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Digital Transformation Maturity Measurement (DTMM) for the Oil and Gas Industry

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Abstract

This study develops and validates a Digital Transformation Maturity Measurement (DTMM) framework tailored to the oil and gas industry, addressing sector-specific regulatory and technological challenges. A mixed-methods approach was employed, integrating semi structured interviews with 10 senior executives and a survey of 240 industry professionals. The data were analyzed via structural equation modeling (SEM) and confirmatory factor analysis (CFA) to assess five maturity factors—leaders, staff, organization, technology, and value for stakeholders—across three key success indicators: financial performance, customer/internal user value, and environmental and societal value. The findings highlight Technology and Value for Stakeholders as the most influential transformation drivers, significantly improving operational efficiency and sustainability. Unlike prior models, the proposed DTMM integrates financial, technological, and sustainability dimensions into a unified assessment tool. This study contributes to the digital transformation literature by offering an empirically validated framework for evaluating and guiding strategic digital initiatives. Policymakers and industry leaders can leverage these insights to enhance digital maturity, prioritize high-impact strategies, and drive sustainable growth in an increasingly competitive landscape.

Keywords: Digital Maturity; Digital Transformation; Maturity Model (DTMM); Oil and Gas Industry.

1. Introduction

In today's highly competitive and dynamically evolving business landscape driven by digital disruption, organizations increasingly prioritize digital transformation (DT) to maintain competitiveness [1]. The COVID-19 pandemic underscored the critical importance of agility, necessitating rapid adaptations to disruptions in supply chains, accelerated product development, and evolving consumer demands [2, 3]. DT fundamentally reshapes business operations, organizational structures, management approaches, and service offerings [3]. Despite extensive research on DT, there remains a lack of clarity in defining and measuring digital transformation success, particularly in traditionally conservative industries such as oil and gas, which face unique operational constraints [4, 5].

Despite digitalization pressures affecting most sectors, significant adoption gaps exist across industries. For instance, the banking sector has been an early adopter due to competitive pressures, whereas the construction and oil and gas sectors remain laggards in DT implementation [1, 6]. This variation in digital maturity levels across industries is evident in Figure 1, which illustrates the comparative digital maturity of different business sectors.

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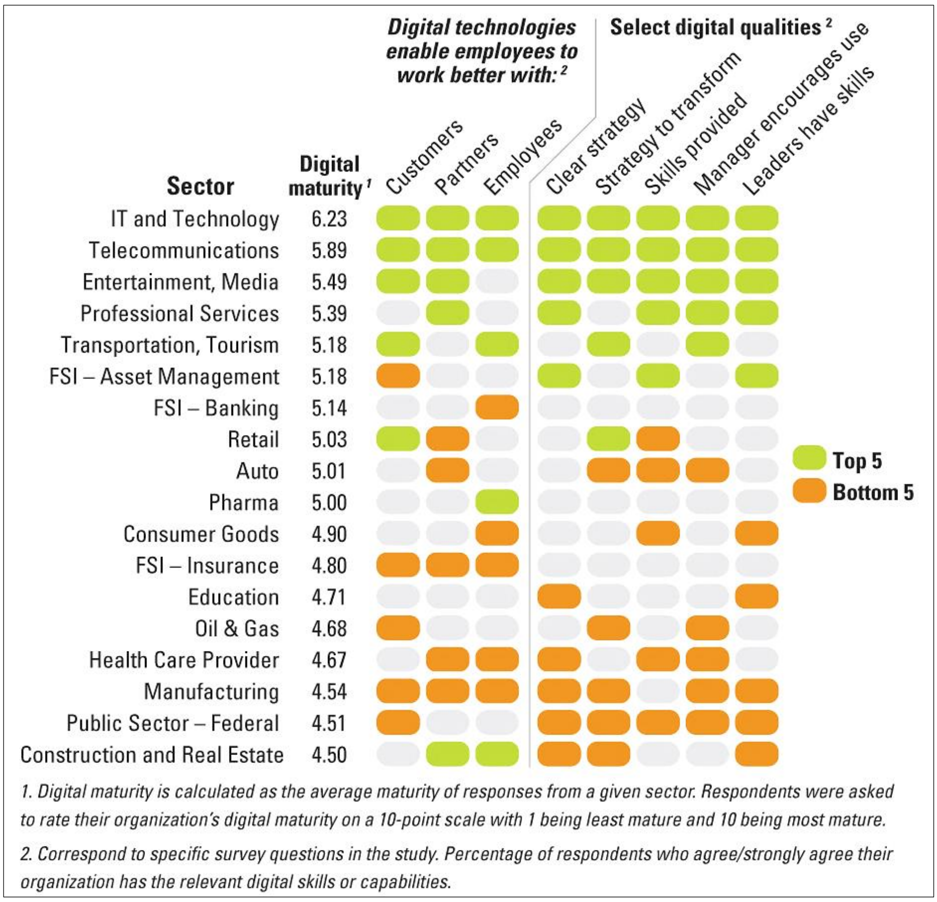

Figure 1. The top 5 and bottom 5 digital maturities by business sector [1]

The oil and gas industry, a cornerstone of the global economy, faces complex challenges, including climate change pressures, volatile geopolitical environments, and increasingly stringent sustainability requirements, all of which intensify the need for digital transformation [7, 8]. In response, advanced digital technologies such as artificial intelligence, predictive analytics, automation, and cloud computing offer transformative potential, enabling companies to optimize efficiency and enhance decision-making processes [9, 10].

Recent studies have identified barriers and enablers shaping digital maturity within the oil and gas sector. Haouel & Nemeslaki [9] highlighted obstacles such as limited digital expertise, cybersecurity vulnerabilities, and organizational resistance to change. Similarly, Al-Hajri et al. [11], noted the absence of structured industry-specific maturity assessments within the Gulf Cooperation Council (GCC), emphasizing the need for tailored digital maturity models. Additionally, Senna et al. [12], noted a major gap in existing frameworks—most fail to incorporate environmental and sustainability considerations, making them insufficient for industries facing regulatory and ecological challenges.

Digital maturity, which reflects an organization's ability to leverage technology and adapt to digital disruptions, is integral to successful digital transformation [13, 14]. Organizations with high digital maturity often exhibit superior financial performance, streamlined operations, and enhanced customer engagement [15]. Consequently, structured digital maturity models are essential tools for systematically assessing, managing, and accelerating digital transformation initiatives in industries facing complex operational constraints.

While recent digital maturity models provide valuable insights, many remain fragmented, focusing on isolated elements such as sales processes [16], blockchain adoption [17], or marketing strategies [18]. For example, Noadoust & Ranjbar [19] proposed a strategic DT model for Iran's offshore oil and gas industry but acknowledged limitations in scalability, particularly concerning financial performance and sustainability dimensions.

