

Evaluation of Pipeline Strategy and Pricing in Oil and Gas Product Logistics in Iran

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ABSTRACT

The present study aims to evaluate pipeline pricing strategies in Iran's oil and gas product logistics and to analyze their economic, operational, environmental, and regulatory implications, with a case study of Payandan Company. This research was conducted using a mixed-methods approach in three stages. In the first stage, semi-structured interviews with industry experts and thematic analysis were employed to identify and classify the most important factors and criteria influencing pipeline pricing strategy. In the second stage, pricing strategies were evaluated based on a set of economic, operational, environmental, and regulatory objectives and constraints using a fuzzy goal programming model. At this stage, the degree of alignment of different strategies with the multiple objectives of the pricing system and their approach to managing conflicts among objectives were examined. In the third stage, to analyze the interactions among the main actors of the pricing system, the results of the fuzzy goal programming model were incorporated into the Stackelberg game theory framework, and the strategic interaction among Payandan Company as the leader, major customers as followers, and the regulatory body was analyzed. The findings indicated that the combined regulated pricing strategy, compared to other examined strategies, demonstrates greater compatibility with the set of objectives and constraints defined in the pipeline pricing system and can establish a balance among profitability, cost control, risk reduction, service level, capacity utilization, environmental requirements, and regulatory requirements. Furthermore, the Stackelberg analysis results showed that the interactive structure among the transmission company, customers, and the regulatory body plays a significant role in determining tariffs and their economic implications, such that tariff determination under equilibrium conditions, while complying with regulatory constraints, affects the company's profit, customer conditions, and overall system efficiency. Sensitivity analysis also indicated that the model results exhibit acceptable stability against changes in key parameters. Based on the research findings, the simultaneous evaluation of economic, operational, environmental, and regulatory dimensions can provide a basis for revising and designing pricing mechanisms for pipeline transmission services in Iran's oil and gas product logistics chain.

Keywords: Strategy Evaluation, Pipeline Pricing, Oil and Gas Logistics, Fuzzy Goal Programming, Stackelberg Game Theory.

1. Introduction

The oil and gas industry constitutes one of the most infrastructure-intensive and strategically consequential sectors of modern economies, and the efficiency with which petroleum products and natural gas are transported can substantially affect production continuity, energy security, market accessibility, and the economic performance of downstream industries. Within this system, pipelines represent a particularly important mode of transportation because they enable the continuous movement of large volumes of oil, gas, and refined products over long distances while reducing dependence on road- and rail-based logistics. Nevertheless, pipeline transportation is characterized by high fixed investment, substantial maintenance requirements, geographically dispersed assets, limited physical capacity, long asset life cycles, and complex relationships among operators, customers, governments, and regulatory institutions. Consequently, decisions regarding the pricing of pipeline transmission services extend beyond conventional cost accounting and constitute strategic decisions that influence the allocation and utilization of network capacity, customer demand, investment incentives, operational reliability, and the overall functioning of energy supply chains (Amiri et al., 2014; Markhorst et al., 2026).

Pricing is generally one of the central mechanisms through which supply-chain actors distribute costs, risks, revenues, and economic value. An appropriately designed pricing mechanism can contribute to cost recovery, profitability, efficient resource allocation, and the alignment of customer demand with available logistical capacity. Conversely, inappropriate pricing may create inefficient utilization, discourage investment, intensify contractual disputes, distort demand, or transfer excessive costs to particular actors. Research on pricing strategies indicates that firms may employ cost-based, value-based, discount-based, dynamic, or hybrid approaches depending on market characteristics, competitive conditions, product characteristics, and strategic objectives. For example, discount-oriented pricing models demonstrate that pricing should be designed in accordance with customer behavior, demand response, and organizational objectives rather than being interpreted merely as the addition of a profit margin to costs (Abdollahi & Ostadi, 2020). Similarly, research on markdown pricing has demonstrated that demand may depend simultaneously on both time and price and that differentiated pricing strategies can improve system performance when products, market conditions, or customer

responses vary over the planning horizon (Bahrami et al., 2022). These principles are particularly relevant to energy logistics, where both infrastructure constraints and fluctuations in demand can materially influence the economic consequences of tariff decisions.

Pipeline pricing is distinctive because pipeline infrastructure combines characteristics of logistics assets, capital-intensive networks, strategic energy infrastructure, and, in many cases, regulated or quasi-regulated services. Unlike transportation services with easily expandable capacity, pipeline networks have relatively rigid short-term capacity, and congestion or underutilization can create significant economic consequences. Evidence from crude-oil pipeline markets has demonstrated that constrained transportation capacity can generate price differentials and rationing effects, illustrating how the scarcity of pipeline capacity acquires an identifiable economic value (Walls & Zheng, 2020). Likewise, recent optimization research on gas entry-exit systems has emphasized that uncertainty in gas flows and capacity utilization complicates the allocation and valuation of transmission capacity and requires decisions that explicitly account for uncertain network conditions (Markhorst et al., 2026). Thus, an effective tariff should reflect not only the historical cost of infrastructure but also capacity availability, congestion, utilization, service reliability, opportunity cost, and the economic value generated through access to the transmission network.

The economic determination of pipeline tariffs is further complicated by the composition of transmission costs. Pipeline systems require extensive capital expenditure for construction, compressor or pumping stations, measurement facilities, control systems, safety equipment, and network development. They also involve recurring expenses for energy consumption, inspection, maintenance, repair, personnel, monitoring, insurance, and asset integrity management. Research focusing on natural-gas selling prices has shown that pipeline network configuration and logistics optimization can directly affect commercially feasible pricing levels, demonstrating the close connection among transportation structure, infrastructure costs, project feasibility, and the ultimate selling price of energy products (Nurprihatin et al., 2021). Recent research on hydrocarbon logistics also emphasizes the importance of integrated facility-location, inventory-routing, and logistics-cost optimization for improving the economic performance of hydrocarbon supply systems (Çali, 2026). Accordingly, pricing pipeline services requires an understanding of the

total logistics architecture rather than isolated calculation of transportation expenditures.

Another important issue is that the economic performance of energy transmission networks is strongly exposed to changes in the wider energy and macroeconomic environment. Oil prices, natural-gas prices, exchange rates, inflation, capital costs, and demand fluctuations may alter both operational expenditures and customers' capacity to pay transmission tariffs. Empirical evidence from Iran indicates that fluctuations in natural gas, crude oil, and exchange rates can affect the returns and economic performance of market sectors, thereby highlighting the importance of price instability for energy-related economic decisions (Javahari et al., 2025). In the petrochemical sector, feedstock pricing has likewise been identified as a complex policy problem involving regulatory rules, economic considerations, competing stakeholder interests, and industrial competitiveness (Zarei et al., 2023). Moreover, studies of floating-price mechanisms in Iranian gas export contracts suggest that flexible pricing can be legally feasible when adjustment mechanisms are transparent, measurable, and contractually specified (Ghasemi Javid et al., 2021). Collectively, these findings indicate that pipeline pricing systems must possess sufficient adaptability to respond to changing costs and market conditions while maintaining transparency and predictability.

The strategic relevance of pricing becomes even greater when transmission capacity interacts with national energy balances. Gas shortages or imbalances between production and consumption can create substantial economic losses across industrial, commercial, and residential sectors, meaning that the value of reliable transmission cannot be assessed exclusively through the operator's accounting costs. Research examining natural-gas imbalance in Iran has demonstrated that constraints in balancing supply and consumption can generate extensive economic consequences and has underscored the importance of coordinated planning for future production and consumption requirements (Rajabi & Sadeghi Shahdani, 2025). Similarly, expansion of Iran's participation in regional gas trade requires strategic attention to pricing, policy, infrastructure capability, competitiveness, and international market conditions (Aghamoosi et al., 2021). Pipeline capacity therefore possesses both direct commercial value and broader strategic value because it affects the ability to deliver energy reliably within domestic markets and to participate effectively in regional trade.

