous Monitoring and Framework Development)

This theme focuses on using AI technologies, such as machine learning and predictive analytics, to improve decision-making and resource allocation in restoration projects. Predictive analysis enables the identification of priority restoration areas and community needs, while process automation, such as automated content creation and digital campaign management, enhances operational efficiency. Supply chain optimization reduces waste and energy consumption, and environmental monitoring, such as tracking soil and water quality, ensures precise management of mining impacts. These capabilities allow organizations to design targeted marketing strategies and allocate resources effectively using big data analysis. For instance, geographic and environmental data analysis enhances project effectiveness by identifying critical restoration sites. These findings align with studies demonstrating that integrating data-driven analytics and resource optimization through AI technologies, such as machine learning and predictive analytics, significantly improves decision-making and resource allocation in environmental restoration projects. Machine learning techniques can identify patterns and predict trends, aiding resource allocation and informing environmental policies (Ekeh et al., 2025). This approach addresses urban and environmental challenges while promoting sustainability and equity in restoration interventions. Predictive analytics in resource management also enhances operational efficiency by forecasting demand and optimizing distribution, critical for effective, sustainability-focused restoration projects (Nayak, 2025).

Beyond operational efficiency, the emergence of this theme reflects the structural complexity of environmental restoration projects in mining. Unlike conventional marketing contexts, restoration projects involve high uncertainty, long project horizons, multidimensional environmental risk, and diverse stakeholder expectations. This explains why predictive analytics and continuous monitoring emerged as dominant dimensions. AI systems reduce informational uncertainty by transforming fragmented environmental and social data into actionable insights. In this sense, data-driven optimization acts as the foundational layer of the entire framework, because accurate prediction and continuous evaluation directly influence strategic resource allocation, communication timing, and restoration prioritization. These findings extend previous studies by showing that AI contributes not only to operational optimization but also to strategic adaptive governance in restoration management.

1) *Stakeholder Engagement, Support, and Participation*

(Targeted Marketing, Ownership and Participation Building, Sentiment Analysis, Educational and Incentive Programs)

This theme emphasizes the importance of engaging stakeholders through personalized messaging and fostering responsibility. Targeted marketing uses behavioral and demographic data analysis to produce messages aligned with community needs and values. Fostering ownership through interactive educational programs and digital platforms increases community participation in restoration projects. Sentiment analysis on social media identifies stakeholder concerns and preferences, while digital educational programs enhance public awareness of restoration benefits. This approach builds stakeholder trust and reduces social resistance, ensuring project success. Studies confirm that targeted marketing using behavioral and demographic data enables tailored messaging, increasing stakeholder participation and fostering ownership and responsibility (Ezeh et al., 2024). Interactive educational programs and digital platforms significantly enhance community engagement in restoration initiatives, while social media sentiment analysis improves understanding of stakeholder concerns, refining communication strategies and reducing resistance (Ishola et al., 2024). This comprehensive stakeholder engagement approach enhances trust and drives environmental initiative success.

A deeper interpretation of this finding suggests that stakeholder engagement emerged as a core theme because environmental restoration in mining is not purely a technical challenge; it is also a social legitimacy challenge. Mining companies often operate in environments where historical ecological damage has weakened public trust. As a result, technological efficiency alone is insufficient to guarantee restoration success. Personalized communication supported by AI reduces informational asymmetry between organizations and stakeholders by addressing localized concerns, cultural sensitivities, and community expectations. This finding expands prior stakeholder theory by demonstrating that AI-enabled personalization serves not only as a communication tool but also as a mechanism for rebuilding social trust, legitimacy, and long-term stakeholder commitment.

Moreover, the strong relationship between targeted marketing and participation suggests a causal pathway: improved personalization enhances perceived relevance, increased relevance strengthens trust, and trust ultimately drives active participation. Therefore, stakeholder engagement functions as the critical mediating mechanism linking AI capabilities to measurable restoration outcomes.