Thus, a critical research gap remains—existing maturity models either lack a multidimensional perspective or fail to adequately address the sector-specific operational and sustainability challenges of oil and gas enterprises. Reports from Roland Berger and the World Economic Forum further validate this gap, revealing a 28% discrepancy between perceived and actual digital maturity within the industry, with an estimated $2.5 trillion in unrealized financial potential over a decade [1, 20].

This study aims to bridge this gap by developing a comprehensive digital transformation maturity model (DTMM) tailored to the oil and gas industry. Specifically, this research seeks to answer the following key questions:

1. What dimensions should a comprehensive DTMM for oil and gas companies include?
2. How can oil and gas companies measure, assess, and enhance their digital maturity effectively?

A mixed-method research approach—integrating systematic literature reviews, expert consultations, and industry-specific case studies—is employed to validate the proposed model. Theoretically, this study advances digital transformation research by integrating financial, technological, organizational, and value-for-stakeholders dimensions into a cohesive framework. Practically, it offers industry leaders strategic insights and actionable recommendations to enhance digital maturity, ensuring improved efficiency, sustainability, and long-term competitiveness in an increasingly digitalized landscape.

1.1. Research Objectives

1. To identify and analyze the key dimensions and factors that define the digital transformation maturity measurement of the oil and gas industry.
2. To develop a customized digital transformation maturity measurement that addresses the unique challenges, complexities, and technological requirements of the oil and gas industry.

2. Literature Review

This study employs the digital transformation maturity measurement (DTMM) framework, which is based on the maturity model methodology, following the structured process of [21]. The DTMM framework integrates people, process, and technology (PPT) principles, emphasizing interconnected leadership, processes, and digital infrastructure.

2.1. Existing Digital Maturity Models in the Oil and Gas Industry

The oil and gas industry is distinguished by its significant economic impact, substantial operational footprint, and unique challenges, lagging behind other sectors in terms of digital adoption [1, 2]. While maturity models have successfully driven digital transformation (DT) in manufacturing sectors [22, 23], limited research specifically addresses digital maturity in oil and gas.

The digital maturity frameworks specific to this sector are sparse and fragmented. Al-Hajri et al. [11], identified gaps in comprehensive regional assessments, particularly in the GCC. Haouel & Nemeslaki [9], highlighted that current frameworks inadequately address sector-specific issues such as cybersecurity, skill shortages, and cultural resistance. Moreover, Al-Lami et al. [18], limited their focus to digital marketing maturity, omitting essential operational and sustainability dimensions. Noadoust & Ranjbar [19], offered a strategic model tailored to Iranian offshore operations but acknowledged the neglect of financial and sustainability aspects. This indicates a clear need for an integrative, multidimensional maturity model specifically suited to the oil and gas industry [9, 11, 18, 19].

2.2. Factors Affecting Digital Transformation Maturity

A systematic literature review was conducted (2015-2024) via Google Scholar and ScienceDirect, initially yielding 50 papers that were screened on the basis of predetermined criteria, resulting in 35 papers for detailed analysis. After rigorous screening criteria were applied, 20 papers were selected for detailed analysis (see Table 1 for the review protocol).

Table 1. Systematic Literature Review Protocol for Digital Maturity Models

Parameter	Details	Outcomes
Search Details	• Timeframe: August - November 2023 • Databases: Google Scholar, ScienceDirect • Access Type: Open access • Initial Scope: Top 50 entries per keyword combination	Initial Pool: 50 articles per keyword search
Key Search Terms	• Primary Terms: *Digital Transformation Maturity Model, Digital Maturity, Digital Readiness Framework, Digital Maturity Assessment*. • Secondary Terms: *Stages/Phases of Digital Transformation, Digital Maturity Levels, Framework/Model variations*.	Combined search results across all terms
Primary Screening Criteria	• Language: English • Keyword presence in title/abstract • Industrial company context • Peer-reviewed publications • Duplicate removal	Selected:35 papers
Secondary Screening Criteria	• Full text accessibility • Research article format • Industrial context focus • Clear maturity model conceptualization • Dimensional framework presence	Final Selection:20 papers
Quality Assessment	• Scientific rigor (peer-review status) • Relevance to industrial context • Conceptual framework clarity • Citation impact	Verification of selected papers

An analysis of these 20 frameworks revealed five recurring critical factors for digital transformation success: leaders, staff, organizations, technology, and value for stakeholders. Table 2 provides a comparative analysis of these academic maturity models, illustrating the various conceptual frameworks and dimensions considered.

Table 2. Comparative analysis of the conceptual framework of the digital maturity model developed by academics

No.	Study	Strategy	Organization/Business model/Corporate	Employees/People	Smart Factory/Plant	Operations	Products/Resource	Data/Information	Customer/Partner	Process	Collaboration	Technology	Culture	Management	Value Chain/Ecosystem	Innovation	Monitoring/control	System	Governance	Connectivity	Competence	Leadership	Platform	Performance
1	Lichtblau et al. [24]	▪	▪	▪	▪	▪	▪	▪																
2	Berghaus & Back [25]	▪	▪				▪		▪	▪	▪	▪	▪	▪										
3	Schumacher et al [26]	▪	▪	▪			▪	▪	▪	▪		▪												
4	Valdez-de-Leon [27]	▪	▪			▪			▪			▪			▪	▪								
5	Bumann & Peter [28]	▪	▪	▪					▪			▪	▪											
6	de Carolis et al. [22]		▪							▪		▪					▪							
7	Leino et al. [29]	▪	▪	▪					▪	▪			▪											
8	Schuh et al. [30]		▪				▪	▪					▪					▪						
9	Colli et al. [31]											▪			▪				▪	▪	▪			
10	Gimpel et al. [32]		▪			▪		▪	▪					▪	▪									
11	Mittal et al. [33]	▪		▪		▪	▪		▪			▪	▪						▪			▪		
12	Ivancic et al. [34]	▪	▪	▪					▪			▪			▪	▪								
13	Rossmann [35]	▪	▪	▪		▪						▪	▪						▪			▪		
14	Schumacher et al. [36]	▪	▪	▪			▪	▪	▪			▪			▪							▪		
15	Verina & Titko [37]		▪	▪				▪	▪	▪		▪										▪		
16	Aslanova & Kulichkina [38]	▪	▪	▪				▪				▪												
17	Gokalp & Martinez [39]			▪				▪		▪		▪							▪					
18	Spaltini et al. [40]			▪			▪		▪	▪		▪											▪	▪
19	Chwiłkowska-Kubala et al. [41]	▪		▪	▪	▪	▪					▪	▪						▪					
20	Nkomo & Kalisz [42]			▪	▪					▪														
		12	14	14	2	6	8	8	11	8	1	15	7	2	5	2	1	1	5	1	1	4	1	1

2.3. Identified Core Factors from Literature

Identifying core dimensions from existing models is challenging because of inconsistent terminology and overlapping subdimensions. Therefore, this research clusters similar dimensions from the reviewed models, establishing 23 core dimensions grouped into five key factors (leaders, staff, organization, technology, and value for stakeholders). These factors collectively drive organizational digital transformation maturity.

