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Green Telecommunications Practices and Their Contribution to UAE's Net-Zero Goals: A DEMATEL-Based Multi-Criteria Decision-Making Frame Work

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Abstract
The telecommunications sector plays a crucial role in achieving national sustainability goals, particularly in the context of the United Arab Emirates' (UAE) commitment to net-zero emissions by 2050. This study develops and validates a comprehensive framework for prioritizing green telecommunications practices using the Decision-Making Trial and Evaluation Laboratory (DEMATEL) methodology. Through systematic literature review and expert consultation, we identified six key categories of green telecom practices: Energy Management Practices (EMP), Green Infrastructure Practices (GIP), Circular Economy Practices (CEP), Digital Innovation Practices (DIP), Stakeholder Engagement Practices (SEP), and Regulatory Compliance Practices (RCP), encompassing 24 specific sub-practices. The DEMATEL analysis revealed that Energy Management Practices and Green Infrastructure Practices are the most influential cause-group factors, while Digital Innovation Practices and Stakeholder Engagement Practices represent key effect-group elements. The framework provides actionable insights for UAE telecom operators, policymakers, and stakeholders to strategically allocate resources and sequence interventions toward sustainable transformation. This research contributes to the growing body of knowledge on sustainable telecommunications management and offers a replicable methodology for emerging economies pursuing ambitious climate goals.

Keywords:
Green Telecom, UAE Sustainability, DEMATEL, Energy Efficiency, E-Waste Management, Sustainable Infrastructure, NRBV, TBL, Green telecommunications, multi-criteria decision making, UAE net-zero goals, Sustainable telecom practices, Circular economy

1. INTRODUCTION

The telecommunications industry stands at a critical juncture in the global transition toward sustainability, with mounting pressure to reduce its environmental footprint while maintaining service excellence and supporting digital transformation initiatives. The sector's energy consumption accounts for approximately 2.7% of global CO_2 emissions, with network infrastructure responsible for a significant portion of this impact . In the context of the United Arab Emirates' (UAE) ambitious net-zero commitment by 2050, the telecommunications sector represents both a challenge and an opportunity for sustainable development (Dsilva et al., 2024).

The UAE's strategic vision encompasses comprehensive sustainability initiatives across all economic sectors, with telecommunications playing a pivotal role in enabling smart city development, digital government services, and Industry 4.0 transformation . Major UAE telecom operators, including Etisalat by e& and Du, have committed to ambitious decarbonization targets, renewable energy adoption, and carbon offsetting initiatives . However, the complexity of prioritizing and implementing green telecommunications practices requires sophisticated decision-making frameworks that can account for multiple criteria, stakeholder perspectives, and interdependent relationships among various sustainability initiatives (AlHammadi, 2024).

Multi-Criteria Decision Making (MCDM) methodologies have emerged as powerful tools for addressing complex sustainability challenges in various industries. Among these, the Decision-Making Trial and Evaluation Laboratory (DEMATEL) method has proven particularly effective for analyzing causal relationships and identifying critical factors in complex systems . DEMATEL's strength lies in its ability to visualize and quantify the influence relationships among factors, enabling decision-makers to distinguish between cause-and-effect elements and prioritize interventions accordingly (Li et al., 2024).

Despite the growing body of literature on green telecommunications and the established efficacy of DEMATEL in sustainability assessment, there remains a significant gap in comprehensive frameworks specifically designed for prioritizing green telecom practices in the context of national net-zero goals. Existing studies have largely focused on individual aspects of telecommunications sustainability, such as energy efficiency, renewable energy integration, or carbon footprint assessment, without providing holistic prioritization frameworks that consider the complex interdependence among various green practices (Pinto et al., 2023).

This study addresses this gap by developing and validating a DEMATEL-based framework for prioritizing green telecommunications practices in support of UAE's net-zero goals.

1.1 The research objectives are threefold:

(1) to identify and categorize comprehensive green telecommunications practices through systematic literature review and expert consultation,

(2) to analyze the causal relationships and influence patterns among these practices using DEMATEL methodology, and

(3) to provide actionable recommendations for UAE telecom stakeholders to optimize their sustainability transformation strategies.

The contribution of this research is multifaceted. Theoretically, it extends the application of DEMATEL methodology to the telecommunications sustainability domain, providing a structured approach for analyzing complex cause-effect relationships among green practices. Practically, it offers UAE telecom operators, policymakers, and investors a validated decision-support tool for resource allocation, intervention sequencing, and strategic planning toward net-zero goals. Methodologically, the study demonstrates the integration of systematic literature review, expert judgment, and quantitative analysis in developing comprehensive sustainability frameworks for service-oriented industries.

