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Presenting a Development Model for the Iranian Oil Pipelines and Telecommunications Company

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ABSTRACT

This study aimed to present a development model for the Iranian Oil Pipelines and Telecommunications Company using a qualitative grounded theory methodology. The study participants comprised 15 academic and industry experts in the fields of petroleum, information technology, and futures studies, who were selected through purposive and snowball sampling. Data were collected through in-depth semi-structured interviews and documentary studies and were analyzed using the systematic three-stage coding procedure of open, axial, and selective coding. During open coding, 66 initial concepts were identified, which were subsequently organized into 26 main categories during axial coding. Selective coding resulted in the integration of these categories into a paradigmatic model of integrated and future-oriented development. The findings indicated that successful integration represents a multidimensional strategic transformation rather than a unidimensional technical project. Its success depends on developing new institutional capacities and a novel model of collaborative governance capable of simultaneously managing coordinated changes across technical, organizational, human, and environmental dimensions. As an indigenous framework with theoretical generalizability, the proposed model can provide policymakers and industry managers with a roadmap for the digital and sustainable transformation of critical infrastructure.

Keywords: model, development, Oil Pipelines and Telecommunications Company, Iran

Introduction

The oil and gas industry constitutes one of the most strategically significant sectors of the Iranian economy, not only because of its direct contribution to national revenue and energy supply but also because of its extensive influence on industrial production, transportation, regional development, employment, and national security. Within this sector, the Iranian Oil Pipelines and Telecommunications Company performs a critical infrastructural role by maintaining the continuity, safety, and reliability of petroleum-product transmission and by providing the communications infrastructure required for monitoring, coordination, and operational control. The development of such a company cannot be reduced to the physical expansion of pipelines or the acquisition of telecommunications equipment. Rather, it involves a multidimensional transformation encompassing technological modernization, organizational restructuring, human capital development, financial sustainability, supply-chain resilience, risk governance, environmental responsibility, and institutional adaptation. As the operational environment of the petroleum industry becomes increasingly complex, infrastructure-oriented organizations must develop integrated models that enable them to respond simultaneously to technological disruption, economic volatility, sanctions, workforce challenges, changing energy markets, and rising expectations regarding safety and sustainable performance.

The strategic development of oil-industry organizations is closely associated with the quality of their managerial and institutional capacities. Development initiatives frequently fail when organizations invest in physical assets without establishing the managerial competencies required to plan, implement, monitor, and continuously improve complex transformation programs. Research on public-sector managerial competencies within the National Iranian Oil Company has shown that effective management in the petroleum sector requires an integrated combination of strategic, interpersonal, professional, ethical, and change-oriented capabilities [1]. Similarly, the development and validation of a competency model for managers of the Iranian Oil Terminals Company has emphasized that managerial effectiveness in strategic petroleum organizations depends on specialized competencies aligned with the technical, operational, regulatory, and environmental characteristics of the industry [2]. These findings suggest that any development model for the Iranian Oil Pipelines and Telecommunications Company must address not only assets and technologies but also the competencies of managers responsible for leading modernization under conditions of uncertainty. Strategic leadership, systems thinking, crisis management, technological literacy, stakeholder coordination, and evidence-based decision-making are particularly important because pipeline and telecommunications operations involve interconnected systems in which localized managerial deficiencies may generate widespread operational consequences.

Human resource development is therefore a central component of organizational development in the petroleum industry. The increasing integration of digital technologies, intelligent monitoring systems, cybersecurity mechanisms, data analytics, automation, and advanced maintenance systems has altered the competency requirements of both managers and technical personnel. A technology-based technical and engineering training model for oil and gas service companies has demonstrated that professional competency development requires training systems that are closely linked to actual technologies, occupational tasks, and industry-specific performance requirements [3]. Conventional classroom-based or generic training programs may be insufficient for organizations undergoing rapid technological transformation because employees must develop applied competencies through simulation, problem-based learning, workplace projects, and continuous exposure to emerging systems. Research on the managerial training process in the National Iranian Oil Products Distribution Company has likewise indicated that managerial education must be systematically connected to organizational strategy, job requirements, and performance evaluation rather than being implemented as a collection of disconnected courses [4]. Furthermore, a competency-based training-system model for managers in the same organization has highlighted the importance of needs assessment, competency mapping, appropriate instructional methods, and post-training evaluation in ensuring that managerial development contributes to organizational objectives [5]. Consequently, the development of the Iranian Oil Pipelines and Telecommunications Company requires an integrated learning architecture that supports technical reskilling, managerial development, digital literacy, cybersecurity awareness, knowledge transfer, and organizational learning.

The capacity to attract, develop, engage, and retain qualified personnel is another decisive factor in the long-term development of oil-industry organizations. Talent management is particularly critical in sectors characterized by specialized technical knowledge, lengthy professional development cycles, hazardous working conditions, geographically dispersed operations, and intense competition for digital and engineering expertise. Research conducted in the National Iranian Oil Products Distribution Company has identified talent identification, recruitment, development, deployment, retention, and succession planning as interconnected components of effective talent management [6]. A talent-management model developed for the National Iranian South Oilfields Company similarly demonstrated that organizational performance depends on the systematic alignment of talent-management practices with strategic priorities and future competency requirements [7]. At the same time, elite employee turnover represents a serious threat to knowledge-intensive petroleum organizations. The model of elite turnover factors developed for the Iranian Offshore Oil Company has shown that managerial practices, career-development opportunities, organizational justice, compensation, working conditions, and perceived organizational support can substantially influence the decision of highly qualified employees to remain in or leave an organization [8]. These considerations are especially important for the Iranian Oil Pipelines and Telecommunications Company, where the loss of experienced engineers, telecommunications specialists, cybersecurity professionals, and maintenance experts may weaken organizational memory and increase operational vulnerability.

Career systems and employee participation also affect the capacity of petroleum organizations to implement sustainable development programs. Employees are more likely to support organizational transformation when they perceive meaningful opportunities for advancement, professional recognition, participation in decision-making, and contribution to strategic initiatives. Research on career success in the National Iranian Oil Company has identified individual, organizational, managerial, and environmental factors as important determinants of employees' professional progress [9]. When career pathways are unclear or disconnected from competency development, organizations may experience reduced motivation, weakened commitment, and the departure of high-potential personnel. In addition, organizational participation can improve the quality of decisions and facilitate the implementation of change by drawing on the practical knowledge of employees working at different operational levels. An integrated model of organizational participation for Iranian governmental organizations, developed through a case study of the National Iranian Oil Company, has emphasized the importance of participatory structures, supportive leadership, organizational trust, information sharing, and employee involvement in improving organizational effectiveness [10]. For a geographically dispersed organization responsible for extensive pipeline and telecommunications networks, participatory governance can help ensure that strategic plans incorporate the experience of field personnel, regional managers, technical experts, maintenance teams, and control-center operators.