- **Leaders:** Effective leadership aligns digital strategies with the organizational vision, involving strategic planning, agile change management, adaptive decision-making, clear communication, and continuous monitoring [25, 30].
- **Staff:** Successful transformation requires employee engagement, skill building, collaboration, knowledge sharing, continuous learning, and cultural transformation [31, 34].
- **Organization:** Aligning organizational structures and processes with digital objectives includes process optimization, governance compliance, performance measurement, resource allocation, and resilience [26, 27].
- **Technology:** Leveraging innovation, data analytics, cybersecurity, scalable platforms, and connectivity supports effective digital transformation [32, 40].
- **Value for Stakeholders:** Effective DT enhances customer relationships, partner collaboration, value propositions, societal impact, and sustainability [35, 37].

These core dimensions are summarized clearly in Table 3.

Table 3. Assessment areas from key factors in the literature review

Key factors	Description of areas assessed
Leaders	Vision alignment, Strategic planning, Agile change management, Decision-making, Monitoring & adaptation, Communication.
Staff	Collaboration, Cultural transformation, Competence building, Employee engagement, Knowledge sharing, Leadership support, Employee well-being, Continuous learning.
Organization	Structure alignment, Process optimization, Governance & compliance, System integration, Performance metrics (KPIs), Operational resilience, Strategic resource allocation.
Technology	Innovation, Data-centric decisions, Data governance, Cybersecurity, Connectivity, Platforms/infrastructure, Scalability & flexibility.
Value for Stakeholders	Business model alignment, Digital product enhancement, Partner collaboration, Customer engagement, Societal value

2.4. Success Dimensions in Oil and Gas Industry Digital Transformation

Specific success dimensions for the oil and gas industry were identified through comprehensive literature analysis. Four critical dimensions emerged—financial performance, customer value, and environmental and societal value—collectively forming a holistic assessment framework for the industry's DT success.

Financial Performance: DTs in oil and gas enhance financial outcomes by increasing operational efficiency, productivity, uptime, and predictive maintenance and reducing operational costs [1, 4, 34]. It also improves decision-making processes and profitability [43, 44].

Customer Value: DT significantly impacts customer satisfaction, company reputation, customer engagement, and partnership networks [45-47]. Enhanced digital interactions contribute to better customer relationships and experiences.

Environmental and Societal Value: DT facilitates sustainability by reducing emissions, energy usage, and ecological impacts while enhancing workforce safety, incident management, and community engagement [8, 44]. DT also supports employee engagement and workplace well-being [48].

These critical success dimensions and indicators are summarized explicitly in Table 4.

Table 4. Key success dimensions and components/indicators for the oil and gas industry

Success Dimension	Sub-Dimension	Detailed Indicators	References
1. Financial Performance	Increased Operational Efficiency	Simplified operations and increased operational accuracy Optimized processes Improved internal processes (Agile Organization: faster, flexible, responsive) Real-time analytics on processes Automated and integrated machine learning Automated production processes Efficient refineries	Kane et al. [1]; Verhoef et al. [4]; Ziadat & Kirkham [8]; Mahraz et al. [49]; Mahmood et al. [50]
	Improved Business Decision-Making	Standardization of asset condition data Standardization of business processes Improved organizational management systems Enhanced subsurface planning Predictive maintenance of assets and infrastructure Business model transformation	Kane et al. [1]; Ivancic et al. [34]; Lei et al. [46]; Mahraz et al. [49]; Mahmood et al. [50]
	Increased Productivity and Uptime	Increased uptime Reduced equipment downtime Enhanced reservoir and well performance Higher recovery rate	Dorner & Edelman [43]; Abukova et al. [51]
	Cost Efficiency	Reduced unit cost Improved workforce efficiency Workforce time saved Improved logistics	Ziadat & Kirkham [8]; Dorner & Edelman [43]; Bello et al. [44]; Issa et al. [52]; Darusulistyo et al. [53]; Roland Berger [54]
	Profitability and Company Value	Increased yield and profit Improved company value (e.g., market cap/market-to-book ratio) Higher total shareholder return	Verina & Titko [37]; Barthel [45]; Roland Berger [54]

2. Customer/Internal User Value	Customer Satisfaction and Reputation	Availability of products Quality of products Timely delivery	Barthel [45]; Lei et al. [46]; Issa et al. [52]; Darusulistyo et al. [53]
	Customer Relationship & Engagement	Greater digital interaction Enhanced collaboration with customers and partners Improved customer experience	Kane et al. [1]; Verina & Titko [37]; Lei et al. [46]; Kraus et al. [47]; Marcolivio & Wade [48]; Mahraz et al. [49]; Mahmood et al. [50]
	Partner Network	Stronger collaboration with partner networks	Barthel [45]
3. Environmental & Societal Value	Sustainability	Decarbonization initiatives Reduced emissions Reduced flaring events Lower energy intensity Optimized water vapor management Sustainable growth	Ziadat & Kirkham [8]; Bello et al. [44]; Intykbayeva [55]; Cadei et al. [56]
	Incident Reduction and Safety	Safety barrier management Improved asset integrity Reduced work and personnel risks	Dorner & Edelman [43]; Bello et al. [44]; Marcolivio & Wade [48]; Issa et al. [52]
	Workforce Engagement and Well-being	Digitally enabled talent management Cultural innovation and branding Internal communication Workplace quality Enhanced well-being Employee satisfaction and retention Learning and growth	Verina & Titko [37]; Barthel [45]; Marcolivio & Wade [48]; Issa et al. [52]; Darusulistyo et al. [53]; Intykbayeva [55]

2.5. Conceptual Framework

The proposed conceptual framework for developing the DTMM integrates the five identified key factors (leaders, staff, organization, technology, and value for stakeholders) with success dimensions (financial performance, customer value, and environmental and societal value) to comprehensively measure digital maturity outcomes. This structure facilitates evaluation, highlighting strengths and areas needing improvement for effective transformation (see Figure 2).