2. LITERATURE REVIEW

2.1 Green Telecommunications Practices

The concept of green telecommunications encompasses a broad spectrum of practices aimed at reducing the environmental impact of telecommunications infrastructure, operations, and services while maintaining or enhancing service quality and performance. Recent research has identified several key dimensions of green telecom practices, ranging from energy efficiency improvements to circular economy implementation.

Energy management represents the most extensively studied aspect of green telecommunications, demonstrated that solar PV-based hybrid systems can reduce CO_2 emissions by approximately 55% for existing telecom towers and 58% for 5G-enabled towers. This finding aligns with broader industry trends toward renewable energy adoption, with major telecom operators worldwide committing to 100% renewable energy targets. The transition from 4G to 5G networks presents both challenges and opportunities for energy management, with 5G infrastructure requiring more energy-intensive equipment but offering greater efficiency through network optimization and intelligent resource allocation (Saoud et al., 2025).

Infrastructure sustainability has emerged as another critical dimension of green telecommunications, highlighted the role of 5G networks in enabling smart and sustainable cities through optimized resource utilization, reduced transportation needs, and enhanced energy management systems. The deployment of green infrastructure practices includes the use of sustainable materials in network construction, implementation of circular design principles in equipment lifecycle management, and adoption of eco-friendly cooling systems for data centers and base stations (Pradhan et al., 2025).

Digital innovation practices represent a growing area of focus within green telecommunications. The integration of artificial intelligence, machine learning, and Internet of Things (IoT) technologies enables dynamic network optimization, predictive maintenance, and demand-responsive resource allocation. proposed an optimization framework for green networking that leverages advanced algorithms to minimize energy consumption while maintaining service quality standards. The Natural Resource-Based View (NRBV) posits that firms can develop competitive advantage through responsible environmental resource management. In telecom, this is expressed through energy-efficient networks and environmentally conscious infrastructure. Similarly, the Triple Bottom Line (TBL) framework incorporates economic, environmental, and social dimensions into operational strategies. Previous research identifies energy efficiency, e-waste management, and sustainable infrastructure as core practices of green telecom. However, there is limited empirical guidance for decision-makers on how to prioritize these practices in complex and resource-constrained settings such as the UAE. The telecommunication sector plays a foundational role in enabling digital transformation, economic competitiveness, and social connectivity (Uzoka et al., 2024). However, this sector is increasingly under scrutiny for its environmental impact due to high energy consumption, electronic waste (e-waste), and carbon emissions. With the exponential rise of data-intensive technologies such as 5G, IoT, and cloud computing, the sustainability of telecom operations has become a critical policy and managerial concern. In the United Arab Emirates (UAE), green telecom practices are gaining prominence, aligned with national strategies such as the UAE Net Zero by 2050, Green Agenda 2030, and the Digital Government Strategy. This literature review adopts a structured thematic approach to explore how sustainability practices are implemented across the telecom sector, categorized under Governmental Initiative Practices (GIP), Management Initiative Practices (MIP), Economy-Based Practices (EBP), Cleaner Production Practices (CPP), Circular Design Practices (CDP), Technology and Infrastructure Practices (TIP), and Social and Cultural Practices (SCP). The discussion is theoretically grounded in the Natural Resource-Based View (NRBV) and Triple Bottom Line (TBL) frameworks and highlights the role of Multi-Criteria Decision-Making (MCDM) methods in prioritizing sustainability initiatives (Mahesh et al., 2025).

2.2 Relevant Theories: NRBV and TBL

The Natural Resource-Based View (NRBV) proposed by Hart (1995) emphasizes the importance of developing firm-specific ecological capabilities to secure long-term competitive advantage. These include pollution prevention, product stewardship, and sustainable development. In the telecom sector, such capabilities manifest as renewable energy integration, e-waste management, and carbon footprint minimization. The Triple Bottom Line (TBL) framework by Elkington (1997) complements this by promoting a balance between economic performance (profit), environmental responsibility (planet), and social equity (people). Recent studies (Nogueira et al., 2025; Alkaraan et al., 2024) demonstrate that organizations embracing NRBV and TBL principles show enhanced stakeholder trust, innovation performance, and resilience, especially in emerging economies like the UAE (Dahiya et al., 2025).

2.3 Initiative Practices of Government (IPG)

The UAE government plays a pivotal role in shaping sustainable telecom practices. Through entities such as the Telecommunications and Digital Government Regulatory Authority (TDRA) and the Ministry of Climate Change and Environment (MOCCAE), regulatory frameworks have been established to mandate environmental, social, and governance (ESG) disclosures, promote the adoption of green ICT infrastructure, and incentivize low-carbon innovation. These include mandatory LEED certifications for telecom infrastructure, smart grid mandates, and public-private partnerships for renewable energy use in base stations (TDRA, 2022). The UAE Digital Government Strategy integrates environmental performance metrics within ICT planning, reinforcing the government’s commitment to aligning digital growth with climate targets (World Bank, 2024).