The development of the Iranian Oil Pipelines and Telecommunications Company must also be examined from the perspective of operational efficiency and supply-chain resilience. Pipeline development projects depend on the timely procurement of equipment, components, monitoring systems, control devices, maintenance services, engineering expertise, and financial resources. In an environment affected by international restrictions, currency fluctuations, administrative complexity, and limited access to advanced technologies, conventional procurement and supply-chain practices may expose strategic projects to substantial delays and cost overruns. Research on lean supply-chain management in Iran's oil and gas industry has demonstrated that the elimination of non-value-adding processes, process integration, supplier coordination, waste reduction, and continuous improvement can enhance operational efficiency [11]. Lean management is relevant not only to logistics but also to project approval, equipment procurement, maintenance planning, inventory management, information flows, and interdepartmental coordination. However, efficiency must not be pursued at the expense of resilience. In critical infrastructure organizations, excessive inventory reduction or dependence on a limited number of suppliers may increase vulnerability to external disruptions. Therefore, a balanced development model should integrate lean processes with strategic reserves, supplier diversification, domestic manufacturing capacity, and risk-based procurement.

Supplier selection and performance evaluation are particularly important because the safety and reliability of pipeline and telecommunications systems depend on the quality of the technologies and services acquired from external organizations. Sustainable prioritization of supplier-selection criteria in the oil and petrochemical industry has shown that technical capability, quality, delivery reliability, financial capacity, environmental performance, flexibility, and long-term collaboration should be considered simultaneously when evaluating suppliers [12]. In the context of sanctions and technological restrictions, supplier evaluation must additionally consider access continuity, domestic support capacity, cybersecurity risks, compatibility with existing infrastructure, localization potential, and the availability of spare parts. At a broader level, the performance of the entire supply chain must be assessed rather than focusing exclusively on isolated organizational units. A performance-evaluation model for large-scale supply chains in the oil and gas industry has emphasized the need to measure financial, operational, customer-related, process, learning, and strategic dimensions in an integrated manner [13]. For the Iranian Oil Pipelines and Telecommunications Company, such an approach would make it possible to evaluate how procurement, transportation, warehousing, maintenance, communications, contractor management, and asset-management processes collectively contribute to reliability, safety, cost control, and service continuity.

Financial volatility constitutes another fundamental challenge to organizational development in the petroleum sector. Large-scale pipeline modernization, digitalization, telecommunications upgrading, corrosion control, intelligent monitoring, and cybersecurity projects require substantial and sustained investment. Nevertheless, the financial capacity of petroleum organizations is affected by fluctuations in oil prices, exchange rates, inflation, export revenues, sanctions, and broader economic crises. Evidence from the Iranian capital market has demonstrated that oil-price fluctuations can influence corporate stock returns and financial performance, illustrating the broader transmission of energy-market volatility throughout the economy [14]. Studies examining the simultaneous effects of the COVID-19 crisis, oil-price fluctuations, and financial tensions have also shown that macroeconomic and crisis-related shocks can affect profitability and investment conditions even in industries outside the petroleum sector [15]. Similar research has indicated that oil-price movements, financial crises, and pandemic-related disruptions may influence organizational performance through changes in costs, demand, investor behavior, and access to financing [16]. Although these studies have focused on pharmaceutical companies, their findings reflect the systemic importance of oil-market volatility in Iran and demonstrate why long-term infrastructure development cannot rely exclusively on stable revenue assumptions.

Accordingly, the development of the Iranian Oil Pipelines and Telecommunications Company requires financial mechanisms capable of supporting long-term investment under uncertain conditions. Capital-allocation decisions should be based on life-cycle costing, asset criticality, risk exposure, operational value, and strategic importance rather than short-term budget availability alone. Aging pipelines may appear operationally functional while generating increasing inspection, repair, energy-consumption, environmental, and accident-related costs. Similarly, postponing investment in intelligent monitoring or secure telecommunications may reduce immediate expenditure but increase the probability of service disruption, leakage, cyber intrusion, and emergency maintenance. A comprehensive development model should therefore incorporate diversified financing, phased investment, project prioritization, domestic technology development, public–private cooperation, and the commercial utilization of existing infrastructure, including telecommunications and fiber-optic capacity. Financial sustainability should be viewed as a strategic capability that enables the company to maintain modernization programs despite fluctuations in revenues and external economic pressures.

Human resource development and organizational excellence must be closely connected to these financial, technological, and operational priorities. A human resource development model for organizational excellence in the National Iranian Drilling Company has emphasized the role of strategic human resource planning, competency development, performance management, leadership support, organizational culture, and employee empowerment in achieving superior organizational outcomes [17]. This perspective is relevant to the Iranian Oil Pipelines and Telecommunications Company because advanced technologies cannot independently improve performance unless employees are prepared to adopt, operate, maintain, and refine them. Digital transformation may even create new risks when organizations acquire sophisticated technologies without developing appropriate governance structures, data-management capabilities, cybersecurity protocols, and user competencies. Organizational development must therefore establish alignment among technological investment, human capital, work processes, organizational structure, and performance indicators. Such alignment can reduce the gap between formal modernization plans and actual operational practices.

The social and spatial dimensions of development should not be overlooked. Oil-industry organizations frequently operate in company towns, remote regions, and communities whose social and physical conditions directly affect employee well-being, recruitment, retention, and organizational legitimacy. Research on indicators of desirable housing in oil company towns has demonstrated that the quality of residential environments, access to services, safety, environmental conditions, social facilities, and spatial planning influence the welfare of oil-industry employees and their families [18]. Although pipeline and telecommunications development is primarily discussed in technical and managerial terms, its implementation depends on personnel who may work in dispersed stations, remote transmission corridors, and operational centers. Development policies should therefore consider employee welfare, occupational safety, regional infrastructure, community relationships, and the environmental and social effects of pipeline projects. A company that modernizes its equipment while neglecting the living and working conditions of its personnel may face difficulties in attracting specialized employees and sustaining operational commitment in remote regions.

Despite the valuable contributions of previous studies, the existing literature is largely fragmented and organization-specific. Some studies have examined managerial competencies, training systems, or career success, whereas others have focused on talent management, organizational participation, supplier selection, supply-chain performance, financial volatility, or employee welfare. These studies provide important insights but do not offer a comprehensive development model tailored to the distinctive characteristics of the Iranian Oil Pipelines and Telecommunications Company. The company simultaneously manages aging physical assets, geographically dispersed operations, petroleum transmission, industrial telecommunications, safety-critical processes, environmental risks, cybersecurity threats, specialized human resources, complex supply chains, and severe external constraints. Consequently, adopting a development model from another organization without considering these interconnected conditions may result in partial or ineffective interventions. A context-sensitive model must explain how causal pressures, organizational and environmental conditions, intervening factors, strategic responses, and expected consequences interact within this specific institutional setting.

Moreover, development in a critical infrastructure organization should be understood as a continuous and adaptive process rather than a temporary modernization project. The integration of pipelines, telecommunications, digital monitoring, asset management, human resource systems, and organizational governance requires a long-term perspective in which short-term stabilization measures are coordinated with medium-term capability development and long-term transformation. Such a model should enable the company to distinguish between urgent repairs and strategic renewal, balance operational continuity with innovation, and convert external constraints into incentives for localization, organizational learning, and technological self-reliance. It should also support the prioritization of investments based on risk and strategic value, the development of partnerships with universities and knowledge-based firms, the retention of specialized personnel, and the institutionalization of participatory and accountable decision-making. Grounded theory is particularly appropriate for developing such a model because it enables the systematic extraction of concepts and relationships from the experiences of academic and industry experts who possess direct knowledge of the company's operational, managerial, technological, and environmental challenges.