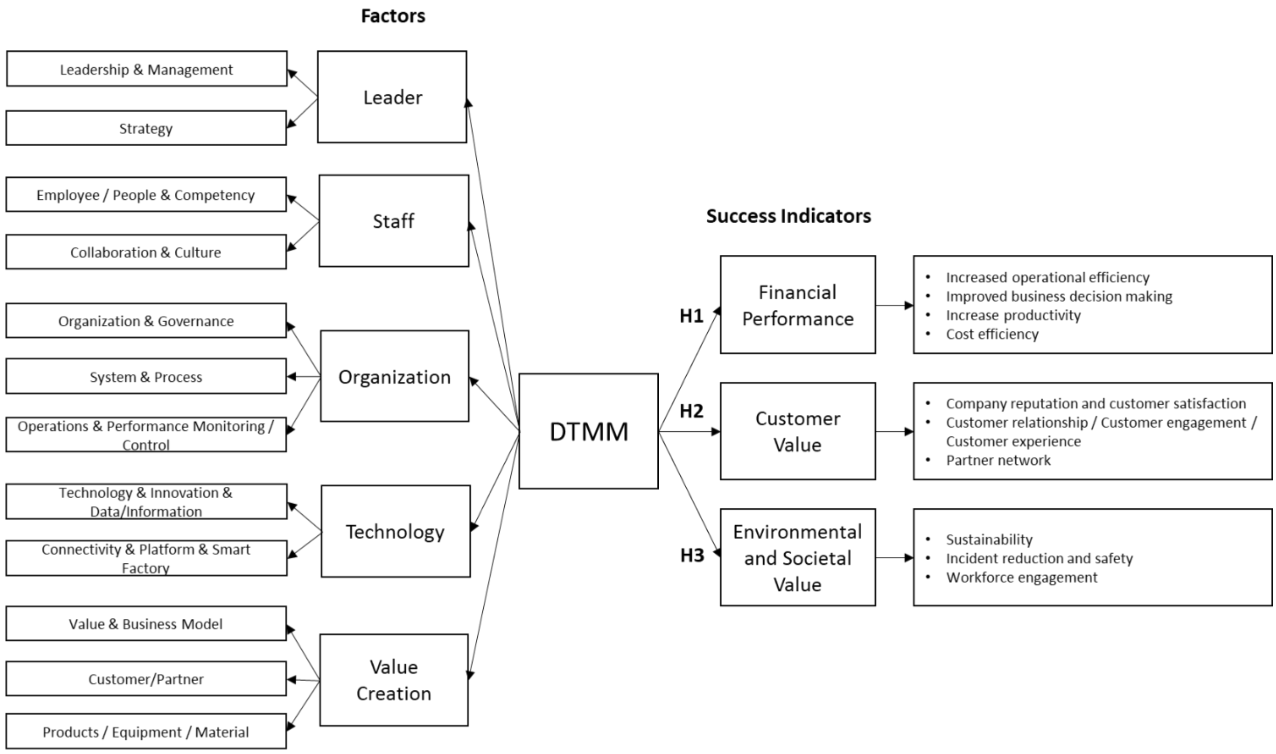

Figure 2. Proposed Conceptual Framework

From this conceptual structure, the following hypotheses are proposed:

H1: Success indicators can be measured from financial performance;

H2: Success indicators can be measured from value to customers/internal users;

H3: Success indicators can be measured from environmental and societal values.

2.6. Hypothesis Justification and Indicator Elaboration

To strengthen the conceptual underpinnings of the proposed hypotheses, each success indicator is clarified with practical and theoretical dimensions.

H1: Financial Performance – Digital transformation efforts often aim to improve financial outcomes such as cost efficiency, operational uptime, productivity, and return on investment. Technologies such as predictive maintenance, automation, and AI can significantly enhance operational and financial metrics, making financial performance a tangible measure of transformation success.

H2: Value to Customers/Internal Users – Customer satisfaction and internal user experience are vital in assessing transformation maturity. Metrics may include digital platform adoption, service delivery quality, user engagement, and partner collaboration. These reflect the organization's ability to deliver timely, relevant, and efficient digital solutions.

H3: Environmental and societal value – Organizations increasingly measure success on the basis of their impact on sustainability and society. Digital tools can support emission monitoring, safety systems, and workforce engagement, aligning business goals with environmental stewardship and social responsibility.

Together, these dimensions offer a comprehensive framework for assessing the outcomes of digital maturity.

3. Research Methodology

This study develops and validates a digital transformation maturity measurement (DTMM) model tailored for the oil and gas industry. It adopts a mixed-method approach grounded in the maturity model development framework proposed by De Bruin et al. [21], integrating people, process, and technology (PPT) principles as the theoretical foundation. These principles emphasize the interconnection between leadership, organizational processes, and digital infrastructure in supporting transformation success [1-6]. The overall research design and data flow are illustrated in Figure 3.

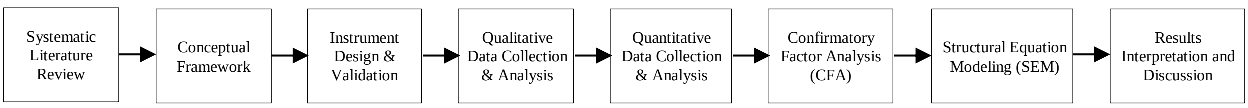

Figure 3. Research Methodology Flow Diagram

3.1. Participants and Data Collection

The target population included senior executives from Thailand's oil and gas sector with direct involvement in digital transformation initiatives. A purposive sampling strategy was used to identify participants with strategic leadership roles, which aligns with prior studies on digital leadership and maturity modeling [57]. In the qualitative phase, semistructured interviews were conducted with 10 senior management levels (Manager/VP/SVP/EVP of the companies) in Thai oil and gas companies. The interviewees all work in the departments responsible for the companies' digital or organizational transformation. The interview questions focused on validating and refining the measurement framework; exploring core DTMM constructs—leaders, staff, organizations, technology, and value for stakeholders—; and identifying the characteristics of a robust maturity model. Their insights were instrumental in refining the digital transformation maturity measurement (DTMM) framework and validating key model constructs. To enhance content validity, the interview protocol and preliminary findings were reviewed collaboratively with the primary research advisor.

In addition, three domain experts were interviewed to assess the logical consistency of the conceptual framework and questionnaire items. Their input supported refinement of the DTMM structure and was used to validate key constructs through the item-objective congruence (IOC) process [58].

After expert review, a pilot survey was conducted with 30 purposively selected participants to test the instrument's reliability. Cronbach's alpha was used to assess internal consistency, yielding a score of 0.92—well above the 0.70 threshold—confirming the questionnaire's suitability for full-scale data collection [59].

In the quantitative phase, a structured questionnaire was administered online via Google Forms via a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree). Access links and QR codes were used to facilitate wide distribution across the selected organizations. A total of 240 valid responses were collected from diverse samples of executives, managers, and frontline employees across departments of oil and gas companies. This diversity ensured a broad perspective on organizational digital maturity. Sampling decisions were informed by the guidelines of Flury et al. [60], and supported by the "10-times rule" proposed by Barclay et al. [61], ensuring an adequate sample size for SEM complexity.

3.2. Instrument Development and Validation

The questionnaire consisted of three main sections. Part 1 collected demographic and organizational data (e.g., company size, role, years of experience, and transformation stage). Part 2 included 40 items measuring digital maturity across five dimensions: leaders, staff, organization, technology, and value for stakeholders. These constructs were adapted from previous DTMM research and models [25, 34]. Part 3 assessed the following transformation success indicators: financial performance, value to customers/internal users, and environmental and societal value, on validated scales [34, 37].

