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Navigating uncertainty in global gas trading: Leveraging cost optimization models within supply chain dynamics

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The impact of geopolitical conflict and supply chain (SC) uncertainties in the global gas trading context is a burgeoning area of research. The strategic imperative of optimizing resource and technology utilization through cost optimization models within SC dynamics is realized. This study examines the effectiveness of linear programming techniques in mitigating the transportation challenges in the landscape of global gas trade, particularly amidst geopolitical disruptions in the SC. Computational tests underscore the substantial efficiency gains provided by this method, highlighting its capacity to generate significantly more efficient solutions to transportation problems. The findings indicate that the model shows promise for practical implementation, showcasing a notable reduction in transportation costs across the three primary markets for liquefied natural gas (LNG). Significantly, this reduction surpasses a quarter of the original expenses, indicating the potential for substantial cost savings in turbulent geopolitical environments and uncertain SCs. This study emphasizes the pivotal role of cost optimization models in navigating uncertainty and enhancing efficiency within the intricate and volatile landscape of global gas trading supply chains.

1. Introduction

The cost optimization models are multi-period numerical equilibrium models of the global natural gas market covering the next three decades (Yu et al., 2022). These models have been widely applied in the natural gas SC to improve efficiency and profitability (Li et al., 2019). These models consider various factors, such as supply security, demand fluctuations, and transportation mechanisms, to find the optimal purchase and sales strategies (Bazmi & Zahedi, 2011). This involves analyzing the entire SC engaged in the production, transportation, and distribution of natural gas to identify areas where costs can be reduced without compromising the overall effectiveness of the SC(Kan et al., 2020). Optimizing trade structures in the global gas trading context is crucial to ensure cost-effectiveness and competitiveness in the market (Alsmairat, 2021; Alsmairat et al., 2022). Implementing optimization models in the complex network enables cost reductions in crude oil trade, which can be extrapolated to natural gas trading scenarios (Dong et al., 2021). Furthermore, integrating power-to-gas technology and carbon trading mechanisms in energy systems optimization models highlights the significance of considering economic benefits, operating costs, and carbon trading costs in achieving overall cost efficiency (Sun et al., 2022). Natural gas is considered a cleaner energy source in the twenty-first century due to its lower greenhouse gas emissions than other fuels, making it a more environmentally friendly option concerning air quality and climate impact (Raza et al., 2023). During the past decades, natural gas has experienced rapid growth and is projected to continue expanding as global demand for clean energy increases (Aczel, 2022). The International Energy Agency forecasts a 0.8% annual growth rate in global natural gas consumption from 2022 to 2025, with the industrial sector being a significant driver, accounting for nearly sixty percent of the rise in demand (Kondratov, 2022). However, the recent constraints on natural gas supply, exacerbated by geopolitical

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conflicts like Russia's Ukraine disputes, have pressured its usage (Lambert et al., 2022). This situation has prompted a need for diversification in gas providers to meet future demands efficiently. The search for alternative gas sources with shorter distances and lower transportation costs has become imperative for ensuring a stable and reliable SC (Wiertz et al., 2023).

To address these challenges, optimization models can offer valuable insights and integrate a multi-objective optimization approach. Considering factors such as transportation costs and SC resilience can help navigate the complexities of global gas trading while ensuring a reliable and efficient SC network. Therefore, this study aims to RO1: Examine and analyze the present natural gas market, focusing specifically on LNG trade dynamics, RO2: explore the viability of identifying alternative gas suppliers that offer expedited supply timelines and decreased delivery expenses, RO3: formulate a transportation model that can efficiently deliver LNG to select destinations at minimized costs.

2. Literature Review

Energy-sustaining modern economies have been a topic recently (Al-Shetwi, 2022; Khan et al., 2022; Perez & Perez, 2022). It plays a vital role in ensuring the efficient functioning of a nation's economy, with interruptions in supply posing significant risks of societal disruption and deprivation of essential services such as heating and electricity. Renewable energy sources have garnered attention for their potential contributions to energy security, social and economic development, climate change mitigation, and environmental sustainability (Olabi & Abdelkareem, 2022) and emphasized that innovative business models can directly lead to promoting energy independence and resilience in the face of supply challenges. Furthermore, scholars who have explored energy consumption, economic growth, and renewable energy have pointed out the importance of securing cost-effective and uninterrupted energy supplies for sustainable development(Jayachandran et al., 2022; Yadav et al., 2020). In terms of global challenges, Pereira et al. (2022) emphasized the significant risks that military conflicts pose to global stability, particularly underscoring the heightened susceptibility of developing nations to economic turmoil resulting from such confrontations. Ostrowski, (2022) provided valuable insights into energy evolution, culminating in their increased potency, as evidenced by recent military actions, such as Russia's incursion into Ukraine. Similarly, (Mohammed et al., 2023) conducted a thorough analysis of the renewable energy sector's response to the Ukraine crisis, revealing contrasting disruptions in traditional energy markets post-WWII and the resilience and expansion of renewable energy markets. Additionally, Cebotari (2022) figured out the potential impacts of energy trade sanctions on the European-Russian relationship, emphasizing the economic consequences and possible shifts in global energy trade dynamics. Building upon these scholarly discussions, the empirical research in this study aims to investigate innovative transportation models tailored to address transportation challenges within the energy sector. Specifically, several transportation cost models for optimizing SC operations and enhancing cost efficiency across various industries have been critically discussed in the previous literature. (Sun et al., 2022) proposed an operation optimization model for an integrated energy system considering power-to-gas technology and carbon trading, highlighting the benefits of a low-carbon integrated electricity-gas system. Farag & Zaki, 2024) emphasized the economic and political determinants of trade in natural gas and highlighted the significance of simulation models in shaping competitive behaviors in the gas market. The complex network needed to optimize the global crude oil trade system required structural optimization, especially in the context of gas SC (Oglend et al., 2020). These investigations highlight the significant role of understanding transportation cost models, providing valuable insights for optimizing transport operations and reducing costs in diverse sectors.