Accordingly, the present study aimed to develop an indigenous, integrated, and future-oriented development model for the Iranian Oil Pipelines and Telecommunications Company based on the experiences and perspectives of academic and industry experts.

Methodology

The present study adopted a qualitative design based on the grounded theory approach. This approach was employed to explain the dimensions, components, and processes involved in developing a model for the Iranian Oil Pipelines and Telecommunications Company. Grounded theory facilitates the development of an indigenous and realistic model derived from experts' experiences.

The research population consisted of academic and industry experts in the fields of petroleum, information technology, and futures studies. A total of 25 experts were selected through purposive and snowball sampling. Interviews continued until theoretical saturation was reached, meaning that newly collected data no longer added new concepts to the emerging model. Data were collected through library research and semi-structured interviews. The preliminary interview themes were derived from a systematic review of the scientific literature and previous studies. With the participants' permission, the interviews were audio-recorded and transcribed verbatim. Each interview was subjected to preliminary analysis immediately after its completion to ensure the accuracy and richness of the data. For triangulation purposes, secondary documents, including official reports and instructional materials, were also examined. The data analysis process was conducted in three grounded theory coding stages:

1. **Open coding:** The data were divided into small conceptual units, and key statements were extracted. In total, 66 initial concepts were identified.
2. **Axial coding:** Similar concepts were integrated into main and subcategories, and the causal, contextual, and strategic relationships among them were identified.

3. **Selective coding:** The axial categories were organized around a central category, and the final development model was presented in the form of a conceptual structure.

The following strategies were applied to enhance the credibility and accuracy of the findings:

1. **Member checking:** The findings were presented to the participants for feedback and revision.
2. **Peer debriefing:** Faculty members and doctoral students who were not directly involved in the study reviewed the analyses.
3. **Participatory analysis:** Participants were involved in the interpretation of the data.
4. **Final feedback and faculty review:** The final version of the model was submitted to experts and professors in futures studies and strategic scenario planning for confirmation.

To ensure dependability, the interviews were conducted with scientific rigor and reviewed several times. The coding procedures were also reviewed and revised, and all research stages were conducted under continuous scientific supervision.

Overall, by applying the grounded theory approach and drawing upon the experiences of academic and industry experts in petroleum, information technology, and futures studies, this research sought to identify a development model for the Iranian Oil Pipelines and Telecommunications Company. This methodology enabled the researchers to derive an indigenous theoretical model from field data to explain the development of the Iranian Oil Pipelines and Telecommunications Company. The model can serve as a foundation for the future development of the company. Table 1 presents a summary of the interviewees' characteristics.

Table 1

Summary of the Interviewees' Characteristics

No.	Expert Code	Highest Academic Degree	Key Area of Expertise	Relevant Experience, Years
1	H1	PhD	Energy policy and economics	25+
2	H2	PhD	Pipeline engineering and safety	20+
3	H3	PhD	Futures studies and strategic scenario planning	15+
4	H4	Master's degree	Information technology and industrial telecommunications	18+
5	H5	PhD	Cybersecurity of critical infrastructure	12+
6	H6	PhD	Strategic management and innovation	22+
7	H7	Master's degree	Transmission network operations and maintenance	19+
8	H8	PhD	Energy law and international sanctions	14+
9	H9	PhD	Environment and sustainable development	16+
10	H10	Master's degree	Investment and financing of petroleum projects	20+
11	H11	PhD	Risk management and organizational resilience	13+
12	H12	PhD	Geopolitics and energy security	17+
13	H13	Master's degree	Digitalization and artificial intelligence in the petroleum industry	11+
14	H14	PhD	Organizational sociology and change management	15+
15	H15	PhD	Emerging technologies in energy transmission	18+

Findings and Results

In this study, the data were analyzed in accordance with grounded theory through the three stages of open, axial, and selective coding.

A. Open Coding

During the open coding stage, the interview data were analyzed line by line and transformed into initial concepts representing the events, experiences, and perceptions of the participants. Similar concepts were subsequently grouped into preliminary categories or conceptual classes. The analytical process involved breaking down the data into smaller components to identify semantic similarities and differences. Each concept was labeled according to its implicit content, and conceptually similar items were organized into more abstract categories. Each category brought together a set of related concepts with substantial explanatory power and was capable of incorporating other subordinate concepts. The final themes emerged through the integration of related categories and were used as the basis for developing the conceptual development model for the Iranian Oil Pipelines and Telecommunications Company. Table 2 presents the results of open coding in terms of the main themes, subthemes, and selected related concepts. To avoid excessive length, only representative examples of the concepts are presented.

Table 2

Results of Open Coding

Main Theme	Subtheme	Extracted Code	Number of Codes	Interview Statement	Source
Causal conditions	International sanctions	Intensity and continuity of international sanctions	5	"The difference between our engineers and their foreign counterparts is neither intelligence nor knowledge; it is access. We are trapped on an information island."	P1, P3, P5, P7, P10
Causal conditions	International sanctions	Restrictions imposed on intermediary companies	3	"Even when we have the money, we cannot purchase the safest control valves. This means that our safety calculations are always accompanied by an 'insecurity factor.'"	P1, P2, P6
Causal conditions	International sanctions	Increased risk associated with all forms of financial transactions	5	"Every financial transaction becomes a complex and costly operation. This not only increases costs but also frightens international partners."	P1, P4, P6, P9, …
Causal conditions	International sanctions	Prohibition from joining international professional associations	3	"We fall behind in updating global standards and practices. In the long term, this isolation calls the quality and safety of our work into question."	P1, P3, P6, …
Causal conditions	International sanctions	Complete blockage of access to the technology market	4	"State-of-the-art global technology is unavailable. We are forced to work with older generations of equipment or adopt suboptimal alternative solutions."	P4, P5, P6, P8
Causal conditions	Global energy transformations	Changes in global energy demand and the energy transition	4	"Our traditional customers are seeking cleaner energy sources. Unless we align our roadmap with these developments, we will lose our market."	P1, P4, P6, P9, …
Causal conditions	Global energy transformations	Gradual decline in oil's share of the European energy mix	3	"Europe is rapidly reducing its dependence. This is a warning sign for our future export revenues."	P1, P3, P6, …
Causal conditions	Global energy transformations	Financial pressure on hydrocarbon projects	4	"Financing new oil and gas projects has become more difficult globally. Investors are increasingly inclined toward greener projects."	P4, P5, P6, P8
Causal conditions	Global energy transformations	Countries' orientation toward energy security and diversification	6	"Countries do not want to depend on a single source. This strategy challenges our exclusive position as a reliable supplier."	P2, P4, P7
Causal conditions	Global energy transformations	Emergence of new markets governed by new rules	5	"Our former customer is now investing in electricity and hydrogen. We need to ask ourselves: what will our transmission network be designed to carry 20 years from now?"	P1, P4, P5, P7, …
Causal conditions	Infrastructure aging	Aging and remaining service life of the existing pipeline network	4	"Many of our pipelines have exceeded their designed service life. Managing these aging assets is becoming more costly and risky every day."	P1, P4, P5, P7, …
Causal conditions	Infrastructure aging	Widening gap between current and legacy safety standards	3	"Pipelines constructed decades ago were never designed to withstand current operating pressures or comply with modern safety standards."	P1, P2, P6, …
Causal conditions	Infrastructure aging	Increasing frequency and cost of major repairs	6	"Maintenance has shifted from planned intervention to emergency response. This is not only costly but also reduces the reliability of the entire system."	P11, P2, P7, …
Causal conditions	Infrastructure aging	Inability to accommodate new capacity requirements	2	"Our existing network frequently becomes a bottleneck and cannot provide the transmission capacity required for developing new fields or meeting peak demand."	P1, P6
Causal conditions	Infrastructure aging	Emergence of "repair" rather than "renewal" as the dominant strategy	6	"We have become trapped in localized patchwork repairs. Our financial and human resources are spent keeping the old system operational rather than investing in a new system."	P1, P6, P9, P2
Causal conditions	Environmental pressures	Intensity of domestic and international environmental regulations	4	"Our operational safety margin is shrinking under the dual pressure of domestic standards and international expectations."	P1, P5, P6, P8, …
Causal conditions	Technological pressures	Rapid development of intelligent pipeline-monitoring technologies	2	"Emerging technologies such as Internet of Things sensors and data analytics have transformed pipeline-management standards. Falling behind this trend will make us uncompetitive."	P1, P2, P6, …
Central phenomenon	Imperative of modernization under siege conditions	Modernization under siege conditions	4	"We are not network managers; we are custodians of an aging museum. I work on a pipeline that survived the Iran–Iraq War. That is not an achievement; it is a disaster waiting to happen."	P11, P3, P6, P7, …