The questionnaire's content validity was reviewed by five subject matter experts in digital transformation and oil and gas. The index of item-objective congruence (IOC) was used to assess clarity and relevance, with all items scoring above the accepted threshold of 0.60 [58]. Reliability was evaluated through a pilot test with 30 respondents from the same industry. The Cronbach's alpha for the full instrument was 0.92, exceeding the standard threshold of 0.70 and confirming strong internal consistency [59].

3.3. Data Analysis

Data analysis was conducted via SPSS and AMOS software, following a two-phase approach.

3.3.1. Descriptive Analysis

Descriptive statistics, including variables such as industry segment, firm size, years of experience, and current stage of digital transformation, were used to summarize respondent demographics and organizational profiles. Measures of frequency, percentage, mean, and standard deviation were calculated to provide contextual insights and establish the foundation for structural analysis [57, 60].

3.3.2. Structural and Triangulation Analysis

Confirmatory factor analysis (CFA) was applied to validate the measurement model, evaluating factor loadings, composite reliability (CR), and average variance extracted (AVE) to confirm construct validity. Structural equation modeling (SEM) was then used to test the hypothesized causal relationships between digital maturity dimensions and success indicators. Model fit was assessed via widely accepted indices, including χ^2/df (< 5.00), CFI (≥ 0.90), NFI (≥ 0.90), TLI (≥ 0.90), and RMSEA (≤ 0.08) [60].

To ensure strong alignment between the qualitative and quantitative findings, a triangulation approach was employed. Thematic coding of the qualitative interview data identified key dimensions influencing digital transformation maturity, which were then cross-validated against the results of the quantitative survey involving 240 participants. The CFA and SEM results confirmed the validity of the proposed dimensions. Where discrepancies arose, iterative expert reviews were conducted to refine and adjust the digital transformation maturity measurement (DTMM) framework. These revisions were further reviewed by the principal research advisor, cothesis advisor, and subject matter experts to ensure accuracy, relevance, and coherence between qualitative insights and empirical evidence [60].

4. Results of Data Analysis

4.1. Demographic Data

This study collected 240 valid responses from professionals in Thailand's oil and gas industry. The majority of the respondents were male (68.3%), and most were aged between 41–50 years (44.6%). With respect to company affiliation, 25.8% were from core oil and gas companies, 4.6% were from related service providers, and 57.9% were from other supporting firms in the energy sector. In terms of job roles, 37.9% were in supervisor or officer-level positions, followed by 24.6% in professional or senior professional roles. The participants represented diverse functional areas, with the largest proportions working in the Information Technology (30.0%) and Drilling and Well departments (20.4%). This range reflects a broad spectrum of operational, managerial, and technical expertise relevant to digital transformation initiatives.

4.2. Descriptive Statistics of the Observed Variables

All observed variables across the eight constructs presented mean values ranging from 3.78 to 4.35, indicating strong agreement with the questionnaire items. The standard deviations ranged from 0.69 to 0.89, suggesting moderate dispersion. The skewness and kurtosis values were within acceptable ranges for normality, supporting the suitability of the data for further structural analysis. Summary statistics are provided in Table 5.

Table 5. Descriptive statistics for each observed variable

Factor	Grand Mean	S.D. Range	Skewness Range	Kurtosis Range
Leaders (LE1–LE6)	4.27	0.72 – 0.79	–1.06 to –0.58	–0.28 to 1.18
Staff (ST1–ST6)	4.02	0.73 – 0.89	–0.68 to –0.25	–0.51 to 0.83
Organization (OR1–OR9)	3.87	0.73 – 0.89*	–0.66 to –0.28*	–0.35 to 1.02*
Technology (TE1–TE6)	4.07	0.73 – 0.89	–0.96 to –0.37	–0.54 to 1.04
Value for Stakeholders (VC1–VC9)	3.92	0.75 – 0.86	–0.77 to –0.48	0.24 to 1.05
Financial Performance (FP1–FP4)	–	0.73 – 0.81	–0.74 to –0.33	–0.01 to 0.84
Customer/Internal Value (CV1–CV4)	–	0.69 – 0.87	–0.60 to –0.23	–0.12 to 0.42
Environmental/Societal Value (ESV1–ESV4)	–	0.78 – 0.86	–0.78 to –0.70	0.67 to 1.06

Note: Grand mean is not calculated for second-order indicators (FP, CV, ESV), as they represent outcome variables. All values indicate a normal data distribution (skewness and kurtosis within ±2).

4.3. Confirmatory Factor Analysis (CFA)

Confirmatory factor analysis (CFA) was performed to validate the measurement model across eight latent constructs: leaders (LE), staff (ST), organization (OR), technology (TE), value for stakeholders (VC), financial performance (FP), value to customers/internal users (CV), and environmental and societal value (ESV).

All the constructs met the required thresholds for model adequacy and convergent validity. The Kaiser–Meyer–Olkin (KMO) values ranged from 0.802 to 0.933, confirming sampling adequacy, whereas Bartlett's test of sphericity was significant for all the constructs ($p < 0.001$), indicating sufficient interitem correlations. The root mean square error of approximation (RMSEA) values were all less than 0.05, reflecting excellent model fit. All factor loadings were statistically significant at $p \leq 0.001$.

These results confirm that the observed variables for each latent construct are reliable and valid for inclusion in the subsequent structural equation modeling (SEM). The detailed results are summarized in Table 6.

Table 6. First-order CFA results for latent variables

Construct	Correlations (min–max)	KMO	Bartlett's Test (χ^2, p)	RMSEA	Result
Leaders (LE)	0.571 – 0.782	0.877	1108.40, p < 0.001	0.033	Passed
Staff (ST)	0.452 – 0.709	0.877	765.24, p < 0.001	0.045	Passed
Organization (OR)	0.491 – 0.746	0.928	1534.80, p < 0.001	0.046	Passed
Technology (TE)	0.479 – 0.743	0.854	795.89, p < 0.001	0.032	Passed
Value for Stakeholders (VC)	0.428 – 0.777	0.933	1527.29, p < 0.001	0.048	Passed
Financial Performance (FP)	0.592 – 0.726	0.802	541.44, p < 0.001	0.033	Passed
Customer/Internal Value (CV)	0.651 – 0.821	0.818	638.11, p < 0.001	0.000	Passed
Environmental and Societal Value (ESV)	0.568 – 0.712	0.802	498.05, p < 0.001	0.000	Passed

4.4. Structural Equation Modeling

The initial SEM analysis indicated a poor model fit, prompting adjustments to improve alignment with the empirical data. The revised model results are presented in Tables 7 to 9 and Figures 4 and 5. As shown in Table 7, the model demonstrates a strong fit across multiple indices (e.g., CMIN/df = 1.471, RMSEA = 0.032). The relationships between the success indicators and the three outcome dimensions—financial performance, customer/internal value, and environmental and societal value—are statistically significant ($p \leq 0.001$). These findings support hypotheses H1 through H3, with full details interpreted in the sections that follow.