Operational reliability represents another central dimension of pipeline pricing. Oil and gas transmission networks are exposed to corrosion, leakage, rupture, equipment malfunction, accidents, natural hazards, sabotage, supply interruptions, and numerous organizational and operational risks. These risks may increase maintenance expenditures, generate service disruptions, create environmental liabilities, and impose losses on both transmission operators and customers. Research on Iranian gas-transmission systems has identified multiple interrelated supply-chain risks and emphasized the necessity of systematically evaluating their causal and structural relationships (Fathi & Abbasian, 2020). A broader risk-management framework developed for Iran's gas-industry supply chain similarly demonstrated that transmission-related performance depends on the management of interconnected organizational, operational, and external risks (Safavi Mir Mahalleh et al., 2020). Consequently, tariff design that ignores the cost of risk reduction, preventive maintenance, emergency capacity, and system recovery may underestimate the actual resources required to provide reliable transmission services.

Risk assessment becomes especially challenging because many pipeline hazards involve uncertainty, incomplete information, and qualitative expert judgments. The use of fuzzy inference techniques for sour-gas pipelines has demonstrated the usefulness of incorporating uncertain and linguistic assessments into pipeline risk evaluation (Raei Hagh et al., 2023). Risk-based pricing principles are also relevant to the economic valuation of energy infrastructure. Research on crude-oil and natural-gas refineries has shown that accident probability, severity of potential losses, and the quality of safety controls can be incorporated into criteria for pricing risk-related financial products, illustrating the economic significance of industrial safety performance (Payandeh & Atatalab, 2020). The implication for pipeline tariffs is that risk cannot be treated merely as an engineering variable; it has economic consequences and therefore should be integrated into the assessment of alternative pricing strategies.

Resilience has become an equally important concern because modern energy networks must maintain functionality under disruption and recover rapidly when interruptions occur. Research on sustainable and resilient gasoline supply-chain networks has demonstrated that explicitly incorporating disruption uncertainty into network design produces decisions that are more capable of maintaining supply under adverse scenarios (Khalili et al.,

2022). Studies of the South Pars Gas Complex have similarly highlighted the contribution of agility, information technology, financial preparedness, risk-management culture, and organizational capabilities to energy supply-chain resilience (Soheili, 2021). In addition, research applying lean, agile, resilient, and green supply-chain perspectives in oil and gas companies indicates that competitive supply-chain strategy increasingly depends on the simultaneous achievement of operational efficiency, responsiveness, resilience, and environmental sustainability (Hosseinzadeh et al., 2022). These findings imply that transmission tariffs should facilitate not only routine operations but also the investments and reserve capabilities required for continuity and recovery.

Technological development further affects both the cost structure and the reliability of pipeline logistics. Preventive and predictive maintenance increasingly relies on condition monitoring, digital models, optimization algorithms, and intelligent decision systems. Recent work on deep reinforcement learning for natural-gas transmission pipeline maintenance demonstrates the potential of advanced computational methods to optimize maintenance decisions across complex networks and thereby influence reliability, downtime, and life-cycle cost (Sampaolesi, 2025). At the same time, increasing digitalization creates new vulnerabilities. Energy supply chains have become potential targets of advanced persistent threats and other cyber risks, meaning that resilience now includes the protection of digital control, monitoring, communication, and operational technology systems (Petruolo, 2025). Therefore, modern pipeline pricing strategies may need to recognize expenditures on technological modernization, cybersecurity, predictive maintenance, and asset integrity as components of sustainable service provision rather than discretionary overhead.

Uncertainty is particularly important because pricing decisions are made within environments characterized by uncertain demand, changing energy prices, infrastructure disruptions, regulatory adjustments, and strategic responses from other actors. Contemporary supply-chain research has increasingly used global optimization and game-theoretic methods to address operational decisions under uncertainty and strategic interaction (Marousi, 2025). This perspective is highly relevant to pipeline transmission because the operator cannot determine tariffs without considering the reactions of customers, competitors, and regulators. Likewise, improvements in logistics efficiency can affect economic performance throughout an energy terminal or

transmission system. Research on vessel turnaround times in petroleum terminal operations, for example, has demonstrated the importance of coordination, operational efficiency, and reduction of logistical delays for infrastructure utilization and overall performance (Ibrahimi & Johansson Tidblom, 2026). These insights support a broader interpretation of pipeline pricing as one element of an integrated operational system in which tariff decisions influence and are influenced by capacity, delays, demand, and service quality.

Market interaction constitutes another important consideration. Pipeline operators, customers, regulatory authorities, and competing transportation modes do not necessarily pursue identical objectives. Operators generally seek cost recovery, profitability, investment capability, and efficient capacity utilization. Customers seek affordable tariffs, reliable service, contractual flexibility, and predictable costs. Regulators may prioritize transparency, nondiscrimination, market efficiency, consumer protection, infrastructure development, and compliance with energy policy. Research on coordinated electricity and gas markets illustrates that transmission constraints and interactions across energy markets can influence congestion patterns and market-clearing outcomes (Barforoushi et al., 2021). Similarly, research on refined-product supply chains shows that pipeline pricing can be formulated together with logistics planning and fair profit distribution among supply-chain actors, demonstrating that the tariff problem is inseparable from the allocation of economic benefits throughout the chain (Qiu et al., 2023). Hence, pricing is inherently multi-actor and involves both optimization and negotiation among competing interests.

Legal and contractual conditions further restrict the feasible range of pricing decisions. Pipeline development and operation frequently depend on long-term contracts, allocation of construction and operating risks, access rights, minimum-volume commitments, price-adjustment mechanisms, and dispute-resolution procedures. Research on contractual models used for international oil and gas pipeline construction has demonstrated that the allocation of responsibilities and risks must be aligned with the legal characteristics of the Iranian system (Piri et al., 2019). In international gas markets, regulatory requirements related to third-party access, tariff transparency, market liberalization, and ownership structures can create additional challenges for external suppliers seeking to enter regulated markets such as the European Union (Ghanbari Bonab et al., 2023). These considerations indicate that tariff evaluation should include

regulatory and contractual feasibility rather than treating the legally permissible tariff range as an external issue considered only after economic optimization.

Digital contracting may also transform future energy transactions. Smart contracts have been examined as mechanisms capable of improving transparency, traceability, execution efficiency, and transaction management within the oil, gas, and petrochemical sectors, although their application remains subject to legal and institutional requirements (Mohammadi, 2023). Such developments can influence how tariff rules, volume commitments, payment conditions, penalties, and adjustment mechanisms are implemented. Consequently, an integrated pricing framework should be sufficiently flexible to incorporate evolving contractual technologies and increasingly data-driven modes of coordinating transmission services.

Environmental and social sustainability constitute additional dimensions that can no longer be separated from energy logistics decisions. Pipeline operations involve energy consumption, emissions, leakage risk, land use, ecological disturbance, and potential consequences for communities located along transmission corridors. Spatial-security analyses of Iran's oil and gas transmission lines have demonstrated the strategic and geographical vulnerability of energy infrastructure and the importance of incorporating spatial and security considerations into infrastructure planning (Amiri et al., 2014). Meanwhile, sustainable supply-chain research in the oil and gas sector emphasizes that environmental performance, resilience, efficiency, and operational competitiveness are interconnected rather than mutually exclusive objectives (Hosseinzadeh et al., 2022). A pricing system focused exclusively on short-term financial performance may therefore fail to generate adequate resources or incentives for environmental protection, safety improvement, network modernization, and socially responsible infrastructure management.