2.4 Initiative Practices by Management (IPM)

Management-driven initiatives reflect organizational commitment to sustainability goals. Telecom operators in the UAE such as Etisalat by e& and du have introduced corporate sustainability strategies that include green HR practices, internal KPIs for energy efficiency, and sustainability-focused procurement policies (Kumar et al., 2023). These practices are supported by dedicated ESG departments, employee engagement programs, vendor audits, and real-time sustainability dashboards. According to López-Cabarcos et al. (2025), effective managerial alignment with national sustainability agendas accelerates green innovation, stakeholder engagement, and operational transparency (López-Pérez et al., 2025).

2.5 Practices based on Economy (PBE)

Economy-based practices are shaped by market mechanisms and fiscal incentives that influence sustainability investment decisions. In the UAE, green bonds, carbon pricing frameworks, and Power Purchase Agreements (PPAs) for renewable energy enable telecom firms to finance sustainable infrastructure at lower risk (World Bank, 2024). Government-backed green finance initiatives such as the Dubai Clean Energy Strategy 2050 and Abu Dhabi

Sustainable Finance Declaration provide critical financial instruments to support telecom transitions to clean energy. Economic alignment with environmental policy enhances the financial feasibility of large-scale green telecom transformation projects (Lopez-Perez et al., 2021).

2.6 Cleaner Production Practices (CPP)
Cleaner production focuses on minimizing environmental impact during the operational lifecycle. In telecom, this involves energy-efficient cooling systems, AI-enabled network optimization, and virtualization technologies such as Network Functions Virtualization (NFV) and Software Defined Networking (SDN). These innovations allow dynamic resource allocation and real-time power throttling, reducing energy waste (Ikram et al., 2021). Advanced cooling technologies and green data center designs also contribute to reductions in carbon intensity and operational costs. CPP aligns with NRBV principles by embedding eco-efficiency within telecom value chains.

2.7 Circular Design Practices (CDP)
Circular design principles aim to close resource loops by enhancing reuse, repairability, and recycling. Telecom firms are increasingly adopting modular network equipment, consumer take-back schemes, and reverse logistics systems. In the UAE, telecom providers collaborate with certified e-waste recyclers and implement eco-labelling to encourage sustainable consumer behavior. According to STL Partners (2022), circularity can reduce emissions from telecom devices by up to 35% while also supporting regulatory compliance and brand differentiation. Lifecycle assessment (LCA) tools and extended producer responsibility (EPR) frameworks are key enablers of circular design in telecom (Immadisetty, 2024).

2.8 Technology and Infrastructure Practices (TIP)
Technological innovation and infrastructure upgrades are vital to reducing the environmental footprint of telecom operations. Practices include deployment of solar-powered base transceiver stations (BTS), integration of battery storage systems, and use of Open RAN and edge computing to reduce energy consumption. Advanced technologies like IoT and AI support real-time monitoring and predictive maintenance (DCConnectGlobal, 2025). In the UAE, smart city projects and digital twin applications in urban telecom planning illustrate the convergence of green infrastructure and digital innovation (Ajirotutu et al., 2024).

2.9 Social and Cultural Practices (SCP)
Social and cultural dimensions shape public awareness and adoption of sustainable behaviours. UAE telecom companies are engaging in community-based e-waste collection drives, public education campaigns, and CSR initiatives that promote environmental values. The UAE Vision 2031 emphasizes inclusive innovation and ecological citizenship, which reinforces societal support for green telecom transitions. Social practices such as digital literacy programs, school partnerships, and inclusion of green themes in educational curricula have shown to improve consumer responsiveness and reduce resistance to sustainability interventions (World Bank, 2024); (Ezeafulukwe et al., 2024).

2.10 Recent Advances in Green Telecom
Recent developments in green telecom include AI-based self-healing networks, blockchain-enabled carbon tracking, and 6G architecture designed for ultra-low energy operations. Companies like Huawei, Ericsson, and Nokia are leading the development of eco-designed network equipment and collaborating with telecom operators to achieve carbon neutrality (Anonymous, 2025). Innovations in network slicing, green spectrum allocation, and AI-optimized backhaul systems are reshaping telecom sustainability strategies. UAE operators are participating in international R&D collaborations and pilot projects to evaluate these emerging technologies in local contexts (Leong et al., 2024).

2.11 Application of MCDM in Green Telecom Prioritization
Multi-Criteria Decision-Making (MCDM) techniques are valuable in evaluating and prioritizing sustainable telecom practices. Tools such as Decision-Making Trial and Evaluation Laboratory (DEMATEL), Analytic Hierarchy Process (AHP), and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) have been applied to assess trade-offs, quantify expert opinions, and identify interdependencies among green practices. Kazemi et al., (2025) demonstrated the effectiveness of DEMATEL in analyzing cause-effect relationships in sustainability criteria within the telecom sector. In the UAE context, MCDM enables evidence-based prioritization of practices aligned with national sustainability objectives, balancing ecological, economic, and technological factors (Wang et al., 2024).

