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Validating the Integrated Supply Chain Model Based on the LARG Hybrid Paradigm in the Oil Industry (Case Study: Abadan Oil Refining Company)

Alireza. Banisilalavi[1], Saber Molla. Alizadeh Zevardehi[2*], Ali. Mahmoodirad[3]

[1] Department of Industrial Management, MaS.C., Islamic Azad University, Masjed Soleiman, Iran.
[2] Department of Industrial Engineering, MaS.C., Islamic Azad University, Masjed Soleiman, Iran.
[3] Department of Mathematics, Bab.C., Islamic Azad University, Babol, Iran

*** Corresponding author email address**: saber.alizadeh@gmail.com

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ABSTRACT

Supply chain management has become one of the key determinants of organizational success in competitive markets, and the LARG hybrid paradigm (Lean, Agile, Resilient, and Green) has been introduced as a comprehensive framework for supply chain optimization. The Iranian oil industry faces challenges such as aging infrastructure, economic sanctions, and environmental requirements, which underscore the necessity of designing an integrated and localized model. The objective of this study was to design and validate an integrated supply chain model based on the LARG paradigm at Abadan Oil Refining Company. The research was conducted using a mixed-methods approach (qualitative–quantitative). In the qualitative phase, meta-synthesis and interviews with 10 experts were employed, while in the quantitative phase, a questionnaire was administered to a sample of 385 participants. Data were analyzed using Fuzzy Delphi, Fuzzy DEMATEL, F.D.ANP, and Structural Equation Modeling techniques. The findings indicated that out of 126 initial indicators, 119 were confirmed. The dimensions of leadership and organizational culture were positioned as causal factors and had significant effects on processes and innovation. All hypotheses were confirmed, and the strongest path coefficient was related to the effect of leadership on processes (β = 0.510). The ranking of LARG components revealed that the Green component (28.1%), Agile (26.3%), Lean (24.5%), and Resilient (21.1%) were prioritized, respectively. The proposed model can serve as a practical tool for enhancing sustainable supply chain performance in the oil industry.

Keywords: *LARG paradigm; Abadan Oil Refining Company; Fuzzy DEMATEL; supply chain; structural equation modeling.*

1. Introduction

Supply chain management has evolved from a predominantly cost-efficiency orientation toward a multidimensional strategic framework encompassing competitiveness, sustainability, resilience, and technological integration. In highly capital-intensive and risk-prone industries such as oil and petrochemicals, supply chain architecture constitutes a critical determinant of operational continuity, environmental compliance, and long-term value creation. Recent research emphasizes that oil industry supply chains operate within complex ecosystems characterized by geopolitical uncertainty, environmental pressures, regulatory volatility, and technological transformation (Ayaran et al., 2022; Piya et al., 2022). These dynamics necessitate the adoption of integrative paradigms capable of simultaneously enhancing efficiency, flexibility, resilience, and sustainability. Within this context, the LARG paradigm—encompassing Lean, Agile, Resilient, and Green dimensions—has emerged as a comprehensive strategic framework for supply chain redesign and performance enhancement (Anvari, 2021; Jamali & Karimi Asl, 2018; Sousa et al., 2020).

The LARG framework synthesizes four complementary strategic logics. The Lean dimension focuses on waste elimination, cost reduction, and process optimization; the Agile dimension emphasizes responsiveness and flexibility; the Resilient dimension addresses risk mitigation and adaptive capacity; and the Green dimension integrates environmental stewardship and sustainable resource management (Anvari, 2021; Jamali et al., 2024). Empirical evidence suggests that the integration of these paradigms generates synergistic effects on supply chain performance, particularly in volatile and environmentally sensitive sectors (Jamali & Karimi Asl, 2018; Sousa et al., 2020). However, implementing LARG strategies within the oil industry poses significant structural and contextual challenges, including infrastructure rigidity, exposure to sanctions, and regulatory compliance demands (Ayaran et al., 2022; Karimi et al., 2022).

The Iranian oil sector represents a particularly compelling context for examining integrated supply chain paradigms. Sanctions, supply disruptions, fluctuating export markets, and technological constraints have increased the strategic importance of resilient and adaptive supply chain configurations (Ayaran et al., 2022). Studies highlight that resilience drivers such as redundancy, flexibility, and collaborative risk-sharing mechanisms play a pivotal role in maintaining operational continuity during systemic shocks (Piya et al., 2022). Moreover, the mediating role of resilience in linking strategic supply chain management practices to performance outcomes has been empirically validated in offshore oil sectors (Karimi et al., 2022). These findings underscore the necessity of embedding resilience within broader strategic supply chain architectures rather than treating it as an isolated capability.