Table 7. Index, criteria, statistics, and results from running SEM after adjusting the nonsuitable model [62, 63]

Index	Criteria	Statistics	Results
CMIN/df	<5.00	1427.137/970=1.471	Passed
NFI	>0.90	0.902	Passed
TLI	>0.90	0.971	Passed
CFI	>0.90	0.988	Passed
RMSEA	<0.05	0.032	Passed

Table 7 presents key model fit indices validating the SEM structure. The relative chi-square (CMIN/df = 1.471) is below the threshold of 5.0, indicating good model fit. The NFI (0.902), TLI (0.971), and CFI (0.988) all exceed the acceptable benchmark of 0.90, confirming strong comparative fit. The RMSEA value of 0.032, which is well below 0.05, suggests minimal approximation error. Collectively, these indicators support the conclusion that the structural model aligns closely with the empirical data, reinforcing the model's validity.

Table 8 provides standardized loading values for each latent variable within the SEM framework. The high values (ranging from 0.862 to 0.985) confirm the strength of the association between the digital transformation factors and the overall success indicators. Notably, Technology (0.985) and Value for Stakeholders (0.980) have the strongest influence, suggesting that digital infrastructure and stakeholder alignment are critical enablers of transformation maturity. These loadings statistically validate the proposed relationships, further strengthening the three hypothesized constructs.

Table 8. Confirmed factor loading, standardized loading, S.E., from SEM analysis

Variables	Success Indicators (SD)		
	(Standardized loading) (β)	S.E.	t
FLE	0.868***	-	-
FST	0.862***	0.119	7.828
FOR	0.955***	0.159	9.605
FTE	0.985***	0.140	9.359
FVC	0.980***	0.162	9.279
FFP	0.895***	0.136	9.622
FCV	0.953***	0.157	9.833
FESV	0.921***	0.154	9.654

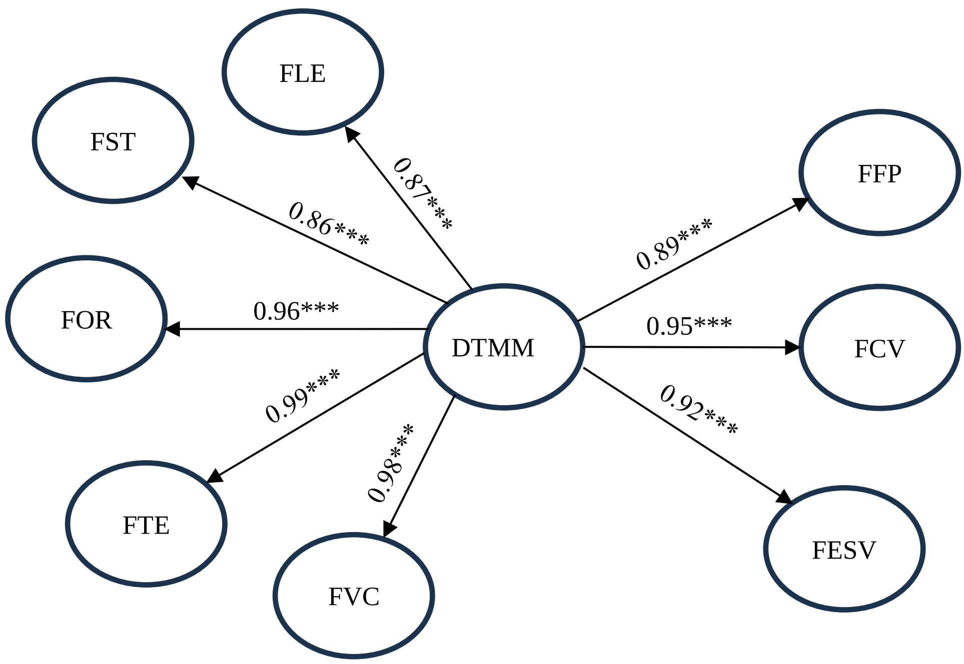

Figure 4. Structural equation modeling illustrating the validated paths from key success indicators (financial performance, customer/internal value, and environmental and societal value) to overall transformation success. Standardized path coefficients (all >0.89*) reflect statistically significant contributions.**

As illustrated in Figure 5 second-order confirmatory factor model of the DTMM showing interrelationships between five key input factors and three transformation success indicators. Subfactor loadings provide insights into specific organizational capabilities that drive digital maturity.

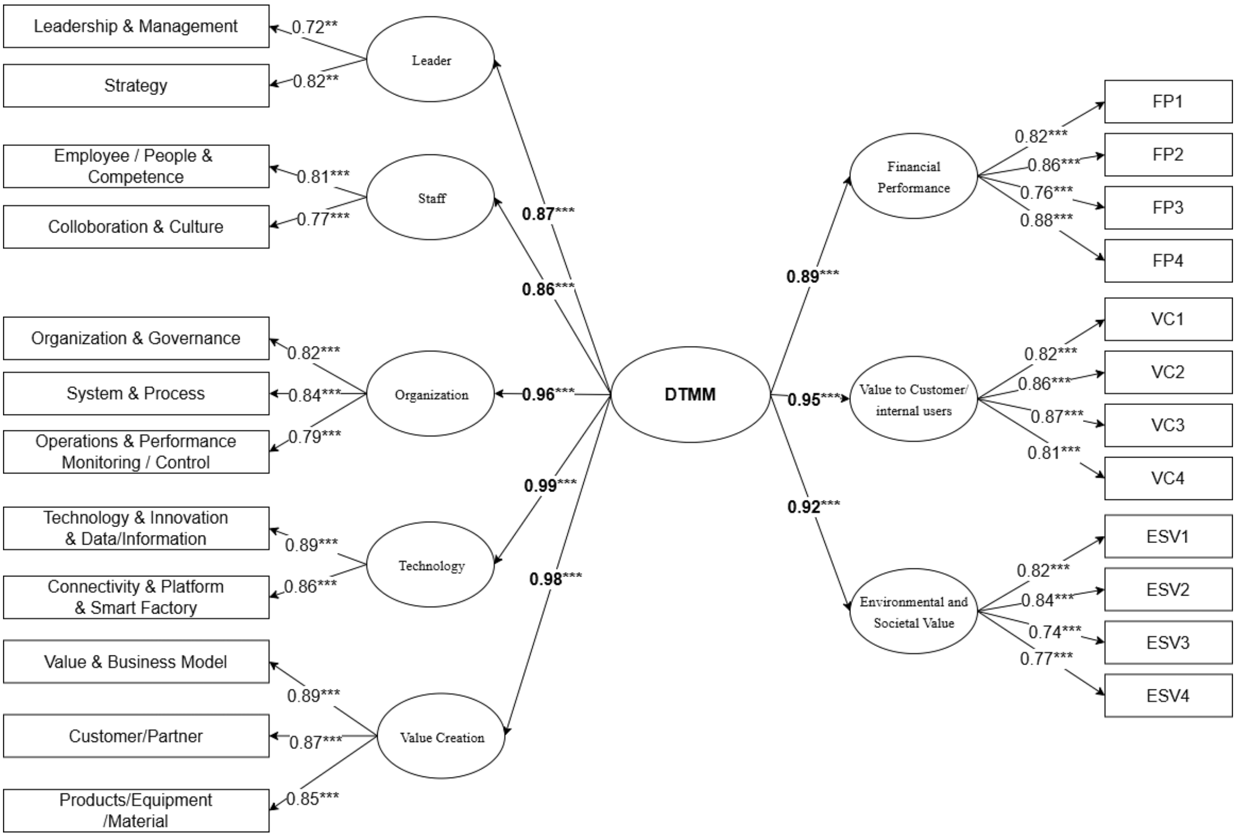

Figure 5. Second-order confirmatory factor model of the DTMM showing interrelationships between five key input factors and three transformation success indicators. Subfactor loadings provide insights into specific organizational capabilities that drive digital maturity.