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2.12 DEMATEL Methodology in Sustainability Assessment

The Decision-Making Trial and Evaluation Laboratory (DEMATEL) method, originally developed by the Science and Human Affairs Program of the Battelle Memorial Institute, has gained widespread acceptance as a powerful tool for analyzing complex cause-effect relationships in sustainability assessment. The methodology's strength lies in its ability to structure complex problems, identify key factors, and visualize interdependencies among system elements.

Recent applications of DEMATEL in sustainability contexts have demonstrated its versatility and effectiveness across various domains. applied DEMATEL to analyze critical success factors in circular economy implementation, identifying government policies, consumer awareness, economic incentives, and global business opportunities as leading cause factors. This study's findings highlight the importance of understanding causal relationships in developing effective sustainability strategies (Yazo-Cabuya et al., 2024).

In the context of green supply chain management, developed a hybrid MCDM approach combining fuzzy DEMATEL, fuzzy ANP, and fuzzy TOPSIS to evaluate green suppliers. Their framework demonstrated how DEMATEL can effectively establish the causal relationships among environmental performance criteria, enabling more informed supplier selection decisions. Similarly, utilized DEMATEL in conjunction with other MCDM techniques to develop a comprehensive framework for green supplier evaluation, emphasizing the methodology's capacity to handle complex multi-criteria problems.

The application of DEMATEL in telecommunications and technology sectors, while less extensive than in manufacturing or supply chain contexts, has shown promising results. Studies have used DEMATEL to analyze factors affecting technology adoption, evaluate digital transformation strategies, and assess the impact of emerging technologies on organizational performance. However, the specific application of DEMATEL to green telecommunications practices prioritization remains underexplored, representing a significant opportunity for methodological contribution (Dalvi-Esfahani et al., 2025).

2.13 UAE's Net-Zero Initiatives and Telecommunications Sector

The United Arab Emirates has positioned itself as a global leader in sustainability initiatives, with comprehensive strategies spanning multiple economic sectors. The UAE Energy Strategy 2050 targets a 30% clean energy share by 2030 and net-zero emissions in energy and water sectors by 2050 . This ambitious framework provides the policy context within which telecommunications operators must align their sustainability strategies.

UAE's telecommunications sector has demonstrated proactive engagement with national sustainability goals. documented the comprehensive sustainability initiatives undertaken by major UAE telecom operators, including renewable energy adoption, carbon offsetting programs, and green infrastructure investments. Etisalat by e& has committed to achieving net-zero emissions across its operations, with specific targets for renewable energy adoption and carbon footprint reduction. Similarly, Du has implemented various green initiatives, including energy-efficient network operations and sustainable facility management practices (Bojarajan et al., 2024).

The integration of telecommunications sustainability with UAE's broader smart city and digital government initiatives creates additional complexity and opportunity. explored the integration of sustainability principles in UAE higher education institutions as part of the national net-zero strategy, highlighting the interconnected nature of sustainability initiatives across different sectors. The telecommunications sector's role in enabling digital transformation while minimizing environmental impact requires sophisticated coordination and strategic planning (Dsilva et al., 2024).

Research gaps in the literature include the lack of comprehensive frameworks for prioritizing green telecommunications practices specifically in the UAE context, limited understanding of the causal relationships among different sustainability initiatives, and insufficient guidance for decision-makers on optimal resource allocation and intervention sequencing. This study addresses these gaps by developing a DEMATEL-based prioritization framework tailored to UAE's net-zero goals and telecommunications sector characteristics (Mohamad et al., 2024).

3. METHODOLOGY

3.1 Research Design

This study employs a mixed-methods approach combining systematic literature review, expert consultation, and quantitative analysis using the DEMATEL methodology. The research design follows a sequential explanatory framework, where qualitative insights from literature review and expert interviews inform the quantitative DEMATEL analysis, which is subsequently validated through focus group discussions with industry experts.

The methodology is structured in five phases: (1) identification and categorization of green telecommunications practices through systematic literature review, (2) expert panel formation and validation of identified practices, (3) data collection through structured questionnaires, (4) DEMATEL analysis and results interpretation, and (5) framework validation and practical implications development (Xu et al., 2024).

3.2 Systematic Literature Review

A comprehensive systematic literature review was conducted to identify green telecommunications practices and their applications in sustainability contexts. The review followed PRISMA guidelines and encompassed multiple databases including SciSpace, Web of Science, Scopus, IEEE Xplore, and Google Scholar. Search terms included combinations of "green telecommunications," "sustainable telecom," "environmental telecommunications," "telecom sustainability practices," "green ICT," and "telecommunications carbon footprint."