Central phenomenon	Imperative of modernization under siege conditions	Need to adopt state-of-the-art technology despite sanctions restricting access	5	"Our problem is choosing between bad and worse. If we do not invest, the network will die. If we invest using inadequate technology, we will throw money into a bottomless pit. If we try to acquire high-quality technology, we cannot obtain it."	P1, P3, P7, P12, …
Central phenomenon	Imperative of modernization under siege conditions	Urgent need for large-scale investment despite severe financial constraints	3	"We must extinguish the fire—emergency repairs—and construct a new building—digital transformation—at the same time. Our resources are insufficient for even one of these tasks."	P1, P8, P6
Central phenomenon	Imperative of modernization under siege conditions	Pressure to increase productivity within a highly disrupted network	2	"We are expected to reduce costs and increase output using pipelines that may fail at any moment. It is like expecting a worn-out vehicle to set a speed record."	P1, P5, …
Contextual conditions	Structural and organizational factors	Dominance of bureaucratic procedures over technical logic	3	"To purchase a single sensor, you must go through the seven trials of Rostam, each located in a different organization. By the time the final authorization is issued, the sensor has become obsolete."	P1, P12, P7, …
Contextual conditions	Structural and organizational factors	Multiple decision-makers and lack of accountability	2	"When a problem occurs, identifying someone willing to accept responsibility for the decision becomes a challenge in itself. Everyone expresses an opinion, but no one is accountable."	P1, P5, …
Contextual conditions	Structural and organizational factors	Abnormally prolonged procurement-to-implementation cycle	4	"A project that should technically be completed within two years takes five years because of administrative processes. This delay multiplies project costs and risks."	P4, P5, P6, P8
Contextual conditions	Organizational culture	Resistance to change and innovation	5	"The culture of 'as long as it works, it is good enough' has become deeply rooted in the organization. Every new system is confronted with the question, 'What was wrong with the previous system?'"	P1, P5, P6, P7, …
Contextual conditions	Macropolicy	Lack of transparency in national energy policies	3	"The country's overarching strategy concerning energy production, exportation, and consumption determines the framework for all our activities. At times, we feel trapped between long-term national objectives and short-term operational constraints."	P2, P3, P8
Contextual conditions	Environmental pressures	Intensification of domestic and international environmental regulations	2	"Our operational safety margin is shrinking under the dual pressure of domestic standards and international expectations."	P11, P3
Contextual conditions	Environmental pressures	Effects of climate change on design and operations	2	"Rainfall and temperature patterns have changed. Older pipelines were not designed for these new conditions. The risk of landslides and flooding along recurring routes has increased."	P11, P7, P9, …
Contextual conditions	Company's financial position	Limited financial health and sustainability of the company	7	"The company's revenue is highly dependent on oil prices and export volumes. Fluctuations in these two variables make any long-term planning for modernization investment impossible."	P2, P3, P6, …
Contextual conditions	National macroeconomic conditions	High inflation and economic instability	3	"Inflation makes project costs unpredictable. A budget approved this year for modernizing a station may not even be sufficient for its routine maintenance next year."	P1, P2, P6, …
Contextual conditions	National infrastructure	Low reliability of the national electricity grid	4	"Our digital transformation and intelligent monitoring systems are completely dependent on a stable power supply. Electricity fluctuations endanger not only routine operations but also the security of our critical data."	P4, P5, P6, P8
Contextual conditions	National infrastructure	Stability and continuity of the national internet network	5	"We require a stable internet connection to transmit sensitive monitoring data. Any disruption at the national level blinds us to what is happening along the pipelines."	P1, P5, P6, P7, …
Intervening conditions	Weaknesses in human capital and knowledge	Profound digital skills gap in the workforce	3	"When our IT specialist arrives, either they are afraid to touch the system in case they damage it, or they leave after two years because another workplace provides greater challenges and respect."	P2, P3, P8
Intervening conditions	Weaknesses in human capital and knowledge	Lack of organizational attractiveness to digital talent	2	"We have still been unable to make employment in a critical but traditional industry attractive to today's digital generation."	P11, P3
Intervening conditions	Weaknesses in human capital and knowledge	Ineffectiveness of existing training programs	6	"Our training courses are predominantly theoretical and repetitive and do not address our immediate practical problems involving emerging technologies."	P4, P5, P7
Intervening conditions	Weaknesses in human capital and knowledge	Limited level of research, development, and innovation within the company	4	"Our research and development budget and culture are largely reactive and focused on solving immediate problems. Creating future-oriented solutions requires a paradigm shift."	P3, P5, P6, P7
Intervening conditions	Weaknesses in human capital and knowledge	Severe shortage of active cyber-defense specialists	4	"We do not have enough cyber-threat analysts to monitor our network around the clock. This represents a major security gap."	P2, P3, P5, P7
Intervening conditions	Managerial characteristics	Organizational agility and speed of response during crises	3	"Our decision-making structure is extremely slow during crises, whereas a cyberattack can cause damage within minutes."	P1, P7, P9, P8
Intervening conditions	Security threats	Increasing complexity and targeted nature of cyber threats	3	"Threats have shifted from general attacks toward attacks specifically targeting critical infrastructure such as ours. In the past, an enemy had to come and plant dynamite; today, a	P2, P3, P8, P4