Concurrently, sustainability considerations have gained prominence in petrochemical and oil supply chains. The integration of environmental management practices into supplier evaluation and operational planning has been shown to enhance long-term competitiveness and stakeholder legitimacy (Sousa et al., 2020). In the Gulf Cooperation Council petrochemical sector, sustainability practices are increasingly institutionalized through environmental performance metrics and corporate governance mechanisms (Alsaif et al., 2025). Likewise, value-added models integrating sustainable development principles within petrochemical supply chains demonstrate measurable impacts on operational and financial performance (Amiri et al., 2024). These developments suggest that green transformation is no longer optional but a strategic imperative.

Technological advancement further reshapes supply chain configurations in the oil and gas industry. Machine learning and advanced analytics enhance forecasting accuracy, inventory optimization, and logistical efficiency, thereby contributing to both lean and agile capabilities (Odimarha et al., 2024). In China's offshore oil and gas equipment manufacturing industry, technological catch-up and innovation have been significantly influenced by supply chain coordination and government policy alignment (Li et al., 2022). Moreover, technological advancement facilitates sustainable and resilient supply chain expansion through digital monitoring, predictive maintenance, and integrated planning systems (Krimi et al., 2025). These insights highlight the increasing interdependence between technological integration and strategic supply chain paradigms.

Within the Iranian context, several studies have addressed elements of LARG and sustainability integration, yet often in fragmented or sector-specific manners. For instance, evaluation of LARG competitive strategies in Iranian cement industries demonstrates the viability of gap analysis in identifying strategic alignment deficiencies (Jamali & Karimi Asl, 2018). Subsequent analyses confirm that LARG-based competitive strategies positively influence supply chain performance metrics (Jamali et al., 2024). Similarly, structural equation modeling approaches have been applied to assess sustainability constructs within oil and gas supply chains (Keyghobadi, 2021). Performance evaluation models for large-scale oil and gas supply chains further underscore the importance of integrated multi-criteria assessment frameworks (Mehri Babadi et al., 2022). Nonetheless, a unified, empirically validated model tailored specifically to the oil refining sector remains underdeveloped.

Reverse logistics and closed-loop supply chain systems represent additional dimensions of sustainable supply chain management within oil and gas industries. Hierarchical modeling approaches have identified critical variables influencing reverse logistics efficiency and environmental compliance (Ghazifard & Rasouli, 2021; Qazi Far & Rasouli, 2021). Furthermore, socially responsible pricing mechanisms in oil product supply chains reveal the interplay between corporate responsibility and competitive dynamics (Dhahir Mohammed et al., 2023). At the organizational level, identifying and ranking critical success factors for sustainable supply chain management provides strategic guidance for petrochemical enterprises striving to achieve world-class standards (Beigmohammadi, 2024). These contributions collectively emphasize the need for integrative, multi-dimensional supply chain frameworks that transcend isolated optimization efforts.

The concept of integrated supply chain paradigms, though relatively modern in management literature, parallels earlier interdisciplinary analytical frameworks where multiple dimensions interact within systemic gradients, as illustrated in broader scientific classification methodologies (Hohenger, 2000). In supply chain research, such integration translates into designing architectures that accommodate efficiency, adaptability, environmental compliance, and resilience simultaneously. The absence of such holistic frameworks may result in strategic trade-offs, where gains in cost efficiency undermine sustainability or resilience objectives. Consequently, the LARG paradigm offers a theoretically coherent and practically relevant foundation for integrated supply chain modeling in complex industrial environments.

Despite the growing body of literature, gaps persist in the empirical validation of integrated LARG-based models within oil refining contexts, particularly in emerging economies subject to external constraints. Most existing studies either emphasize sustainability without fully integrating resilience and agility, or analyze resilience drivers without embedding them in comprehensive structural models (Karimi et al., 2022; Piya et al., 2022). Furthermore, while technological advancement is recognized as a catalyst for sustainable expansion (Krimi et al., 2025; Odimarha et al., 2024), its integration within LARG-oriented structural equation models remains limited. There is therefore a pressing need to develop and empirically test a comprehensive model that synthesizes leadership, organizational culture, operational processes, and innovation within the LARG paradigm framework.

Accordingly, this study aims to design and validate an integrated supply chain model based on the LARG paradigm in the oil industry, with specific application to the Abadan Oil Refining Company.

2. Methods and Materials

The present study is classified as an applied–developmental research in terms of its objective. On the one hand, its findings can be directly utilized to improve performance and strategic decision-making within the supply chain of Abadan Oil Refining Company. On the other hand, it focuses on the design and testing of a novel integrated model based on the theoretical LARG framework and its localization within the national oil industry. In terms of data nature, this research is categorized as a mixed-methods (qualitative–quantitative) study. In the qualitative phase, data were collected through semi-structured interviews with oil industry experts and university scholars and were analyzed using content analysis and coding techniques. In the quantitative phase, data were gathered through a structured questionnaire developed based on the extracted dimensions and indicators and were analyzed using structural equation modeling. From a logical perspective, the study combines two approaches. The inductive approach was applied in the qualitative phase to identify dimensions and indicators based on experts' experiences. The deductive approach was employed in the quantitative phase to test the conceptual model using statistical data.