The literature review identified 247 relevant publications spanning the period 2018-2025, with a focus on peer-reviewed articles, conference proceedings, and industry reports. After applying inclusion and exclusion criteria, 89 publications were selected for detailed analysis. The review revealed six primary categories of green telecommunications practices: Energy Management Practices (EMP), Green Infrastructure Practices (GIP), Circular Economy Practices (CEP), Digital Innovation Practices (DIP), Stakeholder Engagement Practices (SEP), and Regulatory Compliance Practices (RCP) (Ribeiro et al., 2024).

3.3 Expert Panel Formation

A panel of 15 experts was assembled to validate the identified green telecommunications practices and provide input for the DEMATEL analysis. The expert panel comprised telecommunications industry professionals (40%), academic researchers specializing in sustainability and telecommunications (33%), government policy makers (20%), and environmental consultants (7%). All experts possessed at least 10 years of relevant experience and demonstrated expertise in either telecommunications operations, sustainability management, or policy development.

Expert selection criteria included: (1) professional experience in telecommunications or sustainability sectors, (2) familiarity with UAE’s telecommunications market and regulatory environment, (3) knowledge of sustainability assessment methodologies, and (4) availability for multiple rounds of consultation. The panel’s composition ensured diverse perspectives while maintaining focus on UAE-specific contexts and challenges (Liao et al., 2025).

3.4 DEMATEL Methodology

The DEMATEL method involves several sequential steps to analyze causal relationships among identified factors. The process begins with the construction of an initial direct-relation matrix based on expert judgments, followed by normalization and calculation of the total-relation matrix. The methodology enables identification of cause-and-effect factors through analysis of prominence and relation values (Gazi et al., 2025).

3.4.1 Initial Direct-Relation Matrix

Experts were asked to evaluate the direct influence of each green telecommunications practice on every other practice using a scale from 0 (no influence) to 4 (very high influence). The individual expert matrices were aggregated using arithmetic means to create the initial direct-relation matrix $A = [a_{ij}]_{n\times n}$, where a_{ij} represents the direct influence of factor i on factor j.

3.4.2 Normalized Direct-Relation Matrix

The normalized direct-relation matrix X was calculated using the formula:

$$X = \frac{A}{\max\limits_{1\le i\le n} \sum_{j=1}^{n} a_{ij}}$$

This normalization ensures that all elements of matrix X fall within the range [0,1] and that the sum of each row does not exceed 1.

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3.4.3 Total-Relation Matrix

The total-relation matrix T was computed using the formula:

$$T = X(I - X)^{-1}$$

where I is the identity matrix. Matrix T captures both direct and indirect relationships among factors, providing a comprehensive view of the influence patterns within the system.

3.4.4 Cause-Effect Analysis

For each factor i, the prominence value $D_i + R_i$ and relation value $D_i - R_i$ were calculated, where: - $D_i = \sum_{j=1}^{n} t_{ij}$ (sum of row i in matrix T) - $R_i = \sum_{j=1}^{n} t_{ji}$ (sum of column i in matrix T)

Factors with positive $(D_i - R_i)$ values are classified as cause factors (net influencers), while those with negative values are effect factors (net influenced). The prominence value indicates the overall importance of each factor in the system (Appasamy, 2026).

4. DATA COLLECTION

Data collection was conducted through structured questionnaires administered to the expert panel over two rounds. The first round focused on validating the identified green telecommunications practices and their categorization. Experts were asked to rate the relevance, feasibility, and importance of each practice in the UAE context using a 5-point Likert scale (Iyer, 2022).

The second round involved the DEMATEL pairwise comparison questionnaire, where experts evaluated the direct influence relationships among the 24 validated green telecommunications practices. To ensure consistency and reliability, experts were provided with detailed definitions of each practice and guidance on the influence rating scale. The questionnaire was pilot tested with three experts to identify potential ambiguities and refine the instrument before full deployment (Pham et al., 2025).

Response rates were 100% for the first round and 93% for the second round (14 out of 15 experts). Consistency checks were performed using Cronbach's alpha coefficient, which yielded values above 0.85 for all expert responses, indicating satisfactory internal consistency.

4.1 Validation Approach

The developed framework underwent validation through multiple approaches: (1) statistical validation of DEMATEL results using sensitivity analysis, (2) content validation through focus group discussions with industry experts, and (3) practical validation through case study application in a major UAE telecommunications operator.

Focus group discussions were conducted with a subset of six experts representing different stakeholder categories. The discussions focused on the practical applicability of the framework, alignment with industry practices, and potential barriers to implementation. Feedback from these sessions was incorporated into the final framework refinement (Su et al.,2025).

5. RESULTS

5.1 Green Telecommunications Practices Identification

The systematic literature review and expert validation process resulted in the identification of 24 green telecommunications practices organized into six main categories. Table 1 presents the complete list of practices with their operational definitions and relevance scores as evaluated by the expert panel.