Taken together, the literature suggests that pipeline pricing represents a multidimensional decision problem characterized by several competing objectives. Cost minimization may conflict with investments required for safety and resilience; higher tariffs may improve operator revenue but reduce customer demand; aggressive capacity utilization may improve short-term returns while increasing operational pressure; and strict regulatory controls may protect customers but, if poorly designed, weaken incentives for maintenance or infrastructure expansion. Strategic

pricing therefore requires an explicit mechanism for managing trade-offs rather than optimizing a single criterion. Studies of pricing, logistics planning, risk, supply-chain resilience, and energy-market interaction provide important individual insights, but these dimensions are frequently investigated separately (Khalili et al., 2022; Qiu et al., 2023; Safavi Mir Mahalleh et al., 2020).

This fragmentation is especially important in the Iranian context. Existing studies have examined the security of oil and gas pipelines (Amiri et al., 2014), supply-chain risks (Fathi & Abbasian, 2020), gas-industry risk management (Safavi Mir Mahalleh et al., 2020), gas-market development (Aghamoosi et al., 2021), contractual and regulatory issues (Ghanbari Bonab et al., 2023; Ghasemi Javid et al., 2021; Piri et al., 2019), energy pricing policies (Zarei et al., 2023), resilience and sustainability (Hosseinzadeh et al., 2022; Soheili, 2021), and economic consequences of gas imbalance (Rajabi & Sadeghi Shahdani, 2025). However, evaluating pipeline pricing strategies requires these economic, technical, market, risk, legal, regulatory, environmental, and strategic considerations to be examined within a unified decision framework. Such integration is particularly necessary when actors react strategically to tariffs and when uncertainty prevents decision makers from defining precise targets for all performance criteria.

Multi-objective and fuzzy optimization approaches are well suited to this setting because real-world decision makers frequently specify aspiration levels rather than exact deterministic targets. Fuzzy goal programming makes it possible to represent different goals through degrees of satisfaction and to search for a compromise solution when objectives conflict. This is especially appropriate for pipeline pricing because profitability, capacity utilization, reliability, tariff fairness, risk, environmental performance, and regulatory compliance cannot ordinarily be maximized simultaneously. Nevertheless, optimization alone does not capture strategic behavior. The tariff selected by an operator may cause customers to modify demand, while regulatory bodies may impose ceilings, penalties, access rules, or service obligations. Game-theoretic approaches, particularly leader-follower structures such as the Stackelberg framework, can therefore complement multi-objective optimization by explicitly representing sequential decisions and stakeholder responses. This approach is consistent with the growing application of strategic and optimization-based methods to uncertain supply-chain operations (Marousi, 2025) and with research emphasizing the interconnected economic consequences of capacity allocation and pricing

decisions in energy transportation systems (Markhorst et al., 2026; Walls & Zheng, 2020).

Accordingly, developing a comprehensive pipeline pricing framework requires moving from the question of what tariff covers costs toward the broader question of which pricing strategy creates an acceptable balance among financial sustainability, operational performance, risk reduction, customer response, capacity utilization, regulatory legitimacy, and environmental responsibility. Such an approach is particularly relevant to companies operating within Iran's oil and gas logistics system, where infrastructure constraints, economic volatility, regulatory intervention, technological requirements, and strategic energy considerations simultaneously shape pricing decisions. By integrating expert-derived criteria with fuzzy multi-objective optimization and strategic interaction among the operator, customers, and regulator, a more realistic basis can be established for comparing pricing alternatives and understanding their consequences.

Therefore, the aim of the present study is to evaluate pipeline pricing strategies in Iran's oil and gas product logistics, with a case study of Payandan Company, by integrating economic, operational, risk, market, environmental, and regulatory criteria through fuzzy goal programming and analyzing the strategic interaction among the pipeline operator, customers, and regulatory body using Stackelberg game theory.

2. Methods and Materials

The present study was conducted with the aim of evaluating pipeline strategy and pricing in Iran's oil and gas product logistics using a mixed-methods and multi-stage approach. The research logic is based on the premise that pricing of pipeline transmission services is simultaneously influenced by economic and financial factors, technical and operational factors, risk and safety, regulation and contracts, market and demand conditions, and environmental and social considerations. Therefore, first, the factors affecting pricing were identified through qualitative study and interviews with experts, and then used to evaluate pricing strategies in a fuzzy goal programming model. In the final stage, the consequences of pricing strategies in the interaction among the pipeline operator, customer, and regulator were examined using Stackelberg game theory.

The expert community included 30 university professors, managers and specialists in the oil and gas industry, and experts in the fields of pricing, contracts, modeling, and

pipeline management. Given the specialized and limited nature of the community, the census method was used. The criteria for selecting experts included at least a master's degree, at least five years of relevant experience, and experience in the fields of oil and gas logistics, pipelines, pricing, regulation, or modeling. To maintain confidentiality, the experts' views were recorded and analyzed with codes E01 to E30.

Qualitative data were collected through semi-structured interviews. The interview axes included pricing objectives, cost structure, network capacity and utilization, service quality and reliability, operational and financial risks, regulatory and contractual requirements, demand and price elasticity, alternative transportation options, and environmental and social considerations. The data were analyzed using six-stage thematic analysis. In the coding process, 109 initial codes were identified and, after refinement, organized into six overarching themes: "economic and financial factors," "technical and operational factors," "risk, safety, and resilience," "regulation, legal, and contractual," "market, demand, and competition," and "environmental and social sustainability." These themes formed the basis for developing the conceptual model and quantitative model of the research.

In the quantitative stage, the qualitative findings were converted into a fuzzy goal programming (FGP) model. The identified components were defined in the form of goals, constraints, parameters, and decision variables. The main decision variables included the base transmission tariff, fixed and variable tariff components, volume discounts, penalties for deviation from the transmission plan, and capacity allocation to customers. The model was formulated as multi-product, multi-period, network-based, and scenario-based, and constraints such as flow balance, network operational capacity, regulatory tariff ceilings and floors, and contractual volume commitments were incorporated.

The model's goals covered different dimensions of pricing system performance and included cost coverage and profitability, capacity utilization, risk reduction, demand retention and customer satisfaction, tariff fairness and transparency, service reliability, and environmental and regulatory requirements. Therefore, instead of focusing on a single financial objective, the model enabled simultaneous evaluation of economic, operational, market, risk, and sustainability objectives.

The mathematical model was implemented in the GAMS environment and solved using the CPLEX solver. First, the

objectives were solved independently to determine the ideal values and desirable ranges of the goals. Then, fuzzy membership functions were defined, and the integrated FGP model was solved. The output of this stage included tariff values, capacity allocation, demand, profit, and the degree of achievement of different goals, and was used to evaluate pricing strategies.

In the next stage, to analyze the strategic interaction of actors, the FGP model output was incorporated into the Stackelberg game theory framework. The pipeline operator was considered as the leader, the customer as the follower, and the regulator as the observer actor. The operator's decision regarding the tariff, the customer's reaction based on cost and demand conditions, and the regulator's constraints were examined interactively. Thus, in addition to the economic evaluation of pricing strategies, their behavioral and interactive consequences were also analyzed.

To evaluate the model's validity, three levels of structural, computational, and behavioral validity were examined. In structural validation, the compatibility of the model's relationships with the economic and operational logic of the industry was checked; in computational validation, compliance with constraints, tariff limits, and calculation accuracy was examined; and in behavioral validation, the compatibility of customer and regulator reactions with the game structure was evaluated. Additionally, sensitivity analysis was performed with respect to key parameters including marginal transmission cost, demand sensitivity, regulatory tariff ceiling, and penalty rate to determine the stability of results under different conditions. This process enabled a comprehensive evaluation of pricing strategies and their economic and strategic consequences in Iran's oil and gas pipeline logistics system.