Table 9 summarizes the hierarchical structure of the success indicators. Each primary factor (e.g., leaders, staff, organization, etc.) is supported by specific subfactors such as "strategy," "employee competence," and "system & process." These subfactors offer granularity in understanding how broader categories contribute to success. Technology and innovation (0.89***) and systems and processes (0.84***) emerge as particularly impactful subdimensions. This multitier analysis confirms the robustness of the DTMM framework and highlights areas where targeted improvements can yield significant results.

Table 9. Second-order confirmatory analysis of success indicators

Model	Factor/Success Indicator	Sub-Factor	(Standardized loading) (β)
DTMM	Leader	-	0.87***
	Leader	Leadership & Management	0.72***
	Leader	Strategy	0.82***
DTMM	Staff	-	0.86***
	Staff	Employee/People & Competence	0.81***
	Staff	Collaboration & Culture	0.77***
DTMM	Organization	-	0.96***
	Organization	Organization & Governance	0.82***
	Organization	System & Process	0.84***
	Organization	Operations & Performance Monitoring/Control	0.79***
DTMM	Technology	-	0.99***
	Technology	Technology & Innovation & Data/Information	0.89***
	Technology	Connectivity & Platform & Smart Factory	0.86***
DTMM	Value for Stakeholders	-	0.98***
	Value for Stakeholders	Value & Business Model	0.89***
	Value for Stakeholders	Customer/Partner	0.87***
	Value for Stakeholders	Product/Equipment/Material	0.85***

DTMM	Financial Performance	-	0.89***
	Financial Performance	FP1	0.82***
	Financial Performance	FP2	0.86***
	Financial Performance	FP3	0.76***
	Financial Performance	FP4	0.88***
DTMM	Value to Customer/Internal users	-	0.95***
	Value to Customer/Internal users	VC1	0.82***
	Value to Customer/Internal users	VC2	0.86***
	Value to Customer/Internal users	VC3	0.87***
	Value to Customer/Internal users	VC4	0.81***
DTMM	Environmental and Societal Value	-	0.92***
	Environmental and Societal Value	ESV1	0.82***
	Environmental and Societal Value	ESV2	0.84***
	Environmental and Societal Value	ESV3	0.74***
	Environmental and Societal Value	ESV4	0.77***

4.5. Hypothesis Testing

Three hypotheses were tested to examine the relationship between the digital transformation maturity measurement (DTMM) framework and success dimensions: financial performance (FP), value to customers/internal users (CV), and environmental and societal value (ESV). All paths were statistically significant ($p \leq 0.001$), with standardized estimates above 0.89 (Table 10).

H1: The estimate of 0.895 confirms that strong financial performance—reflected in operational efficiency, decision-making, and cost effectiveness—contributes significantly to transformation success.

H2: The highest path estimate, 0.953, underscores the importance of delivering value to customers and internal users. Customer satisfaction, user engagement, and partner networks are key drivers of success.

H3: The path from ESV to success (0.921) highlights the role of sustainability, safety, and workforce engagement. These elements enhance organizational reputation and long-term performance.

The findings confirm that success in digital transformation is multidimensional, requiring alignment across financial, customer, and societal value areas. This finding supports the DTMM framework as a comprehensive tool for assessing transformation outcomes.

Table 10. Hypothesis test and results

Hypothesis	Relationship	(Standardized loading) (β)	Supported
H1	DTMM → Success Indicators could be measured from Financial Performance	0.895***	Accepted
H2	DTMM → Success Indicators could be measured from Value to Customers/Internal Users	0.953***	Accepted
H3	DTMM → Success Indicators could be measured from Environmental and Societal Value	0.921***	Accepted

Notes: ***p value ≤ 0.001.

4.6. Key Factor Contributions (Second-Order CFA)

Second-order confirmatory factor analysis (CFA) confirmed that five core factors significantly influence digital transformation success, each with standardized loadings above 0.86. Technology (0.985***) and value for stakeholders (0.980***) were the strongest contributors, highlighting the importance of innovation, data-driven decisions, and value for stakeholders. Organization (0.955***), staff (0.862***), and leaders (0.868***) also played essential roles—underscoring the impact of structured processes, employee competence, and strategic leadership (see Table 11).

These results align with prior research emphasizing that digital transformation is a multidimensional process requiring the integration of leadership, human capital, systems, technology, and stakeholder focus. The findings support the DTMM framework as a holistic tool for guiding organizations toward long-term transformation success.

Table 11. Second-order Confirmatory Analysis: Key DTMM Factors and Sub-Factors

Key Factor	Sub-Factor(s)	Standardized loading (β)
Leaders (FLE)	Leadership & Management, Strategy	0.868***
Staff (FST)	Employee Competence, Collaboration & Culture	0.862***
Organization (OR)	Governance, Systems & Processes, Operations	0.955***
Technology (FTE)	Innovation, Data & Information, Connectivity	0.985***
Value for Stakeholder (FVC)	Business Model, Customer & Partner Engagement, Product/Service Value	0.980***

Notes: All factor loadings are significant at ***$p \leq 0.001$.

These results align with prior research emphasizing that digital transformation is a multidimensional process requiring the integration of leadership, human capital, systems, technology, and stakeholder focus. The findings support the DTMM framework as a holistic tool for guiding organizations toward long-term transformation success.

5. Discussion

The survey included 240 respondents, predominantly male (68.3%), aged 41--50 years (44.6%), from the oil and gas (O&G) and associated sectors, particularly in IT and drilling/well operations, who hold supervisory or professional roles. This demographic profile suggests substantial sector-specific experience, providing informed perspectives on digital transformation maturity indicators. Confirmatory factor analysis (CFA) was used to validate the relationships between the observed variables and intended constructs, ensuring robust convergent and discriminant validity. The CFA results confirmed a strong model fit (CFI = 0.988, TLI = 0.971, RMSEA = 0.032, CMIN/df = 1.471), indicating that the proposed structure effectively represents digital transformation success indicators. The second-order CFA highlighted three primary dimensions for measuring digital transformation success indicators (SDs): financial performance (FP, 0.895), customer/internal user value (CV, 0.953), and environmental and societal value (ESV, 0.921). Structural equation modeling (SEM) further confirmed the statistical significance of these dimensions, reinforcing their reliability in assessing digital transformation success.