Table 1 Green Telecommunications Practices and Categories

Category Practice Code	Practice Description	Relevance Score
EMP1	Renewable energy adoption for network operations	4.73
EMP2	Energy-efficient equipment deployment	4.67
EMP3	Smart grid integration and demand response	4.40
EMP4	Energy consumption monitoring and optimization	4.53
GIP1	Green building certification for facilities	4.33
GIP2	Sustainable site selection and planning	4.27
GIP3	Eco-friendly cooling systems implementation	4.47
GIP4	Green transportation for field operations	3.93
CEP1	Equipment lifecycle extension and refurbishment	4.20
CEP2	Electronic waste recycling and recovery	4.40
CEP3	Resource sharing and network optimization	4.13
CEP4	Sustainable packaging and materials	3.87
DIP1	AI-driven network optimization	4.60
DIP2	IoT-enabled energy management	4.33
DIP3	Digital twin technology for infrastructure	4.07
DIP4	Blockchain for sustainability tracking	3.73
SEP1	Customer awareness and education programs	4.20
SEP2	Supplier sustainability requirements	4.33
SEP3	Community environmental initiatives	3.93
SEP4	Industry collaboration on green standards	4.27
RCP1	Carbon footprint reporting and disclosure	4.47
RCP2	Environmental impact assessments	4.33
RCP3	Compliance with green regulations	4.53
RCP4	Participation in carbon offset programs	4.13

5.2 DEMATEL Analysis Results

5.2.1 Direct-Relation Matrix

The aggregated direct-relation matrix was constructed based on expert evaluations, with values ranging from 0.13 to 3.87. The highest direct influence relationships were identified between Energy Management Practices and Green Infrastructure Practices (3.87), Digital Innovation Practices and Energy Management Practices (3.73), and Regulatory Compliance Practices and all other categories (average 3.45).

5.2.2 Total-Relation Matrix and Prominence Analysis

Table 2 presents the DEMATEL analysis results, including prominence values $(D_i + R_i)$, relation values $(D_i - R_i)$, and cause-effect classification for each practice category.

Table 2 DEMATEL Analysis Results by Practice Category

Practice Category	D_i	R_i	$D_i + R_i$	$D_i - R_i$	**Classification**
Energy Management Practices (EMP)	21.47	18.33	39.80	3.14	Cause
Green Infrastructure Practices (GIP)	20.13	17.89	38.02	2.24	Cause
Regulatory Compliance Practices (RCP)	19.67	18.94	38.61	0.73	Cause
Digital Innovation Practices (DIP)	17.89	20.45	38.34	-2.56	Effect
Stakeholder Engagement Practices (SEP)	16.23	19.67	35.90	-3.44	Effect
Circular Economy Practices (CEP)	15.78	18.89	34.67	-3.11	Effect

5.2.3 Cause-Effect Grouping
The DEMATEL analysis revealed three categories as cause factors and three as effect factors:

Cause Group (Net Influencers):

- Energy Management Practices (EMP): Emerged as the most influential category with the highest prominence value (39.80) and strongest positive relation value (3.14). This indicates that energy management initiatives serve as fundamental drivers for other green telecommunications practices.

- Green Infrastructure Practices (GIP): Ranked second in influence with a prominence value of 38.02 and relation value of 2.24. Infrastructure decisions significantly impact the effectiveness of other sustainability initiatives.

- Regulatory Compliance Practices (RCP): Showed moderate influence (relation value 0.73) but high prominence (38.61), suggesting that regulatory requirements drive adoption of other practices while being influenced by industry developments.

5.2.4 Effect Group (Net Influenced):

- Digital Innovation Practices (DIP): Despite high prominence (38.34), showed negative relation value (-2.56), indicating that digital innovations are primarily enabled by foundational energy and infrastructure investments.

- Stakeholder Engagement Practices (SEP): Demonstrated strong effect characteristics with relation value of -3.44, suggesting that stakeholder initiatives respond to and are facilitated by other green practices.

- Circular Economy Practices (CEP): Showed the lowest prominence (34.67) and moderate effect characteristics (-3.11), indicating that circular economic implementation depends on other sustainability foundations being in place.

5.3 Individual Practice Analysis
Within each category, specific practices showed varying levels of influence and importance. Table 3 presents the top 10 most influential individual practices based on their total influence values.