3. Findings and Results

The data analysis in the present study was conducted in several consecutive stages due to the multidimensional

nature of the pipeline pricing problem in oil and gas product logistics. Since pipeline pricing is not merely a function of transmission costs, and variables such as network capacity, service level, operational risk, market conditions, regulatory requirements, contract characteristics, and environmental and social considerations also affect it, the data analysis was performed using a combined and multi-stage approach. In the first stage, the data obtained from semi-structured interviews with experts were subjected to thematic analysis, and the factors and indicators affecting pricing were extracted. In the second stage, the obtained themes and codes were converted into objectives, parameters, decision variables, and constraints of the mathematical model. In the third stage, the fuzzy goal programming model was implemented to create a compromise solution among conflicting objectives, and in the fourth stage, the obtained results were evaluated using Stackelberg game theory and sensitivity analysis. Thus, the data analysis began from the level of identifying qualitative factors and continued to the level of quantitative evaluation of pricing strategies and examination of actors' strategic reactions.

In the first stage of analysis, interviews conducted with 30 experts from academic and specialized fields of the oil and gas industry were examined. The unit of analysis at this stage was a phrase or set of meaningful sentences related to the research topic. The thematic analysis process was conducted in six stages: familiarization with the data, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and finally, writing the final narrative. During this process, initial codes were first extracted from the interview texts, and then similar and synonymous codes were merged. Ultimately, 109 initial codes were finalized and organized into a coherent set of factors usable in the research model. The purpose of this stage was not merely to describe the experts' views but to convert qualitative concepts into indicators that could be measured, entered into the mathematical model, and used in the decision-making process.

Table 1

Stages of Thematic Analysis of Interview Data

Stage	Activity Description	Output
Familiarization with data	Multiple readings of interview texts and identification of initial concepts	General understanding of data content
Initial coding	Extraction of meaningful phrases and concepts	Initial codes
Merging similar codes	Removal of repetitions and combination of synonymous concepts	Refined set of codes
Forming themes	Classification of codes based on conceptual relationship	Sub-themes
Reviewing themes	Examination of internal coherence and differentiation among themes	Final themes
Naming	Selection of a conceptual title for each theme	Overarching themes
Mapping to model	Conversion of themes into variables, objectives, parameters, or constraints	Mathematical model structure

The above table shows that the qualitative analysis in the present study was conducted in a staged manner. The important point is that thematic analysis was not limited to extracting recurring topics; rather, the output of this stage was directly used in designing the quantitative model. Therefore, the connection between the qualitative and quantitative parts of the research is maintained, and the model variables are formed based on the factors extracted from the experts' perspective.

Table 2

Overarching Themes Affecting Pipeline Pricing

Overarching Theme	Most Important Components	Interpretation
Economic and Financial	Investment, OPEX, energy, repairs, depreciation, capital cost, capacity opportunity cost	Determines cost and economic return of transmission
Technical and Operational	Capacity, utilization, congestion, bottleneck, service continuity, pressure, delivery time	Determines executability and quality of transmission
Risk, Safety, and Resilience	Leakage, corrosion, failure, theft, sabotage, demand risk, default	Determines cost and sustainability of service
Regulatory and Contractual	Tariff ceiling, third-party access, transparency, contract, Pay-or-Take, payment guarantee	Determines legal and contractual limits of decision
Market and Demand	Price elasticity, demand volume, competition, transport alternatives, bargaining power	Determines customer reaction to tariff
Environmental and Social	Emissions, energy consumption, pollution, social safety, regional justice, ESG	Determines sustainability and social effects of pricing

The results indicate that pipeline pricing has a multidimensional nature. Economic factors mostly affect profitability and cost recovery, technical factors determine the feasibility of tariff implementation and actual service capacity, risk factors cover uncertainty costs, regulatory factors limit the decision scope, market factors shape customer reaction, and environmental and social factors determine the sustainability of the decision. Therefore, any pricing model that ignores one of these dimensions will explain only part of the real problem.

Analysis of Economic and Financial Factors

The examination of qualitative data showed that one of the most important dimensions of pricing is the ability of the tariff to cover the life-cycle costs of pipelines. Initial investment cost, operation and energy costs, repair and maintenance, depreciation, capital cost, and discount rate are among the most important variables in this section. Additionally, unused capacity has an opportunity cost because part of the network capacity that is not utilized loses the possibility of generating revenue or providing service to other customers. Accordingly, the economic analysis of the model was based on the premise that the tariff should be able to establish a balance between cost recovery, achieving

After reviewing, merging, and refining the initial codes, the factors affecting pricing were classified into six main themes. These themes are: economic and financial factors; technical and operational factors; risk, safety, and resilience; regulatory, legal, and contractual factors; market, demand, and competition; and environmental and social sustainability. These six themes collectively form the content framework of the pipeline pricing decision.

appropriate returns, and maintaining the economic attractiveness of the service for the customer.

On the other hand, the results showed that increasing tariffs does not necessarily lead to unlimited increase in revenue or profit, because customers may reduce their demand volume or turn to alternative transportation methods in reaction to price increases. Therefore, the relationship between tariff and profit is not direct and simple, and the effect of price on demand must also be considered simultaneously.

Analysis of Technical and Operational Factors

In the technical dimension, nominal network capacity is not a sufficient criterion for capacity evaluation, and practical capacity, reliable capacity, congestion, bottlenecks, and emergency reserve capacity must also be entered into decision-making. Additionally, indicators such as transmission continuity, downtime, pressure stability, product quality, delivery time, and guaranteed service level were included in the analysis. These factors indicate that the customer does not merely pay for "transferring a specific volume of product" but also values receiving a service with a certain level of reliability and quality.

From this perspective, the tariff under conditions where the network faces excess capacity can have a different structure compared to congestion conditions. When demand approaches the practical capacity of the network, the value of capacity increases, and therefore, capacity-based and dynamic strategies become more important. This issue was also observed in the quantitative model results, and in demand increase scenarios, the role of dynamic and combined strategies increased.

Analysis of Risk, Safety, and Resilience

In the thematic analysis stage, a set of technical, operational, financial, and market risks were identified. Leakage and rupture, corrosion, fire, equipment failure, human error, theft, and sabotage, along with risks of demand reduction, customer default, regulatory changes, energy price fluctuations, and payment delays were among the influencing risks. In addition to accident probability, consequence severity and network recovery capability were also considered in risk assessment.

Accordingly, risk was entered into the quantitative model as one of the main goals, and risk reduction was pursued alongside profitability and service level. This approach prevented the final solution from being directed solely toward routes and tariffs with maximum profit, but also incorporated network reliability and resilience into the decision-making process.

Analysis of Regulatory and Contractual Factors

The results of qualitative analysis showed that the tariff decision in the oil and gas industry environment is influenced by a set of legal and regulatory constraints. Non-discrimination among customers, tariff transparency and auditability, third-party access, tariff ceilings and floors, and legal requirements were among the most important factors in this area. Additionally, contract characteristics including contract duration, minimum volume commitment, Pay-or-Take mechanism, payment guarantee, risk allocation, and dispute resolution mechanism can affect the operator's revenue risk and customer behavior.

In the quantitative model, these factors were entered as constraints, parameters, and components related to fairness and regulation. This caused the optimal solution to be determined not merely based on the operator's profit but to

be placed within a range compatible with regulatory and contractual requirements.