				hacker on the other side of the world can achieve the same result.”	
Intervening conditions	Security threats	Dependence of new systems on insecure communications infrastructure	5	“The more digitalized we become, the more we are unintentionally exposed to the inherent vulnerabilities of national communications infrastructure, such as the internet.”	P1, P8, P9, P5, …
Intervening conditions	Collaboration opportunities	Potential for regional cooperation in energy transmission	6	“Despite the sanctions, opportunities exist for technical and commercial cooperation with neighboring countries, which may provide a window for overcoming isolation.”	P1, P4, P6, P7, …
Intervening conditions	Collaboration opportunities	Possibility of utilizing the capabilities of domestic knowledge-based companies	4	“The growth of domestic knowledge-based companies represents a valuable opportunity. They are more agile and can develop customized solutions to our problems.”	P1, P2, P7, …
Strategies	Short-term strategies	Targeted repairs and continuous monitoring of critical points	3	“We can no longer renew all pipelines simultaneously. Our strategy is to identify the ‘vital arteries,’ place them under intensive surveillance, and achieve the greatest improvement in safety at the lowest possible cost.”	P1, P6, P7
Strategies	Short-term strategies	Establishment of secure digital enclaves around critical systems	5	“Our strategy is no longer to defend the entire perimeter. We have constructed a digital fortress around the most important control equipment. Entry into and exit from this fortress are governed by the strictest rules.”	P1, P2, P6, …
Strategies	Short-term strategies	Continuous simulation of physical and cyber crisis-response scenarios	5	“Every three months, we simulate what each unit must do if Pipeline X in Region Y experiences a leak or cyberattack. These exercises have reduced the element of surprise.”	P1, P4, P5, P7, …
Strategies	Medium-term strategies	Implementation of “frugal innovation”: minimal but high-impact solutions	7	“We are no longer seeking the best technology in the world. We are seeking the technology most appropriate to our circumstances. Sometimes, a simple mechanical solution that we develop ourselves is more effective than a complex imported system.”	P1, P12, P7, …
Strategies	Medium-term strategies	Prioritization of high-impact projects with short payback periods	3	“Instead of massive 10-year projects, we have focused on 18-month projects that produce tangible results. This increases team motivation and convinces management to continue.”	P1, P2, P7, …
Strategies	Medium-term strategies	Formation of consortia with universities and knowledge-based companies for domestic production	4	“Cooperation with universities is less expensive and more sustainable than purchasing from a foreign company. We present the problem, they provide the idea, and students implement it. This has become our research and development model.”	P12, P3, P6, P8, …
Strategies	Medium-term strategies	Development of indigenous communications and encryption protocols	5	“We cannot entrust our security to foreign software. With the assistance of domestic specialists, we are developing our own dedicated communications protocol.”	P1, P6, P9, P2, …
Strategies	Long-term strategies	Planned investment in integrated digital infrastructure	6	“The ultimate objective is to develop an intelligent network capable of diagnosing its own condition. Our current investment in sensors and data platforms constitutes the foundation of that future.”	P12, P3, P8, P5, …
Strategies	Long-term strategies	Transformation of organizational culture toward learning, innovation, and acceptance of calculated risk	4	“We want to build a culture in which testing a new solution, and even failing when the failure is instructive, is encouraged rather than punished. This is our greatest challenge.”	P11, P5, P6, P8, …
Strategies	Long-term strategies	Creation of an indigenous technological ecosystem around the pipeline industry	7	“The objective is not merely to meet our own needs. We want to build a company capable of producing knowledge and technology and potentially exporting technology to others in the future.”	P1, P12, P7, …
Consequences	Organizational consequences	Achievement of technological self-reliance and reduced dependence	3	“If we overcome this difficult period, we will become a company that no one can sanction because it will be capable of producing and understanding everything it needs.”	P1, P4, P6
Consequences	Organizational consequences	Increased network reliability and safety	2	“Our ultimate objective is not merely to maintain the pipeline but to know with complete confidence what is occurring at every moment.”	P1, P5, …
Consequences	Organizational consequences	Transformation of sanctions-related challenges into a driver of domestic innovation	5	“Being compelled to produce domestically has enabled our engineering talent to flourish. Today, we are working on technologies with no foreign equivalents.”	P1, P2, P4, P7, P10
Consequences	Organizational consequences	Reduction in the long-term total cost of operations	4	“Indigenous solutions may initially require greater investment, but their maintenance and repair costs are substantially lower, and they reduce our exposure to exchange-rate fluctuations and sanctions.”	P3, P5, P8, P11
Consequences	Economic consequences	Reduction in life-cycle costs	4	“In pipeline operations, reducing life-cycle costs is an economic consequence of the company’s development.”	P1, P6, P9, P12
Consequences	Economic consequences	Creation of new revenue streams	3	“Selling bandwidth from the pipeline’s fiber-optic network has generated IRR 20 billion in annual non-oil revenue for us.”	P2, P4, P10
Consequences	Economic consequences	Reduction in maintenance costs	6	“In the integrated southern pipeline system, annual maintenance costs are 35% lower than those of comparable stand-alone pipelines.”	P1, P3, P5, P7, P11, …
Consequences	Social consequences	Creation of an indigenous technological ecosystem and exportation of technical services	3	“Our objective is not merely to save ourselves. In cooperation with universities and knowledge-based companies, we intend to create a strong supporting industry capable of exporting services to other countries.”	P2, P6, P8

Consequences	Social consequences	Enhancement of national energy security and fulfillment of a sustainable infrastructural role	4	“A reliable pipeline network ensures secure energy supplies for industries and households. This is our most important social mission.”	P1, P4, P9, P12
Consequences	Operational consequences	Increased reliability	4	“The new integrated system detected a minor leak 48 hours before it could develop into an incident. Previously, this would have been impossible.”	P4, P5, P7
Consequences	Operational consequences	Improved decision-making	3	“With integrated data, we can accurately predict which pipeline section will require maintenance within the next six months.”	P3, P5, P6, P7
Consequences	Strategic consequences	Increased national resilience	4	“The integrated system enabled us to maintain pipeline monitoring through indigenous technologies even under conditions of comprehensive sanctions.”	P2, P3, P5, P7
Consequences	Strategic consequences	Sustainable development	5	“Instead of disturbing 200 hectares of land, the new integrated project affected only 120 hectares and gained the satisfaction of local communities.”	P1, P7, P9, P8
Consequences	Individual consequences	Enhancement of engineering competencies and development of a new generation of specialists	4	“Working under these difficult conditions has transformed our engineers into strong innovators and problem solvers. This experience is their most valuable professional asset.”	P1, P2, P6, P11

B. Axial Coding

The objective of this stage was to establish logical relationships among the categories extracted during open coding. This process was conducted using the paradigmatic model and enabled the researchers to coherently develop a theory of the social process under investigation. During axial coding, a main or axial category was initially identified. The other categories were subsequently linked to the main category as subcategories under the different components of the paradigmatic model, including causal conditions, contextual conditions, intervening conditions, strategies, and consequences.