The statistical population of this study was defined in two phases: qualitative and quantitative. In the qualitative phase, the population included experts, specialists, and scholars in the field of supply chain management in the oil industry who were selected based on criteria including more than 10 years of professional experience, relevant academic or research background, and familiarity with contemporary developments in supply chain management. In this phase, 10 experts were selected using purposive and snowball sampling methods, including 4 from academia, 3 from the manufacturing sector, and 3 from services and logistics. In the quantitative phase, the population comprised all managers, supervisors, and experts working in the supply chain, production planning, warehousing, distribution, and procurement units of Abadan Oil Refining Company. The sample size was estimated at 385 respondents using Cochran's formula at a 95% confidence level. To compensate for potential non-response, 440 questionnaires were distributed using stratified random sampling.

Data collection in this study was conducted using two primary instruments. In the qualitative phase, semi-structured interviews were employed, with a protocol designed in three sections including an introduction to the study and its objectives, core questions based on the LARG theoretical framework, and concluding open-ended questions. The main question domains included evaluating the role of digital transformation in supply chain integration, the importance of intelligent risk management, influential indicators in the oil industry supply chain, and environmental approaches. In the quantitative phase, a researcher-developed structured questionnaire was designed in two sections. The first section included demographic questions (age, gender, education, work experience, and field of activity), and the second section comprised items related to each dimension of the model (Agility, Lean, Resilience, Green, Digital Integration, and Intelligent Risk Management). The items were measured using a five-point Likert scale ranging from "strongly disagree" to "strongly agree."

The validity of the research instrument was assessed through two methods. Content validity was evaluated and confirmed by 5 specialists, including 3 university professors and 2 senior industry managers. The evaluation criteria included clarity, content relevance to research objectives, and comprehensive coverage of dimensions. Construct validity was assessed through confirmatory factor analysis to examine the consistency between measurement items and the theoretical structure. Reliability of the questionnaire was measured using Cronbach's alpha coefficient, and all research dimensions demonstrated reliability coefficients above 0.7, indicating acceptable internal consistency and stability of the instrument (Cronbach, 1951).

Data analysis was conducted at both qualitative and quantitative levels. At the qualitative level, interview data were transcribed and analyzed using MAXQDA software and a three-stage coding process (open, axial, and selective coding) as outlined by Strauss and Corbin (1998). For screening and weighting the indicators, the Fuzzy Delphi technique and the combined F.D.ANP method (Fuzzy DEMATEL and Fuzzy Analytic Network Process) were applied. Causal relationships among dimensions and indicators were identified using the Fuzzy DEMATEL model. At the quantitative level, descriptive statistics including mean, standard deviation, and frequency distribution were calculated using SPSS software. To test the hypotheses and validate the conceptual model, structural equation modeling based on Partial Least Squares (PLS-SEM) was conducted using SmartPLS software.

3. Findings and Results

The analysis of data collected from the qualitative and quantitative phases is presented in this section. The analytical process began with examining the demographic characteristics of respondents, followed by qualitative findings including the extraction of dimensions and indicators through meta-synthesis and expert interviews. Subsequently, the results of indicator screening using the Fuzzy Delphi technique, weighting through F.D.ANP, analysis of causal relationships using the Fuzzy DEMATEL model, and finally evaluation of the structural model using structural equation modeling and hypothesis testing are presented. The final ranking of the LARG paradigm components based on the integration of multi-criteria decision-making methods is provided at the end of this section.

The demographic characteristics of the respondents, including gender, age, education level, work experience, and job position, were examined. Understanding these characteristics allows for evaluating the representativeness of the sample relative to the target population and provides a foundation for more accurate interpretation of the findings. The demographic profile of the 385 respondents is presented in Table 1.