Analysis of Market, Demand, and Competition

One of the important findings of data analysis was the determining role of demand and price elasticity in pipeline pricing. In the model, customer demand was considered as a function of the effective tariff. Therefore, increasing tariffs can reduce demand, and reducing tariffs, if it increases transmission volume, does not necessarily lead to reduced profit. This issue indicates that tariff determination must be accompanied by an understanding of customer behavior and market conditions.

Furthermore, the existence of alternative transportation methods, the cost of switching transportation methods, and the customer's perceived value of pipeline reliability affect the degree of demand sensitivity. Consequently, pricing strategy must consider not only the operator's costs but also the available options for the customer and the cost of switching between transportation methods.

Analysis of Environmental and Social Factors

In the sustainability section, factors such as carbon emissions, energy consumption, soil and water pollution, leakage risk, local community safety, employment, regional justice, and transparency with stakeholders were identified. These factors indicate that pipeline pricing has consequences beyond the economic relationship between operator and customer.

In the fuzzy goal programming model, environmental effects were considered as one of the goals. Thus, the final solution must maintain an acceptable level of environmental performance alongside economic and operational objectives.

Conversion of Qualitative Results into Mathematical Model Structure

After extracting the themes, the qualitative findings were organized into four main groups: objectives, hard constraints, parameters, and decision variables. Objectives represented desirable states that the model attempted to approach as much as possible. Hard constraints were conditions that all feasible solutions must satisfy. Parameters formed the environmental, economic, and technical data of the model, and decision variables were values that the model determined to achieve an appropriate solution.

Table 3

Mapping of Qualitative Findings to Mathematical Model Structure

Qualitative Finding	Type of Entry into Model	Sample Variable/Indicator
Cost recovery	Objective	Total cost
Profitability	Objective	Revenue and profit
Capacity utilization	Objective	Utilization rate
Risk reduction	Objective	Risk index
Tariff fairness	Objective	Inequality index
Service level	Objective	Reliability index
Environmental effects	Objective	Environmental impact index
Network capacity	Constraint/Parameter	Nominal and practical capacity
Flow balance	Constraint	Inflow and outflow
Tariff ceiling	Constraint	Maximum allowable tariff
Demand	Parameter/Function	Customer demand
Base tariff	Decision variable	Transmission tariff
Fixed and variable tariff	Decision variable	Tariff components
Volume discount	Decision variable	Discount rate
Penalty	Decision variable	Over-ceiling penalty
Capacity allocation	Decision variable	Allocated volume

This table represents the link between the qualitative stage and the quantitative stage of the research. In other words, the mathematical model was not designed independently of the field findings; rather, its main variables were formed from the concepts extracted from interviews with experts.

Fuzzy Goal Programming Analysis

To resolve the conflict among different objectives, the fuzzy goal programming model was implemented. In this

model, each objective has a desirable level and a tolerable level, and the degree of achievement of the objective is measured by a fuzzy membership function. The model then seeks a solution that maximizes the minimum satisfaction level among all objectives. This method allows, instead of focusing on a single objective, a set of economic, technical, risk, market, regulatory, and sustainability objectives to be simultaneously considered in the decision.

Table 4

Main Objectives

Objective	Optimization Direction	Interpretation
Total cost	Minimization	Reducing transmission costs
Profit	Maximization	Creating economic return
Risk	Minimization	Reducing operational and market risk
Environmental effects	Minimization	Reducing adverse effects
Service level	Maximization	Increasing reliability
Capacity utilization	Maximization	Effective use of network
Tariff fairness	Maximization	Reducing tariff inequality
Revenue	Maximization	Ensuring sustainable revenue

Fuzzy Goal Programming Model

As observed, the model objectives have different natures and sometimes conflict with each other. For example, increasing profit can be accompanied by increasing tariffs, while increasing tariffs may reduce tariff fairness or customer demand. Also, increasing capacity utilization may increase operational pressure and risk. For this reason, the use of the fuzzy multi-objective method enables the creation of a compromise solution.

Overall, the results of the base model implementation showed that the compromise solution has an overall quality of 0.902 and a minimum satisfaction degree of 0.84. In this solution, total cost was 111.9, revenue was 263.5, and profit was 151.6. Also, the risk index was 0.31, environmental impact index was 65.4, service level was 0.97, capacity utilization was 0.93, and tariff inequality index was 0.11.

Table 5

Results of the Base Fuzzy Goal Programming Solution

Indicator	Value
Overall solution quality	0.902
Minimum satisfaction degree	0.84
Total cost	111.9
Revenue	263.5
Profit	151.6
Risk index	0.31
Environmental impact index	65.4
Service level	0.97
Capacity utilization	0.93
Tariff inequality index	0.11

The base solution shows that the model was able to establish a kind of balance among conflicting objectives. Service level and capacity utilization are at a high level, while profit and revenue are also maintained at an appropriate level. In contrast, tariff fairness has a lower membership degree than some objectives, indicating the existence of a trade-off between economic objectives and tariff fairness. Therefore, the model result should be considered a compromise solution rather than a solution that brings each objective to its best possible value independently.

Comparison of Different Pricing Strategies

To evaluate the model's performance, different pricing strategies including cost-based, value-based, capacity-based,

dynamic, two-part, and combined regulated strategies were examined. Comparison of results showed that each strategy has a different consequence on cost, profit, risk, service level, and satisfaction level. The cost-based strategy is more focused on cost coverage, while the value-based strategy considers the perceived value of service for the customer. The capacity-based strategy is more sensitive to capacity constraint and congestion conditions, and the dynamic strategy enables reaction to demand changes and network conditions. The two-part strategy, by combining fixed and variable components, enables a balance between the operator's fixed revenue and volume-dependent cost.

Table 6

Comparison of Pricing Strategy Results

Strategy	Service Level	Risk	Profit	Cost	Overall Satisfaction
Cost-based	Different	Different	Different	Lower	Different
Value-based	Different	Different	Different	Different	Different
Capacity-based	Different	Different	Different	Different	Different
Dynamic	Different	Different	Different	Different	Different
Two-part	Different	Different	Different	Different	Different
Combined regulated	0.97	0.31	151.6	111.9	0.91

Comparison of strategies shows that no strategy can be evaluated independently of operational, market, and regulatory conditions. The combined regulated strategy in the sample model was able to provide a combination of economic, operational, and risk objectives in the form of a compromise solution. Therefore, the combined structure can be used as a framework for tariff flexibility, provided that its parameters are calibrated with the actual data of each network and the actual conditions of contracts.

Analysis of Demand, Capacity, and Energy Cost Scenarios

To examine the stability of results, different scenarios including demand increase, capacity reduction, and energy cost and risk increase were examined. The results showed that changing environmental conditions can alter the performance of pricing strategies. In the demand increase scenario, profit increased to 164.2, but service level decreased to 0.96 and the risk index reached 0.34. In the capacity reduction scenario, profit was 136.5, service level

was 0.91, and risk was 0.39. Also, in the energy cost and risk increase scenario, profit decreased to 128.9.

Table 7

Scenario Analysis Results

Scenario	Risk	Service Level	Profit	Interpretation
Base state	0.31	0.97	151.6	Balance among objectives
Demand increase	0.34	0.96	164.2	Increased revenue with greater pressure on network
Capacity reduction	0.39	0.91	136.5	Increased constraint and reduced service level
Energy cost and risk increase	—	—	128.9	Increased cost and risk pressure

Demand increase creates the opportunity to increase profit on one hand but exerts more pressure on network capacity on the other. Capacity reduction also increases constraints and reduces service level. Energy cost and risk increase also puts pressure on profit margins. Therefore, pricing strategy must have the ability to adapt to different scenarios and should not be designed based on the conditions of a single period.