C. Selective Coding: Theory-Development Stage

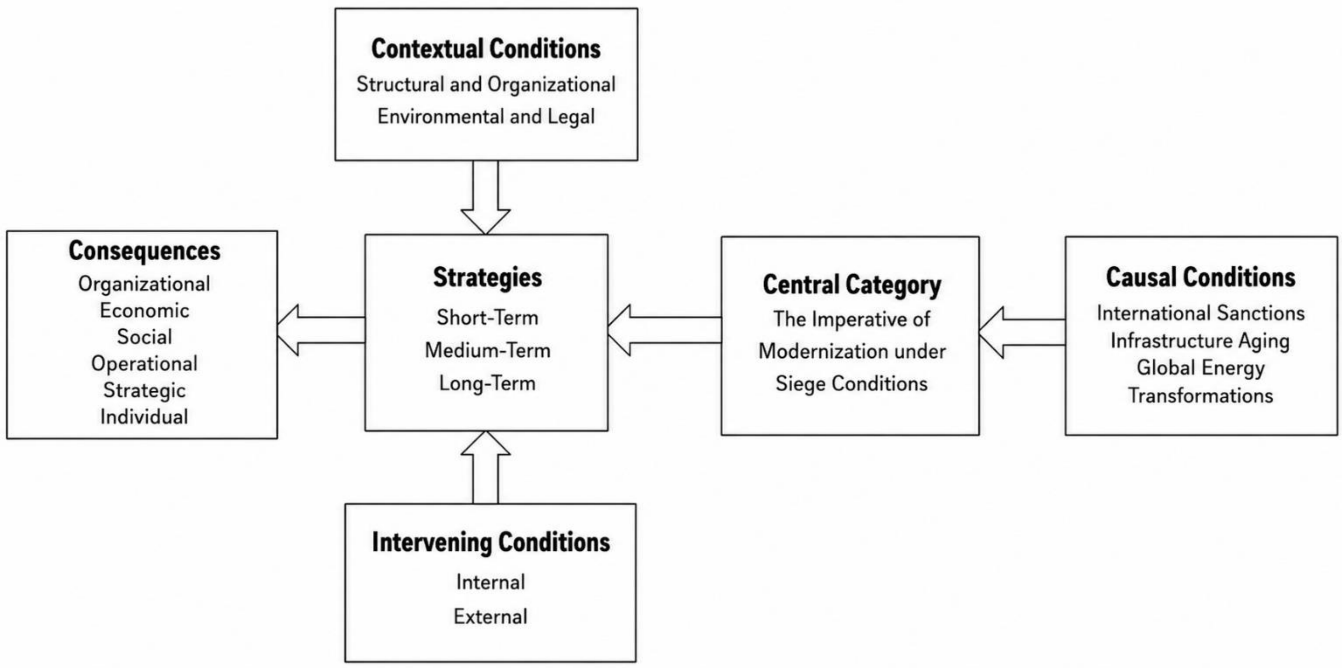
Selective coding is the stage during which the analyses generated through open and axial coding are integrated into a coherent theory, thereby enabling the presentation of the final research model. At this stage, the central category is systematically linked to the other dimensions and categories, and the causal, contextual, and strategic relationships within the model are explained through an analytical narrative (Strauss & Corbin, 1998, p. 136). In the present study, the development model for the Iranian Oil Pipelines and Telecommunications Company was designed based on selective coding. The main dimensions and components of the model were as follows:

- **Causal conditions—three components:** international sanctions, infrastructure aging, and global energy transformations.
- **Central category—one component:** the imperative of modernization under siege conditions.
- **Intervening conditions—two components:** internal factors and external factors.
- **Contextual conditions—two components:** structural and organizational factors and environmental and legal factors.
- **Strategies—three components:** short-term, medium-term, and long-term strategies.
- **Consequences:** organizational, economic, social, operational, strategic, and individual consequences.

At this stage, the researchers analyzed the interview transcripts, integrated them with the preceding findings, organized the relationships among the dimensions, and graphically presented the final model in Figure 1. The findings indicated that causal conditions influence contextual and intervening conditions, although this relationship requires further examination in independent studies. The objective of selective coding was to develop a theory that not only describes the phenomenon but also presents a comprehensive and indigenous structure for the development of the Iranian Oil Pipelines and Telecommunications Company. This model can serve as a foundation for the development of the Oil Pipelines and Telecommunications Company of the Islamic Republic of Iran.

Figure 1

Final Development Model for the Iranian Oil Pipelines and Telecommunications Company



Theoretical propositions represent the general relationships between the central category and the other categories that ultimately lead to specific results and consequences. The propositions encompass the relationships and conceptual structure expressed in the theory presented in Figure 1. Based on the research narrative and the development model for the Iranian Oil Pipelines and Telecommunications Company, six propositions were formulated. Because grounded theory generates conceptual relationships, each of the following propositions may be formulated as a hypothesis and empirically examined in future studies.

Proposition 1: International sanctions—including the intensity and continuity of international sanctions, restrictions imposed on intermediary companies, increased risks associated with financial transactions, prohibition from joining professional associations, and complete blockage of access to the technology market—together with infrastructure aging—including the aging and remaining service life of the network, the widening gap between current and legacy safety standards, the increased frequency and cost of major repairs, the inability to accommodate new capacity requirements, and the emergence of "repair" as the dominant strategy—and global energy transformations—including changes in global energy demand and the energy transition, the gradual decline in oil's share of the European energy mix, financial pressure on hydrocarbon projects, countries' orientation toward energy security, and the emergence of new markets governed by new rules—as causal conditions influence the central category of the imperative of modernization under siege conditions.

Proposition 2: The need to adopt state-of-the-art technology despite sanctions restricting access, the urgent need for large-scale investment despite severe financial constraints, and pressure to increase productivity within a highly disrupted network constitute central elements of the development model for the Iranian Oil Pipelines and Telecommunications

Company. As the central category, the imperative of modernization under siege conditions influences short-term, medium-term, and long-term strategies, as described in Proposition 5.

Proposition 3: Internal factors—including the profound digital skills gap, lack of organizational attractiveness to digital talent, ineffectiveness of training programs, limited research and development capacity, and a severe shortage of cyber-defense specialists—and external factors—including the increasing complexity of cyber threats, dependence of new systems on insecure infrastructure, potential for regional cooperation, and opportunities to utilize the capabilities of knowledge-based companies—function as intervening conditions affecting short-term, medium-term, and long-term strategies.

Proposition 4: Structural and organizational factors—including the dominance of bureaucratic procedures over technical logic, multiple decision-makers and lack of accountability, an abnormally prolonged procurement cycle, and resistance to change and innovation—and environmental and legal factors—including the lack of transparency in national energy policies, intensification of environmental regulations, and the effects of climate change on design and operations—function as contextual conditions affecting short-term, medium-term, and long-term strategies.

Proposition 5: The imperative of modernization under siege conditions constitutes the consequence and outcome of short-term strategies—including targeted repairs and continuous monitoring, the establishment of secure digital enclaves, and continuous crisis-response scenario exercises—medium-term strategies—including the implementation of frugal innovation, prioritization of projects with short payback periods, formation of consortia with universities and knowledge-based companies, and development of indigenous communications protocols—and long-term strategies—including investment in integrated digital infrastructure, transformation of organizational culture, and creation of an indigenous technological ecosystem.

Proposition 6: The imperative of modernization under siege conditions is specifically characterized by organizational consequences—including the achievement of technological self-reliance and reduced dependence, increased network reliability and safety, transformation of sanctions-related challenges into a driver of domestic innovation, and reduction in the long-term total cost of operations; economic consequences—including reduced life-cycle costs, creation of new revenue streams, and reduced maintenance costs; social consequences—including the creation of an indigenous technological ecosystem, exportation of technical services, enhancement of national energy security, and fulfillment of a sustainable infrastructural role; operational consequences—including increased reliability and improved decision-making; strategic consequences—including increased national resilience and sustainable development; and individual consequences—including the enhancement of engineering competencies and the development of a new generation of specialists.