2) *Ethical Governance and Sustainability*

(Data Privacy Management, Reducing Algorithmic Bias, Long-Term Sustainability, Interdisciplinary Collaboration)

This theme underscores the need for ethical principles and sustainability in AI use. Data privacy management, focusing on protecting personal data and obtaining informed consent, maintains stakeholder trust. Reducing algorithmic biases through regular evaluation and diverse data inputs ensures equitable access to information. Promoting long-term sustainability, such as reducing environmental impacts and encouraging responsible behaviors, supports sustainable restoration projects. Interdisciplinary collaboration among ecologists, data scientists, and marketing experts delivers innovative solutions to restoration challenges. Research highlights that effective data privacy management is essential for maintaining stakeholder trust by protecting personal data and ensuring informed consent (Adanma et al., 2024). Addressing algorithmic biases through regular evaluations and diverse data enhances equity and AI effectiveness in restoration projects (Al-Adwan, 2025). Interdisciplinary collaboration drives innovative environmental solutions, reinforcing the need for ethical AI frameworks (Bashiir, 2025).

The prominence of this theme reveals a critical paradox in AI adoption within sustainability-focused industries. While AI enhances precision, scalability, and responsiveness in smart marketing, greater reliance on data-driven systems simultaneously increases ethical vulnerability. Specifically, algorithmic opacity, data misuse, and embedded biases may undermine stakeholder trust and weaken public acceptance of restoration initiatives. This explains why ethical governance emerged not as a peripheral concern but as a central moderating factor within the framework. The findings suggest that ethical governance determines whether AI-driven marketing becomes a mechanism for sustainable value creation or a source of social resistance.

Furthermore, long-term sustainability was strongly associated with interdisciplinary collaboration, indicating that technological capability alone cannot ensure sustainable restoration outcomes. Effective restoration requires integration of ecological expertise, AI analytics, policy governance, and stakeholder communication. This finding expands previous research by demonstrating that sustainability in AI-based restoration projects is best understood as a governance outcome rather than solely an environmental outcome.

3) *Technological Innovation in Smart Marketing*

(*Emerging AI Technologies*, *Digital Platforms and Analytics*, *Innovative Content Production*)

This theme highlights the role of advanced technologies in transforming marketing for restoration projects. Emerging technologies, such as generative AI and augmented reality, provide novel stakeholder engagement tools. Developing digital platforms, like mobile apps and interactive websites, facilitates information access. Real-time analytics enables campaign performance monitoring and rapid strategy adjustments, while innovative content production, such as multimedia and interactive content, captures community attention. These approaches enhance marketing effectiveness and public participation. Studies confirm that emerging technologies like generative AI and augmented reality offer innovative engagement tools (Kumar, 2025). Digital platforms enhance information access and participation, real-time analytics enable rapid strategy adjustments, and innovative content increases community engagement (Kumar, 2025).

The emergence of this theme indicates that technological innovation functions as the enabling infrastructure underlying all other dimensions of the framework. Unlike traditional digital marketing systems that mainly disseminate information, AI-driven technologies create adaptive and intelligent communication ecosystems capable of learning continuously from stakeholder interactions. This adaptive capability explains why technological innovation was strongly connected to both data-driven optimization and stakeholder engagement. Real-time analytics, generative AI, and interactive platforms allow restoration communication strategies to evolve dynamically in response to environmental changes and stakeholder feedback.

A critical comparison with previous literature shows that earlier studies largely examined AI as a technical efficiency tool or a marketing automation mechanism. In contrast, the present findings reveal that technological innovation should be understood more broadly as a strategic capability that integrates predictive intelligence, communication adaptability, and ecosystem responsiveness. This broader perspective represents one of the key theoretical contributions of the study.

4) *Final Discussion and Conclusion*

AI-based smart marketing, through advanced data analytics, personalized communication, and continuous monitoring, plays a pivotal role in enhancing the effectiveness of environmental restoration projects in mining.