Table 1

Demographic Characteristics of Respondents

Variable	Category	Frequency	Percentage
Gender	Male	273	70.9
	Female	112	29.1
Age	Under 30 years	58	15.1
	30–40 years	147	38.2
	40–50 years	124	32.2
	Over 50 years	56	14.5
Education	Diploma and Associate Degree	78	20.3
	Bachelor's Degree	166	43.1
	Master's Degree	114	29.6
	Doctoral Degree	27	7.0
Work Experience	Less than 5 years	47	12.2
	5–10 years	89	23.1
	10–20 years	168	43.6
	More than 20 years	81	21.1
Job Position	Senior Manager	37	9.6
	Middle Manager	81	21.0
	Senior Expert	124	32.2
	Expert	102	26.5
	Technician/Operator	41	10.6

The results presented in Table 1 indicate that the majority of respondents were male (70.9%), which is consistent with the technical and operational nature of the oil refining industry. In terms of age distribution, the largest proportion belonged to the 30–40-year age group (38.2%), reflecting a workforce predominantly composed of individuals with moderate professional experience. The largest educational group consisted of respondents holding a bachelor's degree (43.1%), while the substantial proportion of master's and doctoral degree holders (36.6%) indicates adequate scientific and managerial capacity within the organization. The analysis of work experience revealed that the largest group had 10–20 years of experience (43.6%), suggesting relative workforce stability and the potential for experiential knowledge transfer. The distribution of job positions demonstrates a considerable proportion of senior experts (32.2%) and experts (26.5%), highlighting the critical role of mid-level human resources in operational and semi-managerial functions within the organization.

The extraction of the model's primary dimensions and indicators was conducted through the meta-synthesis method and content analysis of semi-structured interviews with 10 experts from the oil industry. Qualitative data included 182 valid written sources and the transcribed interview texts, which were analyzed using MAXQDA software and a three-stage coding procedure (open, axial, and selective coding) as proposed by Strauss and Corbin (1998). A summary of the extracted dimensions and indicators is presented in Table 2.

Table 2

Dimensions and Number of Indicators Extracted from Qualitative Analysis

Dimension	Number of Indicators	Description
Functional	53	Productivity, cost reduction, time management, quality, energy efficiency
Paradigmatic	42	Flexibility, resilience, green logistics, digital integration
Innovation–Sustainability	31	Emission reduction, renewable resources, social commitment, sustainable design
Total	126	—

The results presented in Table 2 indicate that a total of 126 indicators were extracted across three principal dimensions through the three-stage coding process. The Functional dimension, with 53 indicators, accounted for the largest share and encompassed indicators related to workforce productivity, operational cost reduction, product quality improvement, equipment energy efficiency, and material flow optimization. The Paradigmatic dimension, comprising 42 indicators, included structural flexibility, operational resilience, green logistics, digital integration, and intelligent risk management components. The Innovation–Sustainability dimension, with 31 indicators, covered areas such as emission reduction, utilization of renewable resources, corporate social responsibility, and sustainable design. These indicators were subsequently employed as inputs for the screening phase using the Fuzzy Delphi technique.

The screening of the indicators identified during the qualitative phase was conducted in two rounds using the Fuzzy Delphi technique. Expert responses were collected based on a triangular fuzzy scale, and the fuzzy mean for each indicator was calculated. Indicators with a fuzzy mean equal to or greater than the agreement threshold of 0.7 were retained, while the remaining indicators were eliminated. The screening results are presented in Table 3.

Table 3

Results of Indicator Screening Using the Fuzzy Delphi Technique

Dimension	Initial Indicators	Confirmed Indicators	Eliminated Indicators
Functional	53	53	0
Paradigmatic	42	39	3
Innovation–Sustainability	31	27	4
Total	126	119	7

The results shown in Table 3 indicate that out of the 126 initial indicators, 119 indicators (94.4%) achieved a fuzzy mean equal to or above the 0.7 threshold and were therefore confirmed, while 7 indicators were eliminated. All 53 indicators of the Functional dimension were approved by the experts, reflecting their high importance within the oil industry supply chain. In the Paradigmatic dimension, 3 indicators were removed, and in the Innovation–Sustainability dimension, 4 indicators were eliminated due to insufficient agreement levels. The excluded indicators were primarily those with limited applicability under the specific conditions of the Iranian oil industry. This outcome reflects expert consensus and convergence of viewpoints, with emphasis placed on indicators demonstrating the highest levels of importance, feasibility, and alignment with the research model's objectives.

The determination of the relative importance of the confirmed indicators was conducted using the Fuzzy Analytic Network Process (F.D.ANP). This method, by considering internal relationships and interdependencies among indicators, enables precise and realistic weighting. The distribution of total weight across the three principal dimensions of the model and the clustering of indicators into four institutional dimensions are presented in Table 4.

Table 4

Final Weights of the Main Model Dimensions

Institutional Dimension	Title	Final Weight	Percentage
D1	Leadership and Policymaking	0.245	24.5
D2	Organizational Culture and Learning	0.263	26.3
D3	Processes and Operations	0.211	21.1
D4	Innovation and Sustainability	0.281	28.1
—	Total	1.000	100

The results in Table 4 demonstrate that the Innovation and Sustainability dimension, with a weight of 0.281 (28.1%), holds the highest priority in the model. It is followed by Organizational Culture and Learning with a weight of 0.263 (26.3%), Leadership and Policymaking with 0.245 (24.5%), and Processes and Operations with 0.211 (21.1%). This distribution indicates that experts emphasized the simultaneous importance of sustainable innovation, cultural-learning infrastructure, and strategic orientation. The relatively balanced weight distribution among dimensions reflects a comprehensive and integrative approach in model design, fostering synergy among operational efficiency, managerial vision, and sustainable innovation. The highest weight assigned to Innovation and Sustainability underscores recognition of the importance of integrating advanced technologies, green practices, and responsible resource management within the oil industry.