Sensitivity Analysis with Respect to Demand Changes

The results of sensitivity analysis showed that change in demand volume is one of the factors affecting model performance. With increasing demand, there is the possibility of increasing profit and revenue, but at the same time, network capacity is under more pressure, and service level and minimum satisfaction degree can decrease. With a

20% increase in demand, the minimum satisfaction degree decreased to 0.82. This result indicates that demand growth without proportionate capacity development may lead to reduced service quality and increased operational pressure.

Sensitivity Analysis with Respect to Objective Weights

Subsequently, the effect of changing objective weights on results was examined. Increasing the weight of cost and profit increased the model's focus on economic performance and, in contrast, led to a relative decrease in fairness. Increasing the weight of risk strengthened the allocation of flow to safer routes but was accompanied by reduced profit. Increasing the weight of service level led to reduced shortage and increased cost, and increasing the weight of tariff fairness reduced tariff dispersion while reducing revenue.

Table 8

Effect of Changing Objective Weights on Model Output

Weight Change	Main Observed Effect	Consequence
Increasing cost and profit weight	Greater focus on economic performance	Increased profit and reduced fairness
Increasing risk weight	Transfer of part of flow to safer routes	Reduced profit
Increasing service level weight	Reduced shortage and increased service capability	Increased cost
Increasing fairness weight	Reduced tariff dispersion	Reduced revenue

Sensitivity analysis of weights shows that the model output depends on the decision-maker's preferences. However, the overall structure of the solution did not completely change with conventional weight changes, indicating the relative stability of the proposed framework. In practical application, determining weights should be done with stakeholder participation and based on the actual priorities of the organization and regulator.

Analysis of Stackelberg Game Theory Results

After determining the compromise solution in the fuzzy model, the Stackelberg framework was used to examine the interactive behavior of actors. In this structure, the pipeline operator as leader first determines the announced tariff. Then

the customer, based on the effective tariff and market conditions, determines their demand quantity, and the regulator limits the operator's behavior by applying the tariff ceiling and penalty. In this framework, the tariff decision becomes an interactive decision, and the final result is a function of the mutual reaction of the operator, customer, and regulator.

In the calculated equilibrium, the announced tariff was 3.4784 and the regulatory tariff ceiling was 3.4074; therefore, the effective tariff for the customer was determined equal to the regulatory ceiling, i.e., 3.4074. The equilibrium demand was 85.9384 units, revenue was

298.9349, and profit was 179.5. Also, consumer surplus was 369.2702 and the social welfare index was 545.7942.

Table 9

Stackelberg Equilibrium Results

Indicator	Equilibrium Value
Announced tariff	3.4784
Regulatory tariff ceiling	3.4074
Effective tariff	3.4074
Equilibrium demand	85.9384
Revenue	298.9349
Profit	179.5
Penalty	0.6049
Consumer surplus	369.2702
Social welfare	545.7942
Capacity utilization	85.94%
Service level	92.94%

The results show that the operator's announced tariff was at a level higher than the regulatory ceiling, but the effective tariff for the customer was stabilized at the allowable level due to the regulatory ceiling. This result demonstrates the importance of the regulator's role in limiting the complete transfer of tariff increases to the customer. Also, the operator's profit and revenue in the Stackelberg equilibrium increased compared to the FGP base point, but service level and capacity utilization decreased compared to the base solution. This difference indicates the consequence of entering actors' strategic behavior into the pricing problem.

Table 10

Comparison of FGP Solution and Stackelberg Equilibrium

Indicator	Stackelberg	FGP	Change
Profit	179.5	151.6	Increase
Revenue	298.9349	263.5	Increase
Capacity utilization	85.94%	89%	Decrease
Service level	92.94%	96%	Decrease

As observed, the entry of strategic interaction causes a change in the combination of results. The increase in profit and revenue in equilibrium has occurred along with a relative decrease in utilization and service level. This finding indicates that evaluating a pricing strategy based solely on the economic output of the model is not sufficient, and customer reaction and regulatory constraints must also be examined.

Overall, the analysis of research data showed that pipeline pricing in the oil and gas industry is a multi-objective and multi-actor problem. In the qualitative stage, 109 final codes

Comparison of Fuzzy Solution and Stackelberg Equilibrium

Comparison of the two stages of analysis shows that the FGP solution and Stackelberg equilibrium answer two different questions. The FGP model determines what compromise solution can be created among conflicting objectives if different objectives are considered simultaneously, while the Stackelberg model examines how this solution changes against customer and regulator reactions.

were organized into six main themes, and it was determined that economic, technical, risk, regulatory, market, and sustainability factors simultaneously affect the pricing decision. In the quantitative stage, these factors were converted into objectives, parameters, constraints, and decision variables, and the fuzzy goal programming model enabled the creation of a compromise solution. The base result of the model had an overall quality of 0.902 and a minimum satisfaction degree of 0.84 and included indicators such as profit of 151.6, service level of 0.97, and capacity utilization of 0.93.

In the next stage, scenario and sensitivity analysis showed that changes in demand, capacity, energy cost, risk, and objective weights can alter the combination of results. Demand increase, although increasing profit, exerted more pressure on network capacity; capacity reduction led to reduced service level and increased risk; and energy cost and risk increase put pressure on profit. Finally, Stackelberg analysis showed that the entry of strategic behavior of the operator, customer, and regulator can change the pricing result compared to the initial multi-objective solution. Therefore, the final data analysis confirms that to evaluate pipeline pricing strategies, the combination of expert qualitative analysis, fuzzy goal programming, scenario writing, sensitivity analysis, and game theory can provide a more comprehensive picture of decision consequences.

4. Discussion and Conclusion

The present study evaluated pipeline pricing strategies in Iran's oil and gas product logistics by integrating qualitative thematic analysis, fuzzy goal programming, scenario and sensitivity analysis, and Stackelberg game theory. The findings confirmed that pipeline pricing cannot be adequately understood as a simple cost-recovery decision because economic and financial considerations operate simultaneously with technical and operational conditions, risk and resilience, legal and regulatory requirements, market and demand characteristics, and environmental and social sustainability. In the qualitative phase, 109 final codes were classified into six overarching themes, demonstrating the multidimensional character of pipeline pricing decisions. In the quantitative phase, these dimensions were translated into conflicting objectives and constraints, and the fuzzy goal programming model produced a compromise solution with an overall quality of 0.902 and a minimum satisfaction degree of 0.84. The combined regulated pricing strategy showed the greatest compatibility with the multiple objectives incorporated into the model, while subsequent Stackelberg analysis demonstrated that the entry of customer responses and regulatory constraints altered the economic and operational outcomes of the initial optimization solution. These findings collectively reinforce the proposition that the evaluation of pipeline tariffs requires simultaneous consideration of system-wide objectives and strategic stakeholder behavior rather than reliance on a single financial or operational criterion.

One of the principal findings was that economic and financial factors constitute a fundamental but insufficient

basis for pipeline pricing. The qualitative results identified investment expenditures, operating costs, energy costs, repair and maintenance, depreciation, cost of capital, and opportunity costs associated with unused capacity as important determinants of tariffs. At the same time, the analysis showed that increasing tariffs does not necessarily generate a proportional increase in profitability because higher prices may reduce demand or encourage customers to consider alternative transportation arrangements. This finding corresponds with the broader pricing literature, which emphasizes that effective pricing requires attention to demand responses and organizational objectives in addition to cost recovery (Abdollahi & Ostadi, 2020). Similarly, research on price- and time-dependent demand demonstrates that customer responses can change the economic consequences of alternative pricing structures (Bahrami et al., 2022). In the context of gas supply through pipeline networks, the integration of network optimization with feasibility analysis has likewise demonstrated that transportation infrastructure and operating conditions affect commercially sustainable selling prices (Nurprihatin et al., 2021). The present results therefore support a transition from purely accounting-based tariffs toward pricing mechanisms that incorporate costs, demand elasticity, capacity utilization, and the economic value of transmission services.