Discussion and Conclusion

The present study aimed to develop an indigenous, integrated, and future-oriented model for the development of the Iranian Oil Pipelines and Telecommunications Company. The grounded theory analysis resulted in a paradigmatic model comprising causal conditions, a central phenomenon, contextual conditions, intervening conditions, short-, medium-, and long-term strategies, and organizational, economic, social, operational, strategic, and individual consequences. The central phenomenon was identified as the "imperative of modernization under siege conditions," reflecting the simultaneous necessity of renewing aging infrastructure and the severe restrictions imposed on access to capital, technology, equipment, knowledge networks, and international markets. The findings demonstrate that organizational development in the company cannot be treated as a conventional technical upgrading project. Rather, it is a complex strategic transformation requiring the coordinated development of physical infrastructure, digital systems, human capital, organizational culture, governance mechanisms, supply chains, financial capacities, and external partnerships.

The findings identified international sanctions, infrastructure aging, and global energy transformations as the principal causal conditions generating pressure for development. International sanctions were found to restrict access to advanced equipment, financial transactions, intermediary companies, professional associations, and global technology markets. These restrictions increase procurement costs, extend project implementation cycles, limit access to technical knowledge, and compel the company to continue operating older generations of equipment. The effects of external financial and energy-market instability are consistent with studies demonstrating that oil-price fluctuations, financial tensions, and major crises can significantly influence organizational profitability, investment capacity, and performance [14-16]. Although these previous studies examined firms in the Iranian capital market, their findings support the broader conclusion that organizations operating within an oil-dependent economy remain vulnerable to fluctuations in energy revenues and macroeconomic conditions. For the Iranian Oil Pipelines and Telecommunications Company, such volatility may reduce the predictability of long-term modernization budgets and reinforce short-term, reactive approaches to asset management.

Infrastructure aging was another major causal factor. The participants emphasized the declining remaining service life of pipelines, the growing gap between legacy and contemporary safety standards, the increasing frequency of major repairs, and the inability of the existing network to accommodate emerging transmission requirements. A particularly important finding was the gradual replacement of renewal by repair as the dominant organizational strategy. Under financial and technological constraints, resources are repeatedly directed toward maintaining the functionality of existing assets rather than replacing them with safer and more efficient systems. This pattern may create an escalating cycle in which aging infrastructure consumes increasing amounts of financial and human resources while reducing organizational capacity to invest in long-term transformation. The findings concerning supply-chain performance support this interpretation because performance in large-scale oil and gas supply chains depends on the integrated management of financial, operational, learning, process, and strategic dimensions rather than isolated short-term interventions [13]. Therefore, asset renewal should be incorporated into a comprehensive performance-management framework that considers life-cycle costs, reliability, safety, and strategic value.

The third causal condition concerned global energy transformations, including changes in international energy demand, the gradual reduction of oil’s share in certain markets, increasing financial pressure on hydrocarbon projects, the growing importance of energy security, and the emergence of new energy markets. These developments indicate that the company’s development strategy should not be limited to preserving its current infrastructure and operating model. Instead, it must examine the future functions of pipeline and telecommunications networks within a changing energy system. Existing pipeline corridors, communications infrastructure, control systems, and technical capabilities may potentially support the transmission, monitoring, or management of different energy carriers and services. Consequently, futures studies and scenario planning are essential for preventing the organization from investing exclusively in infrastructure designed around historical assumptions regarding energy demand. The competency literature also indicates that managers in strategic petroleum organizations require future-oriented, analytical, professional, and change-management capabilities to respond effectively to complex environmental developments [1, 2]. Thus, the findings suggest that managerial competency development should include strategic foresight, energy-transition literacy, technological assessment, and scenario-based decision-making.

The central phenomenon of modernization under siege conditions captures a fundamental strategic paradox. The company must adopt advanced technologies, increase investment, improve productivity, and strengthen safety precisely when its access to financial and technological resources is severely constrained. This paradox distinguishes the company's development process from ordinary modernization projects in which decision-makers can select technologies from competitive international markets and mobilize capital through conventional channels. Under siege conditions, the organization must simultaneously manage emergency repairs and pursue digital transformation, while also ensuring uninterrupted transmission operations. The competency-based training literature supports the importance of developing managers capable of making complex decisions under such conditions. A systematic training architecture based on competency needs, managerial responsibilities, and organizational strategy can increase managers' capacity to respond to uncertain and contradictory demands [4, 5]. Moreover, technology-based engineering education can improve the practical competencies required to adopt and maintain emerging technologies despite restricted access to external expertise [3].

The contextual conditions identified in the study included structural and organizational characteristics, organizational culture, national energy policies, environmental pressures, financial conditions, macroeconomic instability, and the reliability of national electricity and internet infrastructure. Bureaucratic procedures, multiple decision-makers, unclear accountability, and abnormally prolonged procurement cycles were reported to weaken the organization's capacity to respond rapidly to technical and operational needs. These findings demonstrate that technological modernization cannot succeed without governance reform. Even when financial resources and technical solutions are available, fragmented decision-making and administrative delays may cause technologies to become obsolete before procurement and implementation are completed. The integrated organizational-participation model developed for the National Iranian Oil Company similarly highlights the importance of information sharing, participatory structures, organizational trust, and supportive leadership in enhancing organizational effectiveness [10]. Greater participation by technical experts and operational personnel may reduce the gap between administrative decisions and field requirements while strengthening accountability for project outcomes.

Resistance to change emerged as another significant contextual factor. Participants described an organizational culture in which the continued operation of existing systems is sometimes considered sufficient justification for avoiding innovation. Such a culture can undermine digital transformation because new technologies frequently require changes in routines, responsibilities, authority relationships, performance criteria, and professional identities. The findings are aligned with research showing that human resource development, employee empowerment, leadership support, performance management, and an excellence-oriented organizational culture are essential for organizational transformation in petroleum-sector companies [17]. Furthermore, employee participation can increase acceptance of change by involving personnel in problem identification, solution design, and implementation [10]. Therefore, cultural transformation should not be approached solely through motivational statements or formal training. It requires changes in reward systems, decision-making procedures, experimentation practices, failure management, and the organizational treatment of innovative ideas.

Weaknesses in human capital and knowledge were among the most influential intervening conditions. These included a profound digital skills gap, difficulty attracting digital talent, ineffective training programs, limited research and development capacity, and a severe shortage of cybersecurity specialists. These findings are particularly important because the proposed development model depends extensively on digital monitoring, integrated data platforms, artificial intelligence, secure communications, and intelligent asset management. Without appropriate human resources, the acquisition of advanced systems may create technological dependence rather than organizational capability. Previous research has shown that technology-based technical and engineering training must be closely connected to occupational competencies and practical industry requirements [3]. Similarly, managerial training should be based on systematic needs assessment and linked to organizational performance [4, 5]. Therefore, training in the company should shift from generic and theory-oriented courses toward problem-based, workplace-centered, and technology-specific development programs.