One of the most important theoretical contributions of this study is the identification of causal and interactive relationships among the four overarching themes. Data-driven optimization provides the analytical foundation necessary for accurate targeting and evidence-based decision-making. These analytical capabilities strengthen stakeholder engagement by enabling personalized communication and increasing support and participation. Ethical governance moderates these relationships by preserving trust, transparency, fairness, and social legitimacy, while technological innovation acts as the enabling infrastructure that enhances adaptability, scalability, and responsiveness across the entire framework. This hierarchical relationship suggests that AI-based smart marketing should be understood as an integrated socio-technical system rather than a collection of independent technological tools.

Compared with prior studies, which often examined AI, sustainability, stakeholder engagement, or restoration management separately, this study offers a more comprehensive interdisciplinary model that explains how these dimensions interact to influence restoration outcomes. This analytical integration addresses an important gap in previous literature by moving beyond descriptive categorization toward explanation of causal mechanisms.

This study’s identification of 4 overarching themes and 17 constituent themes, encompassing 144 basic codes, provides a comprehensive framework for leveraging AI in sustainable marketing. However, success depends on addressing ethical challenges, such as data privacy and algorithmic biases, and fostering interdisciplinary collaboration.

From a theoretical perspective, this study contributes to sustainable marketing literature by proposing an integrated framework linking technological capability, stakeholder behavior, governance quality, and restoration effectiveness. From a practical perspective, the framework offers actionable guidance for mining managers, policymakers, and environmental practitioners in designing AI-enabled restoration strategies that are technologically advanced, socially legitimate, and ethically responsible.

This framework applies not only to the mining industry but also to other environmental sectors, serving as a model for promoting long-term sustainability. Future research should focus on developing regulatory policies and ethical standards for AI use in marketing to ensure public trust and effectiveness.

Future research should investigate this framework using quantitative and mixed-method approaches to empirically test the causal relationships among the four overarching themes identified in this study. Structural equation modeling (SEM) or multi-criteria decision-making methods could be employed to examine the relative influence of AI-driven optimization, stakeholder engagement, ethical governance, and technological innovation on restoration effectiveness. Comparative cross-industry studies involving sectors such as oil and gas, construction, and waste management may help evaluate the transferability of the proposed framework beyond mining contexts. Longitudinal studies are also recommended to examine how AI-based smart marketing influences stakeholder trust, participation, and environmental restoration outcomes over time. Furthermore, future studies should investigate the moderating roles of contextual factors such as regulatory environments, digital infrastructure maturity, organizational readiness, and cultural differences in shaping the effectiveness of AI-enabled restoration strategies. Experimental studies evaluating specific AI tools, such as generative AI, sentiment analysis systems, or real-time predictive analytics, would also provide more granular insights into which technologies generate the greatest practical impact under different restoration conditions.

B. *Research Limitations*

Limitations are an inevitable part of any research, providing opportunities for future studies and innovative solutions. Some limitations of this study include:

1. Qualitative data analysis based on an interpretive paradigm may be influenced by the researcher's subjectivity, though efforts were made to mitigate bias by focusing on participants' experiences.

2. Data collection relied solely on interviews, which could be strengthened with complementary methods.

3. Conducting the study within a specific timeframe may not reflect dynamic changes in user or market behavior. Longitudinal studies are recommended to examine these changes.

4. Despite the methodological rigor applied in participant selection, this study has several limitations that should be acknowledged. First, the use of snowball sampling may have introduced selection bias, as participants were recruited through professional referral networks. This sampling approach may increase the likelihood of recruiting experts with similar professional backgrounds, perspectives, or social connections, potentially limiting the diversity of viewpoints represented in the dataset. Although efforts were made to include participants from both academic and industry sectors to reduce this bias, the possibility of homogeneity in certain perspectives cannot be fully eliminated. Therefore, the findings should be interpreted within the context of the selected expert sample. Future studies may benefit from employing purposive or stratified sampling strategies to achieve broader representation across different stakeholder groups, industries, and geographical contexts.

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