The importance of capacity constraints represented another significant finding. The results indicated that nominal pipeline capacity alone is insufficient for tariff evaluation because practical capacity, reliable capacity, congestion, bottlenecks, reserve requirements, and actual utilization determine the economic value of network access. This interpretation is consistent with evidence that pipeline capacity scarcity can generate substantial price differentials and economic consequences when available transportation infrastructure is insufficient relative to demand (Walls & Zheng, 2020). It is also aligned with recent optimization research demonstrating that uncertainty in gas flows and entry-exit capacity utilization substantially affects transmission decisions (Markhorst et al., 2026). Barforoushi et al. further demonstrated that constraints in gas transmission infrastructure influence market interactions and congestion outcomes (Barforoushi et al., 2021). Accordingly, the current study's finding that capacity-based and dynamic strategies became more prominent when demand increased and the network approached capacity limits has a strong conceptual basis: as spare capacity declines, the opportunity cost of network utilization

increases and a uniform tariff becomes progressively less capable of reflecting actual system conditions.

The findings concerning risk, safety, and resilience further indicate that transmission tariffs should incorporate the economic consequences of uncertainty and disruption. The qualitative analysis identified leakage, rupture, corrosion, fire, equipment failure, human error, theft, sabotage, demand reduction, customer default, regulatory change, and energy-price fluctuations as relevant sources of risk. These results are consistent with previous research identifying complex and interdependent risks across gas transmission supply chains (Fathi & Abbasian, 2020). They also align with findings that risk management in Iran's gas-industry supply chain requires attention to external, operational, organizational, and transmission-related sources of uncertainty (Safavi Mir Mahalleh et al., 2020). The relevance of fuzzy approaches in the present study is further supported by research showing that fuzzy inference systems are appropriate for incorporating ambiguous and qualitative information into the assessment of sour-gas pipeline risks (Raei Haghi et al., 2023). Moreover, risk-based pricing research demonstrates that accident probability, damage severity, and safety-control quality have direct implications for financial valuation (Payandeh & Atatalab, 2020). These converging findings indicate that risk-related expenditure should not be interpreted as an external technical issue but as part of the economic architecture of sustainable pipeline service provision.

The emphasis on resilience also agrees with previous energy supply-chain research. The current study showed that a pricing strategy should support reliability, reserve capacity, maintenance, and the ability to recover from disruption rather than simply maximize current-period revenues. This observation is consistent with research demonstrating that disruption uncertainty should be explicitly incorporated into the design of sustainable and resilient gasoline supply-chain networks (Khalili et al., 2022). Soheili similarly emphasized agility, information technology, financial resources, and risk-management capabilities as determinants of resilience in the South Pars Gas Complex (Soheili, 2021). Research employing the lean-agile-resilient-green perspective has additionally shown that resilience must be integrated with sustainability and competitive supply-chain management in oil and gas operations (Hosseinzadeh et al., 2022). From this perspective, the inclusion of risk minimization and service-level maximization within the fuzzy goal programming model represents an important feature because pricing

mechanisms that systematically underfund maintenance or resilience may improve short-term financial indicators while deteriorating long-term network performance.

The technical and operational results also demonstrated that pricing should reflect service quality rather than transportation volume alone. Continuity of transmission, pressure stability, product quality, delivery time, downtime, and reliability were identified as important components of service value. This finding is especially important in capital-intensive networks where customers depend on uninterrupted energy flows for their own production processes. Advances in predictive maintenance provide further support for this interpretation. The application of deep reinforcement learning to natural-gas transmission pipeline maintenance illustrates how optimized maintenance policies can influence reliability, failures, and network performance (Sampaolesi, 2025). At the same time, digitalization introduces additional vulnerabilities, particularly advanced cyber threats directed against critical energy supply chains (Petruolo, 2025). Thus, the tariff required to maintain a reliable contemporary pipeline network includes not only traditional repair and operating expenditure but also investments in monitoring, predictive maintenance, digital infrastructure, cybersecurity, and recovery capability.

Another important finding concerned regulatory and contractual factors. The study identified tariff ceilings and floors, nondiscrimination, third-party access, transparency, contractual duration, minimum-volume commitments, payment guarantees, Pay-or-Take arrangements, risk allocation, and dispute-resolution mechanisms as factors constraining or shaping pricing decisions. These findings are compatible with research on floating-price mechanisms in Iranian gas export contracts, which highlights the importance of transparent and calculable price-adjustment formulas (Ghasemi Javid et al., 2021). They are also consistent with findings concerning third-country access to the European gas market, where tariff transparency, third-party access requirements, regulatory independence, and structural market rules constitute important conditions for participation (Ghanbari Bonab et al., 2023). Studies of international pipeline contracts similarly demonstrate that infrastructure development requires appropriate contractual allocation of responsibilities and risks (Piri et al., 2019). The results therefore indicate that tariff design and contractual design should be treated as interconnected mechanisms. A tariff may be economically efficient in isolation but become impractical when contractual commitments, access rules,

regulatory ceilings, or payment-risk allocation are considered.

Technological changes in contracting also support the need for greater transparency and adaptability in pricing mechanisms. Smart contracts have been proposed in the oil, gas, and petrochemical sectors as instruments capable of improving traceability, reducing transaction frictions, and facilitating contract execution (Mohammadi, 2023). Although the present study did not specifically model smart-contract implementation, its emphasis on transparent tariff structures, enforceable commitments, penalties, and regulatory constraints is consistent with a broader transition toward more automated and auditable contractual arrangements. Such mechanisms may become particularly valuable where dynamic pricing, volume commitments, capacity allocation, and deviation penalties must be implemented consistently among multiple actors.

A particularly important quantitative result was the existence of trade-offs among the model objectives. The fuzzy goal programming solution achieved an overall quality of 0.902 and minimum satisfaction of 0.84, with total cost of 111.9, revenue of 263.5, profit of 151.6, risk index of 0.31, environmental impact index of 65.4, service level of 0.97, capacity utilization of 0.93, and tariff inequality index of 0.11. These findings demonstrate that no pricing strategy simultaneously optimizes every objective. Increasing the emphasis on cost and profit improved economic performance but reduced fairness; giving greater weight to risk shifted flows toward safer routes but decreased profit; emphasizing service increased costs; and prioritizing tariff fairness reduced revenue. This multidimensional conflict accords with research on global optimization and game-theoretic approaches to supply-chain operations under uncertainty, which demonstrates that operational decisions frequently require compromises among competing objectives and actors (Marousi, 2025). The results are also compatible with pipeline pricing and logistics research showing that tariff design must address both logistical efficiency and the distribution of profits among participants (Qiu et al., 2023).

The superiority of the combined regulated strategy within the study model should therefore be understood as the consequence of its ability to accommodate several objectives rather than maximize one isolated indicator. Cost-based pricing may be comparatively straightforward and useful where costs are stable and capacity constraints are weak, whereas value-based, capacity-based, dynamic, and two-part approaches respond to different market or operational

conditions. The combined strategy permits the tariff structure to adjust to several of these considerations while remaining within regulatory constraints. This interpretation is compatible with research emphasizing the strategic role of competitive conditions and appropriate pricing for strengthening Iran's participation in regional gas markets (Aghamoosi et al., 2021). It also corresponds with studies of petrochemical feedstock pricing that identify competing stakeholder interests, changing regulations, and economic conditions as central difficulties in designing pricing policy (Zarei et al., 2023). Accordingly, the present findings do not imply that one tariff structure should be universally imposed across all pipelines, products, or periods; rather, they support a regulated framework within which the tariff composition can adapt to actual network and market conditions.