Each success indicator was measured through key metrics:

- FP: cost efficiency, operational accuracy, predictive maintenance, and business model transformation;
- CV: customer satisfaction, engagement, digital service enhancement, and partner network strength; and
- ESV: sustainability practices, emission reduction, workforce well-being, and regulatory compliance.

Additionally, SEM identified five critical influencing factors: Technology (0.985), Value for Stakeholders (0.980), Organization (0.955), Leaders (0.868), and Staff (0.862). Among these, Technology and Value for Stakeholders had the strongest influence, emphasizing the importance of robust digital infrastructure, data-driven innovation, and strategic stakeholder alignment. The reliability of the constructs was confirmed, with Cronbach's alpha values exceeding 0.7 and composite reliability (CR) and average variance extracted (AVE) values surpassing the recommended thresholds (CR > 0.7, AVE > 0.5), ensuring measurement validity. These findings suggest that companies in the oil and gas sector should prioritize investments in digital technology, stakeholder engagement, and sustainability to increase transformation success. The high impact of CV and ESV also indicates a shift toward customer-centric and environmentally responsible digital strategies.

This study reinforces prior literature emphasizing digital transformation as inherently multidimensional, involving technological, organizational, environmental, and human components [7, 12, 16]. The prominent role of Technology (0.985) aligns closely with Kane et al. [1] and Issa et al. [52], who highlighted technological infrastructure, automation, and innovation as critical determinants of digital transformation effectiveness, particularly in data-intensive industries such as oil and gas. Similarly, value for stakeholders (0.980) plays a dominant role, which is consistent with Verhoef et al. [4], and Al-lami et al. [18], who emphasize the need for alignment with regulatory expectations, investor priorities, and evolving customer demands. The oil and gas sector is highly regulated, making compliance, transparency, and sustainability-driven digital initiatives essential for securing investment and market trust.

While leadership (0.868) and staff (0.862) remain influential, their impact is less pronounced than that of technology and value for stakeholders. Unlike technology, which directly enables operational efficiency, and stakeholder alignment, which ensures external viability, leadership and workforce capabilities primarily support transformation efforts rather than drive them. This finding diverges from Bilgeri et al. [6], who emphasized human-centered factors but aligns with sector-specific studies [11, 19]. However, strengthening staff competence through HR interventions and continuous training can enhance organizational adaptability, innovation readiness, and long-term transformation success. Moreover, the three success indicators—Financial Performance (FP), Customer Value (CV), and Environmental & Societal Value (ESV)—are interdependent and reinforce one another rather than functioning independently. Improved FP through improved operational efficiency and cost reduction enables organizations to reinvest in CV enhancements, such as improving customer experience and digital engagement. In turn, strong ESV performance, such as sustainability initiatives and regulatory compliance, enhances brand reputation and investor confidence, which supports long-term financial stability. The SEM and CFA results confirm that the FP (0.895), CV (0.953), and ESV (0.921) are key success indicators. FP is prioritized in early digital transformation stages, as financial efficiency and automation are essential for ensuring ROI. CV becomes central in mid-stage transformation, emphasizing customer engagement, service personalization, and data-driven decision-making. In mature stages, once financial stability and customer satisfaction are achieved, ESV gains strategic priority, aligning digital initiatives with sustainability, regulatory compliance, and corporate social responsibility goals. These findings suggest that organizations should adopt a phased digital transformation approach, ensuring financial sustainability while progressively integrating customer and environmental value dimensions.

5.1. Theoretical Contributions

This study contributes to theory by developing a digital transformation maturity model (DTMM) that integrates technological, organizational, stakeholder, and human dimensions. It addresses gaps in existing research that often treats these areas separately [12, 22]. Unlike prior models, the DTMM is tailored to the oil and gas industry, offering a context-specific framework for a traditionally conservative sector.

The model enhances the understanding of digital maturity as a holistic, dynamic construct and shows how alignment across key dimensions drives transformation. It contributes to theory-building by empirically validating the importance of multidimensional integration for transformation success [12, 19].

5.2. Managerial Implications

Managerially, the DTMM highlights that successful transformation requires more than technology adoption. Oil and gas firms must also address stakeholder needs, leadership capability, workforce readiness, and organizational processes [18]. The model identifies five critical success factors: technology, value, leaders, staff, and organization.

To overcome sector-specific challenges such as legacy systems and regulatory complexity, companies should align interventions with each factor. This includes investing in infrastructure, stakeholder alignment, leadership development, and upskilling. DTMM also serves as a tool for ongoing assessment, helping firms adapt strategies in response to evolving digital and sustainability demands.

6. Conclusion

This research addresses significant gaps in digital maturity frameworks by proposing and validating a comprehensive digital transformation maturity model specifically designed for the oil and gas industry. Empirical validation confirmed that digital transformation success is accurately measurable through the financial performance, customer/internal user value, and environmental and societal value dimensions. Among the influencing factors identified, Technology and Value for Stakeholders emerged as the most critical, emphasizing the unique sector-specific needs for robust infrastructure, innovation, and strategic stakeholder alignment.

Theoretically, the study significantly contributes to the digital maturity literature by integrating technological, organizational, stakeholder, and human dimensions into a single coherent model. This integrative approach bridges previously isolated research areas, offering comprehensive insights into achieving successful digital transformation in traditionally conservative industries.

Practically, the DTMM provides oil and gas organizations with a structured framework for systematically evaluating and enhancing their digital maturity, ensuring alignment with broader organizational objectives and sustainability standards. Managers can leverage these insights to formulate actionable digital strategies, prioritize investments, and maintain competitive advantage amid evolving digital and sustainability demands.

6.1. Future Research

Future research should focus on extending the applicability of the DTMM across different regional and organizational contexts, further enhancing its strategic generalizability and operational relevance. Additionally, exploring longitudinal studies could provide deeper insights into the dynamic nature of digital maturity evolution within the oil and gas sector.

7. Declarations

7.1. Author Contributions

Conceptualization, C.K. and W.P.; methodology, C.K. and D.H.; software, C.K. and D.H.; validation, C.K., W.P., and D.H.; formal analysis, C.K.; investigation, C.K.; resources, C.K. and W.P.; data curation, C.K.; writing—original draft preparation, C.K.; writing—review and editing, W.P. and D.H.; visualization, C.K.; supervision, W.P.; project administration, C.K.; funding acquisition, C.K. All authors have read and agreed to the published version of the manuscript.

7.2. Data Availability Statement

The data presented in this study are available in the article.

7.3. Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

7.4. Institutional Review Board Statement

Not applicable.

7.5. Informed Consent Statement

Not applicable.

7.6. Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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