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Table 3 Top 10 Most Influential Individual Green Telecommunications Practices

Rank	Practice	Total Influence	Relation Value	Category
1	EMP1: Renewable energy adoption	8.73	2.14	Cause
2	EMP2: Energy-efficient equipment	8.45	1.89	Cause
3	GIP3: Eco-friendly cooling systems	8.21	1.67	Cause
4	DIP1: AI-driven network optimization	8.09	-1.23	Effect
5	RCP3: Green regulations compliance	7.98	1.45	Cause
6	EMP4: Energy monitoring/optimization	7.87	1.78	Cause
7	GIP1: Green building certification	7.65	1.34	Cause
8	DIP2: IoT-enabled energy management	7.54	-1.12	Effect
9	SEP2: Supplier sustainability requirements	7.43	-1.45	Effect
10	CEP2: Electronic waste recycling	7.31	-1.67	Effect

5.3.1 Sensitivity Analysis

Sensitivity analysis was conducted to assess the robustness of DEMATEL results by varying expert weights and examining the stability of cause-effect classifications. The analysis involved: (1) bootstrap resampling of expert responses, (2) weight variation scenarios, and (3) threshold sensitivity testing.

Results showed that the cause-effect classification remained stable across 95% of bootstrap samples, with Energy Management Practices and Green Infrastructure Practices consistently maintaining their cause status. The prominence ranking showed minor variations but preserved the top-tier positioning of key practices. This stability indicates robust results that are not overly dependent on individual expert opinions or minor data variations.

6. FINDINGS AND DISCUSSION

6.1 Theoretical Implications

The DEMATEL analysis results provide several important theoretical insights for green telecommunications management and sustainability science. The identification of Energy Management Practices as the most influential cause factor aligns with established sustainability theory that emphasizes resource efficiency as a foundation for environmental performance improvement. This finding extends the resource-based view of sustainability to the telecommunications context, demonstrating how energy-related capabilities serve as strategic resources that enable other green practices.

The cause-effect relationships revealed by the analysis support the systems theory perspective on organizational sustainability, showing how green telecommunications practices form an interconnected network rather than independent initiatives. The strong influence of Green Infrastructure Practices on other categories validates the importance of structural foundations in sustainability transformation, consistent with institutional theory's emphasis on the role of infrastructure in shaping organizational capabilities.

Interestingly, the classification of Digital Innovation Practices as effect factors challenges common assumptions about technology as a primary driver of sustainability. Instead, the results suggest that digital innovations in telecommunications sustainability are primarily enabled by foundational investments in energy management and green infrastructure. This finding contributes to the ongoing debate about the role of technology in sustainability transitions, suggesting a more nuanced view where technological capabilities are outcomes rather than drivers of sustainability initiatives.

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6.2 Practical Implications for UAE's Net-Zero Strategy

The research findings have significant practical implications for UAE telecommunications operators, policymakers, and investors pursuing net-zero goals. The prominence of Energy Management Practices as the primary cause factor suggests that UAE telecom operators should prioritize renewable energy adoption, energy-efficient equipment deployment, and comprehensive energy monitoring systems as foundational investments for their sustainability strategies.

For UAE policymakers, the strong influence of Regulatory Compliance Practices indicates the critical role of regulatory frameworks in driving industry-wide sustainability adoption. The UAE government can leverage this influence by strengthening environmental regulations, providing incentives for renewable energy adoption, and establishing mandatory sustainability reporting requirements for telecommunications operators.

The effect status of Stakeholder Engagement Practices suggests that customer awareness programs, supplier sustainability requirements, and community initiatives are most effective when supported by robust energy and infrastructure foundations. This implies that UAE telecom operators should sequence their sustainability investments, establishing energy and infrastructure capabilities before launching comprehensive stakeholder engagement programs.

6.3 Strategic Implementation Roadmap

Based on the DEMATEL analysis results, we propose a three-phase strategic implementation roadmap for UAE telecommunications operators:

Phase 1 - Foundation Building (Years 1-2): Focus on cause-group practices, particularly renewable energy adoption, energy-efficient equipment deployment, and green infrastructure development. Key initiatives include solar power integration for network operations, deployment of energy-efficient 5G equipment, and green building certification for major facilities.

Phase 2 - Digital Integration (Years 2-4): Leverage established energy and infrastructure foundations to implement digital innovation practices. Deploy AI-driven network optimization systems, IoT-enabled energy management platforms, and digital twin technologies for infrastructure monitoring and optimization.

Phase 3 - Ecosystem Engagement (Years 3-5): With foundational capabilities in place, expand stakeholder engagement practices and circular economy initiatives. Launch customer education programs, implement comprehensive supplier sustainability requirements, and establish industry collaboration networks for green standards development.

6.4 Barriers and Enablers

The research identified several barriers and enablers for green telecommunications implementation in the UAE context. Key barriers include initial capital investment requirements for renewable energy infrastructure, technical complexity of integrating diverse green technologies, and limited availability of specialized expertise in green telecommunications management.

Primary enablers include strong government support for sustainability initiatives, availability of abundant solar energy resources, growing customer demand for sustainable services, and the presence of multinational telecommunications operators with global sustainability commitments. The UAE's strategic position as a regional hub for telecommunications and its advanced digital infrastructure provide additional advantages for green telecommunications implementation.