The analysis of causal relationships among the principal model dimensions was performed using the Fuzzy DEMATEL method. The fuzzy pairwise comparison matrix was constructed based on expert opinions, and following computation of the total relation matrix, the influence index (D), the influenced index (R), the interaction level (D+R), and the causal position (D–R) were calculated for each dimension. The results of the Fuzzy DEMATEL analysis are presented in Table 5.

Table 5

Results of Fuzzy DEMATEL Analysis (Influence and Influenceability Indices)

Dimension	D (Influence)	R (Influenced)	D+R	D–R	Position
D1 – Leadership and Policymaking	0.807	0.661	1.468	0.146	Cause
D2 – Organizational Culture and Learning	0.766	0.642	1.408	0.124	Cause
D3 – Processes and Operations	0.724	0.793	1.517	-0.069	Effect
D4 – Innovation and Sustainability	0.646	0.877	1.523	-0.231	Effect

The results in Table 5 indicate that Leadership and Policymaking (D–R = 0.146) and Organizational Culture and Learning (D–R = 0.124) occupy causal positions and exert direct and indirect effects on other model dimensions. This finding aligns with systemic theories emphasizing the role of contextual and structural variables in facilitating organizational change (Senge, 1990). In contrast, Processes and Operations (D–R = -0.069) and Innovation and Sustainability (D–R = -0.231) were identified as effect dimensions influenced by the causal dimensions. The highest interaction level (D+R = 1.523) was associated with Innovation and Sustainability, indicating its extensive interconnection with other dimensions. This suggests that the quality and efficiency of operational processes and green innovation capacity depend substantially on the organization's managerial, policy, and cultural infrastructure.

The evaluation of the measurement and structural models was conducted using Partial Least Squares Structural Equation Modeling (PLS-SEM) in SmartPLS software. Construct reliability was assessed using Cronbach's alpha and composite reliability (CR), convergent validity was evaluated through Average Variance Extracted (AVE), and discriminant validity was examined using the Fornell–Larcker criterion (Fornell & Larcker, 1981). Model fit indices were also evaluated. A summary of the model assessment results is presented in Table 6.

Table 6

Model Fit and Reliability Indices

Construct	Cronbach's Alpha	Composite Reliability (CR)	AVE	Status
Leadership and Policymaking (D1)	0.88	0.91	0.65	Confirmed
Organizational Culture and Learning (D2)	0.85	0.89	0.61	Confirmed
Processes and Operations (D3)	0.82	0.87	0.58	Confirmed
Innovation and Sustainability (D4)	0.84	0.88	0.60	Confirmed

Model Fit Indices

Index	Value	Status
χ^2/df	2.41	Good
GFI	0.92	Good
CFI	0.95	Excellent
RMSEA	0.061	Acceptable

The results in Table 6 indicate that all research constructs demonstrated Cronbach's alpha values ranging from 0.82 to 0.88 and composite reliability values between 0.87 and 0.91, all exceeding the 0.7 threshold, thereby confirming acceptable construct reliability (Hair et al., 2019). The AVE values ranged from 0.58 to 0.65, exceeding the 0.5 threshold and indicating satisfactory convergent validity. Model fit indices, including χ^2/df (2.41), GFI (0.92), CFI (0.95), and RMSEA (0.061), were all within acceptable or desirable ranges, confirming the model's adequate fit with the empirical data. These findings provide a robust foundation for subsequent hypothesis testing.