The scenario analysis provided additional evidence for this need for adaptability. Under increased demand, profit increased from 151.6 to 164.2, but the risk index increased from 0.31 to 0.34 and the service level declined from 0.97 to 0.96. When capacity was reduced, profit declined to 136.5, service level fell to 0.91, and risk increased to 0.39. Under higher energy costs and risk, profit declined further to 128.9. The sensitivity analysis likewise showed that a 20% increase in demand reduced the minimum satisfaction degree to 0.82. These results demonstrate that demand growth cannot automatically be interpreted as an improvement in system performance because higher throughput can intensify congestion and operational pressure when capacity is not expanded proportionately. This finding is consistent with the economic importance of capacity constraints identified by Walls and Zheng (Walls & Zheng, 2020) and the uncertainty of capacity utilization emphasized by Markhorst et al. (Markhorst et al., 2026). It also supports the broader logistics argument that efficient energy infrastructure requires coordination among routing, capacity, operational resources, and costs (Çali, 2026). Therefore, pricing and capacity-development decisions should be coordinated rather than treated as independent managerial processes.

Environmental and social considerations constituted another meaningful component of the results. The qualitative analysis identified emissions, energy consumption, pollution, leakage, community safety, regional justice, and environmental responsibility as relevant dimensions of pricing evaluation. This finding reinforces the sustainable supply-chain perspective in which environmental objectives are incorporated into strategic and operational decisions rather than added after economic optimization (Hosseinzadeh et al., 2022). It is also consistent with the

broader geographical and security significance of Iranian oil and gas transmission infrastructure demonstrated by spatial-security analyses of energy pipelines (Amiri et al., 2014). Consequently, tariffs that provide insufficient resources for environmental management, safety improvements, asset integrity, or infrastructure adaptation may transfer costs from the operator to society even when they appear economically attractive at the firm level.

Perhaps the most distinctive result emerged from the Stackelberg analysis. The operator announced a tariff of 3.4784, whereas the regulatory ceiling was 3.4074, causing the effective tariff to remain at 3.4074. Equilibrium demand was 85.9384 units, revenue was 298.9349, profit was 179.5, consumer surplus was 369.2702, and social welfare was 545.7942. Compared with the fuzzy-goal-programming solution, strategic interaction increased profit and revenue but reduced capacity utilization and service level. This finding illustrates that a technically optimal multi-objective solution can change once actual stakeholder reactions are introduced. The result is consistent with research emphasizing strategic interaction in uncertain supply-chain operations (Marousi, 2025) and with evidence that pipeline constraints and interacting markets can materially affect prices and resource allocation (Barforoushi et al., 2021). It also complements Qiu et al.'s emphasis on linking pipeline pricing with logistics planning and profit distribution among supply-chain participants (Qiu et al., 2023). The implication is that tariff optimization without behavioral modeling may overstate the stability of the selected strategy.

The Stackelberg results additionally clarified the regulator's role. Because the announced tariff exceeded the ceiling, regulation prevented the entire proposed price increase from being transferred to customers. At the same time, the results indicated that the ceiling and penalty structure influence the operator's incentives and thus require careful calibration. Excessively weak regulation may permit tariffs to diverge from broader system objectives, while excessively restrictive regulation may weaken incentives for investment, maintenance, or capacity development. This result aligns with the emphasis on transparent and balanced regulatory arrangements in gas markets (Ghanbari Bonab et al., 2023) and with the need for legally coherent price-adjustment mechanisms (Ghasemi Javid et al., 2021). Moreover, the economic importance of reliable gas supply demonstrated by estimates of the consequences of natural-gas imbalance in Iran suggests that regulatory tariff design should account not only for customer prices but also for the

long-term ability of the infrastructure to provide reliable transmission (Rajabi & Sadeghi Shahdani, 2025).

Overall, the findings indicate that pipeline pricing in Iran's oil and gas logistics should be conceptualized as a coordinated system of economic valuation, operational planning, risk management, capacity allocation, contractual governance, regulation, and sustainability management. The principal contribution of the study is therefore the integration of qualitative expert knowledge, multi-objective fuzzy optimization, scenario and sensitivity analysis, and strategic game-theoretic interaction within a single analytical framework. The combined regulated pricing approach demonstrated the ability to maintain relatively high service and capacity utilization while balancing profitability, risk, environmental considerations, and regulatory requirements. Nevertheless, the results also show that any tariff generated through optimization remains conditional on customer behavior, capacity conditions, risk, cost changes, and regulatory intervention. Pipeline pricing should consequently be treated as an adaptive decision-support process rather than a fixed administrative calculation.

The present study has several limitations that should be considered when interpreting its findings. First, the qualitative phase was based on the perspectives of 30 academic and industry experts, and although these participants possessed relevant expertise, their judgments may not encompass the full diversity of views across Iran's oil and gas transmission sector. Second, the quantitative model was calibrated using the data and parameter assumptions available for the case study of Payandan Company; therefore, numerical outputs such as optimal tariffs, demand levels, profit, social welfare, and capacity utilization should not be generalized directly to all national pipeline networks. Third, the Stackelberg framework necessarily simplified the behavior of market actors by representing the pipeline operator, customer, and regulator within a defined leader-follower structure and by employing a specified demand function. Real markets may contain multiple heterogeneous customers, competing operators, nonlinear demand responses, changing contractual relationships, and political or institutional influences that are more complex than those incorporated into the model. Finally, some uncertainty was represented through fuzzy objectives and scenario analysis rather than through complete probabilistic distributions, and the model did not comprehensively incorporate every possible disruption, technological change, capital-budget constraint, or long-term infrastructure-development decision.

Future studies should validate the proposed framework using actual operational, financial, contractual, and demand data from several pipeline operators and geographical regions in Iran to assess its external validity and determine whether strategy performance changes across different network structures. Researchers should also estimate demand elasticity econometrically using historical transmission volumes, tariffs, competing road and rail transportation prices, product characteristics, and customer-specific contractual information instead of relying primarily on calibrated demand parameters. The game-theoretic framework could be extended to include multiple heterogeneous customers, several competing transmission operators, alternative modes of transport, and regulatory institutions with different objectives. Future studies could additionally employ nonlinear demand functions, stochastic and robust optimization, distributionally robust models, dynamic games, agent-based simulation, or multi-period investment models to represent uncertainty and behavioral adaptation more realistically. Integrating infrastructure expansion decisions, maintenance scheduling, cyber-risk exposure, carbon costs, climate resilience, and technological modernization into the pricing model would also provide a more comprehensive representation of long-term pipeline economics.

For practical application, pipeline operators and regulatory authorities should establish an integrated tariff decision-support system that continuously incorporates operating and maintenance costs, reliable capacity, congestion, demand elasticity, service-level indicators, safety and risk information, contract conditions, environmental indicators, and regulatory constraints. Rather than applying a single uniform tariff to all lines, products, customers, and periods, decision makers should evaluate cost-based, capacity-based, dynamic, two-part, and combined components according to actual operating conditions and transparent regulatory rules. Tariff revision should be coordinated with maintenance planning and capacity-development decisions so that growing demand does not reduce reliability or intensify bottlenecks. Regulators should jointly calibrate tariff ceilings, penalties, service-quality requirements, and investment incentives to balance customer protection with the operator's ability to maintain and develop infrastructure. Finally, operators should periodically conduct scenario and sensitivity analyses before implementing tariff changes and should involve customers, technical specialists, financial managers,

contract experts, environmental specialists, and regulators in determining the relative importance of pricing objectives.

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

Data are available for research purposes upon reasonable request to the corresponding author.

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Declaration of Interest

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