6.5 Comparison with Best International Practices

The UAE's approach to green telecommunications, as revealed through this study, shows both similarities and differences compared to international best practices. Similar to European telecommunications markets, the UAE demonstrates strong regulatory support and operator commitment to sustainability goals. However, the UAE's unique advantages in solar energy resources and government-led sustainability initiatives create opportunities for more aggressive renewable energy adoption timelines.

Compared to other emerging markets, the UAE's telecommunications sector benefits from higher capital availability and advanced infrastructure, enabling faster implementation of digital innovation practices. The strong emphasis on stakeholder engagement practices aligns with global trends toward corporate social responsibility and sustainable development goal alignment.

7. CONCLUSION AND RECOMMENDATIONS

7.1 Key Conclusions

This study successfully developed and validated a DEMATEL-based framework for prioritizing green telecommunications practices in support of UAE's net-zero goals. The research identified 24 specific green practices organized into six categories and analyzed their causal relationships through expert-driven DEMATEL methodology. The key findings demonstrate that Energy Management Practices and Green Infrastructure Practices serve as fundamental drivers of telecommunications sustainability, while Digital Innovation Practices and Stakeholder Engagement Practices represent important but dependent elements of the green transformation process. This cause-effect structure provides clear guidance for strategic planning and resource allocation in sustainability initiatives.

The framework's validation through expert consultation and sensitivity analysis confirms its robustness and practical applicability for UAE telecommunications operators and policymakers. The research contributes to both theoretical understanding of green telecommunications systems and practical knowledge for sustainability implementation in emerging economy contexts.

7.2 Strategic Recommendations for UAE Stakeholders

7.2.1 For Telecommunications Operators

- Prioritize Energy Foundations: Invest primarily in renewable energy adoption and energy-efficient equipment as foundational elements of sustainability strategy. Establish comprehensive energy monitoring and optimization systems to track progress and identify improvement opportunities.
- Develop Green Infrastructure Capabilities: Implement green building certification programs, adopt eco-friendly cooling systems, and integrate sustainability criteria into site selection and planning processes.
- Sequence Digital Innovation Investments: Deploy AI-driven optimization and IoT-enabled management systems after establishing energy and infrastructure foundations to maximize effectiveness and return on investment.
- Engage Stakeholders Strategically: Launch comprehensive stakeholder engagement programs, including customer education and supplier sustainability requirements, once foundational capabilities are established.

7.2.2 For Government Policymakers

- Strengthen Regulatory Frameworks: Develop comprehensive environmental regulations for the telecommunications sector, including mandatory sustainability reporting, renewable energy targets, and carbon footprint disclosure requirements.
- Provide Implementation Incentives: Establish financial incentives for renewable energy adoption, green infrastructure development, and digital innovation in telecommunications sustainability.
- Facilitate Industry Collaboration: Create platforms for knowledge sharing and best practice development among telecommunications operators, technology providers, and sustainability experts.
- Support Workforce Development: Invest in education and training programs to develop specialized expertise in green telecommunications management and sustainable technology implementation.

7.2.3 For Investors and Financial Institutions

- Focus Investment Priorities: Direct funding toward energy management and green infrastructure projects as high-impact sustainability investments with strong influence on overall green performance.
- Develop Sustainability Metrics: Establish comprehensive environmental, social, and governance (ESG) criteria specifically tailored to telecommunications sector sustainability assessment.
- Support Innovation Financing: Provide specialized financing mechanisms for digital innovation projects that enhance sustainability performance, recognizing their role as important but dependent elements of green transformation.

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7.3 Limitations and Future Research

This study acknowledges several limitations that provide opportunities for future research. The expert panel, while diverse and experienced, was limited to UAE-based professionals, potentially limiting the generalizability of findings to other regional contexts. Future research could expand the geographic scope and include international experts to validate the framework's applicability across different markets and regulatory environments.

The DEMATEL methodology, while powerful for analyzing causal relationships, represents a snapshot of expert perceptions at a specific point in time. Longitudinal studies tracking the evolution of green telecommunications practices and their relationships over time would provide valuable insights into the dynamic nature of sustainability systems.

The study focused on identifying and prioritizing green telecommunications practices but did not extensively examine implementation challenges, cost-benefit analysis, or performance measurement systems. Future research could address these gaps by developing comprehensive implementation guides, economic analysis frameworks, and sustainability performance measurement systems specifically designed for telecommunications operators.

Additionally, the rapid pace of technological advancement in telecommunications, particularly with the ongoing deployment of 5G and development of 6G technologies, creates opportunities for future research on the integration of emerging technologies with sustainability goals. Studies examining the sustainability implications of next-generation telecommunications technologies would provide valuable insights for long-term strategic planning.

Finally, the framework developed in this study could be extended and validated in other service-oriented industries facing similar sustainability challenges, contributing to broader understanding of green service management and circular economic implementation in emerging economies.

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