The findings regarding talent attraction and retention are also supported by previous studies. Effective talent management in petroleum organizations requires systematic processes for talent identification, development, deployment, succession, and retention [6, 7]. The difficulty of attracting digital professionals may be intensified by rigid organizational structures, limited professional autonomy, unclear career pathways, and competition from more dynamic technology-oriented organizations. Research on elite employee turnover in the Iranian Offshore Oil Company has similarly shown that managerial practices, career opportunities, organizational support, working conditions, and perceived justice influence the retention of highly qualified personnel [8]. Moreover, career success in the National Iranian Oil Company is affected by individual, managerial, organizational, and environmental conditions [9]. These findings imply that the Iranian Oil Pipelines and Telecommunications Company must establish specialized career pathways for digital, cybersecurity, telecommunications, data-analysis, and advanced engineering personnel rather than attempting to retain them exclusively through conventional administrative employment systems.

The study also identified cyber threats and dependence on insecure communications infrastructure as major intervening factors. The digitalization of monitoring and control systems can improve operational visibility and predictive maintenance, but it simultaneously increases exposure to cyber intrusion, data manipulation, communications failure, and attacks on critical infrastructure. The lack of sufficient cyber-defense specialists further intensifies this vulnerability. Accordingly, digital transformation must be accompanied by cybersecurity-by-design principles, network segmentation, indigenous encryption capabilities, secure data governance, continuous threat monitoring, and crisis-response exercises. The company's dependence on national electricity and internet infrastructure also means that organizational resilience cannot be achieved solely within the company's formal boundaries. Redundant communications, backup power, offline operational capabilities, and alternative control mechanisms are necessary to maintain service continuity during national-level disruptions.

The strategies emerging from the findings were organized into short-, medium-, and long-term horizons. Short-term strategies focused on targeted repairs, continuous monitoring of critical assets, establishment of secure digital enclaves, and repeated simulation of physical and cyber crises. These strategies reflect a risk-based approach in which the organization directs limited resources toward the most critical assets and vulnerabilities. Such prioritization is more realistic than attempting to modernize the entire network simultaneously. However, short-term actions should be based on transparent asset-criticality criteria, condition-monitoring data, and measurable safety outcomes to prevent political or administrative considerations from distorting priorities.

Medium-term strategies included frugal innovation, prioritization of high-impact projects with short payback periods, cooperation with universities and knowledge-based companies, and the development of indigenous communications and encryption protocols. The concept of frugal innovation is particularly appropriate under resource and access constraints because it emphasizes solutions that are affordable, maintainable, context-sensitive, and capable of producing substantial operational value. The emphasis on university and knowledge-based-company collaboration also corresponds with supplier-management research demonstrating that technical competence, flexibility, quality, sustainability, and long-term collaboration are important supplier-selection criteria in the oil and petrochemical industry [12]. Moreover, lean supply-chain principles emphasize process integration, waste reduction, coordination, and continuous improvement [11]. Collaboration should therefore move beyond occasional contracting toward long-term technological partnerships involving joint problem definition, prototype development, field testing, intellectual-property arrangements, and commercialization.

Long-term strategies emphasized investment in integrated digital infrastructure, transformation of organizational culture, and creation of an indigenous technological ecosystem around the pipeline industry. This finding indicates that localization should not be interpreted merely as substituting individual imported components with domestic products. Sustainable technological self-reliance requires an ecosystem comprising research institutions, engineering firms, universities, knowledge-based companies, suppliers, financing mechanisms, professional development systems, and regulatory support. Such an ecosystem could reduce technological dependence while creating new revenue opportunities through the commercialization and exportation of technical services. The development of this ecosystem also depends on human resource excellence, talent retention, participatory governance, and specialized managerial competencies [1, 6, 17].

The anticipated consequences of the model were multidimensional. Organizational consequences included technological self-reliance, improved network safety and reliability, increased domestic innovation, and reduced long-term operating costs. Economic consequences included reduced life-cycle and maintenance costs and the creation of new revenue streams. These findings reinforce the argument that development investments should be evaluated through life-cycle performance rather than initial expenditure alone. The use of integrated communications assets, including fiber-optic capacity, may also enable the organization to diversify income sources. Operational consequences included improved reliability and more accurate decision-making through integrated data, while strategic consequences included national resilience and sustainable development. The social consequences—energy security, local technological ecosystem development, and technical-service exports—demonstrate that the company’s development has implications beyond organizational profitability. Finally, the individual consequences included enhanced engineering competencies and the development of a new generation of specialists. The inclusion of employee living conditions and welfare in broader development planning is also important, as research on oil company towns has shown that housing quality, services, safety, and environmental conditions affect employee welfare and organizational attractiveness [18]. Overall, the findings confirm that the development of the Iranian Oil Pipelines and Telecommunications Company is a systemic process whose effectiveness depends on the alignment of infrastructure, technology, human capital, governance, finance, culture, and external collaboration.

This study had several limitations. First, the findings were derived from the perspectives of a limited number of academic and industry experts, and the experiences of operational employees, contractors, technology suppliers, regional managers, and external regulatory stakeholders may not have been represented to the same extent. Second, the qualitative and context-dependent nature of grounded theory limits the statistical generalizability of the findings, although the model may have analytical relevance to comparable critical infrastructure organizations. Third, access restrictions and the strategic sensitivity of pipeline, telecommunications, and cybersecurity information may have prevented participants from discussing certain technical or institutional issues in full detail. Fourth, the study relied primarily on interview data and selected documentary evidence, and direct observation of organizational processes, procurement cycles, control centers, maintenance operations, and crisis simulations was limited. Finally, the dynamic nature of sanctions, energy markets, digital technologies, environmental regulations, and cybersecurity threats means that some model components may evolve over time.

Future studies should quantitatively test the relationships proposed in the paradigmatic model by developing and validating measurement instruments for the causal, contextual, intervening, strategic, and outcome dimensions. Structural equation modeling could be used to examine the direct and indirect relationships among infrastructure aging, sanctions, organizational capacity, digital readiness, strategic responses, and development outcomes. Comparative studies should also assess the applicability of the model in other Iranian petroleum, gas, electricity, transportation, and telecommunications organizations. Longitudinal research could investigate how modernization strategies influence safety, reliability, cost efficiency, employee competencies, and organizational resilience over time. Additional qualitative studies should include operational employees, regional units, private contractors, domestic technology companies, local communities, and policymakers. Scenario-based research could further evaluate alternative energy-transition pathways, sanctions conditions, cyber-threat environments, and financing arrangements. Future investigations should also develop maturity models for digital infrastructure, cybersecurity, talent management, organizational culture, and indigenous technological ecosystems.

Managers and policymakers should translate the proposed model into a phased development roadmap with clearly defined responsibilities, milestones, budgets, and performance indicators. The company should first identify critical assets and prioritize targeted renewal and intelligent monitoring based on safety, operational risk, and life-cycle costs. A centralized but participatory transformation-governance structure should be established to reduce fragmented decision-making and accelerate procurement and implementation. Specialized career and training systems should be created for digital technology, cybersecurity, telecommunications, data analytics, and advanced pipeline engineering. The company should establish permanent consortia with universities and knowledge-based firms for technology development, field testing, and domestic production. Digital transformation projects should incorporate cybersecurity, communications redundancy, backup power, and crisis-response protocols from their initial design. Finally, the organization should adopt a balanced performance framework covering reliability, safety, financial sustainability, environmental impact, employee development, innovation, and national resilience.

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Authors' Contributions

All authors equally contributed to this study.

Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants. Written consent was obtained from all participants in the study.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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