Table 7

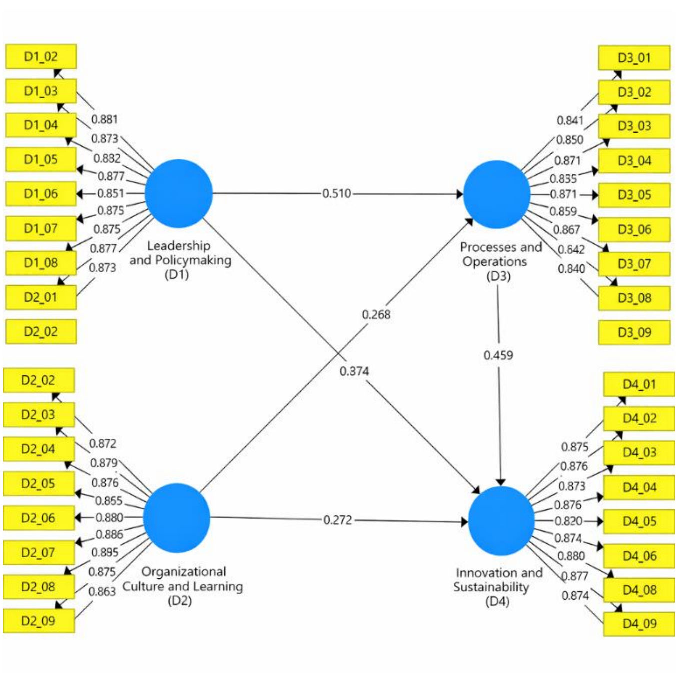
Results of Hypothesis Testing

Hypothesis	Path	Path Coefficient (β)	t-value	p-value	Result
H1	Leadership and Policymaking → Processes and Operations	0.510	6.327	< 0.001	Confirmed
H2	Organizational Culture and Learning → Innovation and Sustainability	0.272	3.105	0.002	Confirmed
H3	Processes and Operations → Innovation and Sustainability	0.459	5.412	< 0.001	Confirmed
H4	Leadership and Policymaking → Innovation and Sustainability	0.374	4.588	< 0.001	Confirmed

The results presented in Table 7 indicate that all research hypotheses were confirmed at a significance level below 0.05. The strongest structural path corresponds to the effect of Leadership and Policymaking on Processes and Operations (β = 0.510, t = 6.327), highlighting the pivotal role of leadership orientation in enhancing operational coherence and efficiency. The path from Processes and Operations to Innovation and Sustainability (β = 0.459, t = 5.412) also demonstrates a strong effect, emphasizing the importance of streamlined and lean operations in achieving sustainable innovation. The direct effect of Leadership and Policymaking on Innovation and Sustainability (β = 0.374, t = 4.588) reflects the role of leadership in inspiring and accelerating sustainable transformation. The effect of Organizational Culture and Learning on Innovation and Sustainability (β = 0.272, t = 3.105) was also confirmed, indicating the importance of a learning-oriented cultural context in strengthening organizational innovation capacity. The coefficient of determination (R^2) for the Innovation and Sustainability construct was 0.542, suggesting that more than 54% of its variance is explained by the predictor variables. The final structural equation model in its standardized coefficient form is illustrated in Figure 1. This figure depicts the path coefficients among latent constructs and the factor loadings of the indicators. The positive and statistically significant path coefficients among all constructs confirm the hypothesized relationships in the conceptual research model. The structural pattern demonstrates that Leadership and Organizational Culture, through the mediating role of Processes, enhance Innovation and Sustainability. All model paths yielded t-values greater than 2.77, confirming the statistical significance of relationships at a high confidence level.

Figure 1

Structural Equation Model with Standardized Coefficients



The final ranking of the LARG paradigm components was conducted using a combined F.D.ANP and Fuzzy TOPSIS approach. The final weights obtained from F.D.ANP were used as inputs in the Fuzzy TOPSIS method, and the final ranking was determined based on relative closeness to the ideal solution. The results of the ranking of the four LARG components are presented in Table 8.

Table 8

Final Ranking of LARG Paradigm Components

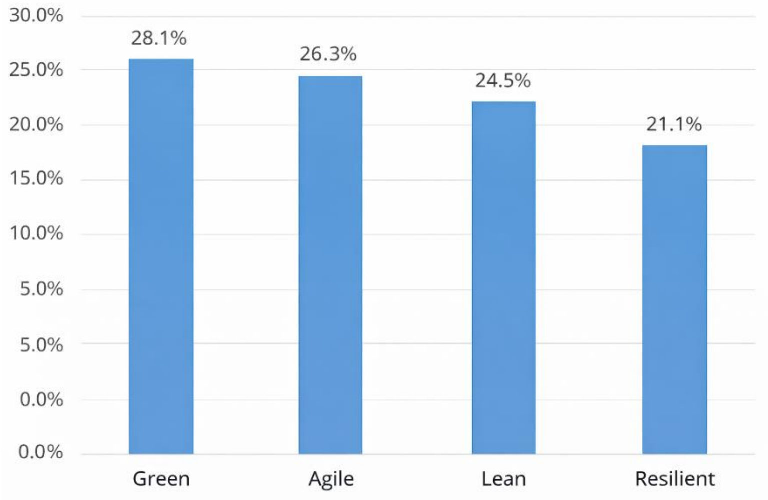
Rank	Component	Corresponding Dimension	Final Weight	Percentage
1	Green	Innovation and Sustainability	0.281	28.1
2	Agile	Organizational Culture and Learning	0.263	26.3
3	Lean	Leadership and Policymaking	0.245	24.5
4	Resilient	Processes and Operations	0.211	21.1

The results presented in Table 8 indicate that the Green component, with a weight of 0.281 (28.1%), ranks first in importance, reflecting the prioritization of environmental sustainability and green innovation in the integrated supply chain model of Abadan Oil Refining Company. The Agile component, with a weight of 0.263 (26.3%), ranks second, emphasizing the importance of flexibility, organizational learning, and rapid responsiveness to environmental changes. The Lean component, with a weight of 0.245 (24.5%), ranks third, followed by the Resilient component, with a weight of 0.211 (21.1%), in fourth position. The relatively balanced distribution of weights across the four components (ranging from 21.1% to 28.1%) confirms the integrated nature of the LARG model, which does not disregard any component while providing a clear prioritization framework for resource allocation and managerial attention.

The final weighted percentage distribution of the LARG components is illustrated in Figure 2. This figure visually represents the relative importance of each component and facilitates rapid comparison of their respective weights. The relative dominance of the Green component, followed by Agile, is clearly observable in the figure, aligning with environmental requirements and market dynamism within the oil industry. The relative balance among components highlights the necessity of simultaneous attention to all dimensions of the LARG paradigm in supply chain management.

Figure 2

Final Weighted Percentage of LARG Components



4. Discussion and Conclusion

The findings of the present study provide robust empirical support for the integrated LARG-based supply chain model in the context of the oil refining industry. The structural equation modeling results confirmed that all hypothesized relationships were statistically significant, with Leadership and Policymaking exerting the strongest influence on Processes and Operations ($\beta = 0.510$), followed by the effect of Processes and Operations on Innovation and Sustainability ($\beta = 0.459$). Additionally, Leadership and Policymaking demonstrated a direct and meaningful impact on Innovation and Sustainability ($\beta = 0.374$), while Organizational Culture and Learning significantly influenced Innovation and Sustainability ($\beta = 0.272$). The coefficient of determination ($R^2 = 0.542$) for Innovation and Sustainability indicates that more than half of its variance is explained by the proposed predictors, suggesting substantial explanatory power of the model. These findings collectively validate the systemic logic underlying the LARG paradigm and confirm the necessity of a balanced integration of strategic, cultural, and operational dimensions in oil supply chains.

The strong causal effect of Leadership and Policymaking on Processes and Operations underscores the centrality of strategic orientation in shaping operational efficiency and coherence. This result aligns with previous empirical evidence demonstrating that strategic supply chain management practices significantly influence operational performance and that resilience often mediates this relationship (Karimi et al., 2022). In the Iranian industrial context, LARG-based competitive strategies have been shown to require strong top-management alignment to effectively translate into operational improvements (Jamali & Karimi Asl, 2018; Jamali et al., 2024). The present findings extend these insights to the oil refining sector, emphasizing that leadership-driven policy frameworks are critical enablers of lean and agile operational processes. Without coherent strategic direction, operational optimization efforts may remain fragmented and unsustainable.

The significant path from Processes and Operations to Innovation and Sustainability highlights the operational foundations of sustainable transformation. This finding resonates with sustainability-oriented supply chain studies indicating that green and environmental initiatives are most effective when embedded within operational routines and logistics systems (Sousa et al., 2020). Moreover, research in the Gulf petrochemical sector shows that sustainability practices become institutionalized when integrated into operational decision-making and supply chain governance mechanisms (Alsaif et al., 2025). The weight assigned to the Green component in the ranking analysis further reinforces this interpretation, demonstrating that environmental sustainability is not peripheral but central within the integrated model. The prioritization of Innovation and Sustainability also aligns with value-added supply chain models developed for petrochemical industries, where sustainable development contributes directly to competitive advantage and value creation (Amiri et al., 2024).

The causal analysis using Fuzzy DEMATEL revealed that Leadership and Policymaking and Organizational Culture and Learning occupy “cause” positions within the system, whereas Processes and Operations and Innovation and Sustainability are “effect” dimensions. This systemic structure supports theoretical arguments that contextual and cultural infrastructures act as enablers of operational and innovative outcomes. Structural equation modeling approaches in oil and gas industries similarly demonstrate that organizational and structural variables significantly predict sustainability performance (Keyghobadi, 2021). Furthermore, performance evaluation frameworks in large-scale oil supply chains emphasize the need for multidimensional governance mechanisms to enhance operational and sustainability outcomes (Mehri Babadi et al., 2022). The present findings corroborate these models by empirically confirming the upstream influence of leadership and culture on downstream operational and sustainability constructs.

The relative importance ranking of LARG components—Green (28.1%), Agile (26.3%), Lean (24.5%), and Resilient (21.1%)—reflects contextual priorities of the oil refining industry. The prominence of the Green dimension corresponds to increasing environmental pressures and regulatory requirements in the petrochemical sector. Studies of reverse logistics and closed-loop supply chains in oil and gas industries highlight environmental compliance and waste reduction as key determinants of long-term viability (Ghazifard & Rasouli, 2021; Qazi Far & Rasouli, 2021). The growing emphasis on corporate social responsibility in competitive oil product supply chains further reinforces the strategic significance of environmental sustainability (Dhahir Mohammed et al., 2023). Therefore, the ranking results demonstrate convergence between empirical modeling and broader sustainability trends within the industry.

The Agile component's second-place ranking underscores the importance of flexibility and adaptive capacity in volatile markets. The oil industry's exposure to sanctions and geopolitical disruptions has intensified the need for agile response mechanisms (Ayaran et al., 2022). Research on supply chain resilience during the COVID-19 pandemic confirms that agility and redundancy are critical resilience drivers in oil and gas industries (Piya et al., 2022). While Resilience ranked fourth in relative weight, its structural role remains vital, particularly as a mediator linking strategic management to performance outcomes (Karimi et al., 2022). The relatively balanced distribution of weights among LARG components indicates that the model achieves integration rather than dominance of any single paradigm, thereby reducing potential trade-offs between cost efficiency, flexibility, and sustainability.

Technological advancement also plays a complementary role in strengthening the LARG paradigm. Machine learning applications in oil and gas supply chains improve demand forecasting, routing optimization, and predictive maintenance, thereby supporting lean and agile objectives (Odimarha et al., 2024). Similarly, technological catch-up in offshore equipment manufacturing demonstrates how supply chain coordination and policy alignment accelerate innovation processes (Li et al., 2022). More recent evidence indicates that technological advancements enable sustainable and resilient supply chain expansion, particularly in Gulf petrochemical industries (Krimi et al., 2025). Although technology was not modeled as an independent construct in the present study, its influence is implicitly embedded within the innovation and process dimensions, reinforcing the interconnectedness of digitalization and LARG implementation.

The integration logic of the model reflects broader systemic frameworks in interdisciplinary research, where interacting gradients define structural patterns (Hohenger, 2000). Translating this logic to supply chain management suggests that isolated implementation of lean or green initiatives is insufficient. Instead, integrated paradigms are required to ensure coherence across strategic, cultural, operational, and sustainability domains. The empirical confirmation of all hypothesized relationships supports this integrative approach and contributes to bridging fragmented strands of literature on sustainability, resilience, and competitiveness in oil supply chains (Anvari, 2021).

Overall, the discussion indicates that the proposed integrated LARG model not only aligns with prior empirical findings but also extends them by offering a unified structural framework tailored to the oil refining sector. The model demonstrates how leadership and cultural infrastructures activate operational processes, which in turn drive sustainable innovation outcomes. By empirically validating these relationships within a high-risk and resource-intensive industry, the study contributes to both theoretical advancement and practical decision-making in supply chain management.

Despite its contributions, this study is subject to several limitations. First, the empirical data were collected from a single oil refining company, which may limit the generalizability of findings to other petrochemical or oil sectors with different structural characteristics. Second, the cross-sectional design restricts the ability to capture dynamic changes in supply chain configurations over time, particularly in response to external shocks such as sanctions or market fluctuations. Third, while advanced multi-criteria and structural modeling techniques were employed, reliance on perceptual questionnaire data may introduce response bias. Finally, technological integration, although conceptually embedded, was not explicitly modeled as an independent construct, which may underestimate its direct influence on supply chain performance.

Future studies should expand the empirical scope by conducting multi-case or cross-country comparisons across oil and petrochemical industries to enhance external validity. Longitudinal research designs are recommended to examine how LARG-based configurations evolve under dynamic environmental conditions. Incorporating objective performance indicators alongside perceptual measures would further strengthen empirical rigor. Additionally, future models may explicitly integrate digital transformation and artificial intelligence constructs to explore their mediating or moderating roles within LARG-based supply chain systems. Comparative studies examining trade-offs between lean efficiency and resilience capacity under crisis conditions could also provide deeper strategic insights.

From a managerial perspective, the findings highlight the necessity of aligning leadership policies with operational process optimization to achieve sustainable innovation outcomes. Managers should prioritize environmental sustainability initiatives while simultaneously strengthening organizational learning and agility capabilities. Investment in cultural development and cross-functional coordination mechanisms can amplify the impact of strategic directives on operational performance. Furthermore, adopting integrated decision-making frameworks that balance lean, agile, resilient, and green dimensions can facilitate more effective resource allocation and long-term competitive positioning within the oil refining industry.

Authors' Contributions

Authors contributed equally to this article.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

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Ethics Considerations

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