Over the recent years, natural gas has emerged as a pivotal energy source for numerous nations worldwide. Technological advancements and liquefaction innovations, coupled with the decline in LNG prices, have spurred an escalation in gas production to meet the escalating demand. Governmental laws and regulations, spanning both domestic and international spheres, wield significant influence over the natural gas market, encompassing exploration, production, consumption, and environmental protection incentives. Global gas production surged to 4036.9 billion cubic meters (bcm) in 2021, a notable increase from 3257.3 bcm in 2011, translating to a steady annual growth rate of 2.4%. Predominantly, North America is the leading contributor to gas production, accounting for approximately 28% of the global output, followed by the Commonwealth countries at around 22%, the Middle East at 18%, and the Asia-Pacific region at 17%. Concurrently, natural gas consumption exhibited an upward trajectory, rising from 3234.0 bcm in 2011 to 4037.5 bcm in 2021, reflecting an average annual growth rate of 2.5%. Natural gas consumption now constitutes over 25% of the global energy consumption. North America emerged as the largest consumer in 2021, representing nearly 26% of the total consumption, followed by the Asia-Pacific region at 23%, the Middle East at 14.3%, and Europe at 14.2%.

Based on the above, implementing advanced cost optimization models in the natural gas industry can streamline production processes, mitigate costs, and enhance SC efficiency, thereby contributing to sustainable energy practices and bolstering energy security in the face of evolving market dynamics.

3. Research Methodology

The transportation model represents a fundamental component of network optimization challenges essential in logistics and SC management networks. In our research, we intend to employ linear programming, a mathematical model designed to determine the optimal strategy for achieving the most favorable outcomes within the transportation industry. The general linear programming formulation of a transportation problem serves as a structured framework:

$$\min z = \sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij}x_{ij}$$

subject to

$$\sum_{j=1}^{n} x_{ij} \le s_i, \quad \text{for} \quad i = 1,\ldots,m$$

$$\sum_{j=1}^{m} x_{ij} \le d_j, \quad \text{for} \quad \mathrm{j} = 1,\ldots,n$$

$$x_{ij} \ge 0, \quad i = 1,\ldots,m \ \text{ and } j = 1,\ldots,n$$

where c_{ij} and x_{ij} represent the cost and the amount of product transferred from location *i* to location *j,* respectively. In addition, d_j denotes the demand for j^{th} location and s_i represents the supply of the i^{th} location.

To solve the transportation model efficiently and determine the minimum cost solution, the North-West Corner Rule, a linear programming technique, will be applied using the QM for Windows Application. This method utilizes the concept of the northwest corner to calculate the most cost-effective shipping routes. The QM for Windows Application will promptly generate the optimal shipping cost by inputting the array values and populating the input table. The North-West corner model is beneficial for managing the movement of goods from multiple sources to various destination points. It assumes a fixed quantity of commodities available at each source and a predetermined number of items required at each destination. This model aims to minimize overall transportation expenses by efficiently scheduling shipments from origins to destinations. Selecting variables from the north to west corner, i.e., from the top to the left corner, aids in identifying a practical solution for the transportation model. Data about LNG demand, supply, and transportation costs were sourced from reputable references such as the Statistical Review of World Energy, the US Department of Energy, the Energy Information Administration (EIA), and statista.com. These sources provide reliable information to support analyzing and optimizing transportation costs in the natural gas industry.

4. Discussion & Analysis

4.1 Economic Analysis

Natural gas prices fluctuate on supply and demand, weather patterns, geopolitical events, and market dynamics. LNG prices, for example, are typically stated as dollars per million BTU (MMBTU). Because of high demand and limited domestic supply, the price of the Pacific Basin is often higher than that of the Atlantic Basin. The price of an assortment of alternative fuels is used to calculate the cost of LNG in European and Asian markets. In contrast, the Henry Hub price is utilized in the North American market. Natural gas is continuously delivered via pipelines, liquified natural gas carriers across oceans, and, occasionally, trucks. The mode of transportation is determined by several factors, such as distance, topography, infrastructure availability, and economic concerns, such as the size of the cargo and the fuel cost. Furthermore, due to the flammability of natural gas, safety and environmental concerns are crucial in its transportation. LNG is frequently transported in massive tankers with capacities ranging from 25,000 to 160,000 cubic meters. The global natural gas trade is dynamic, with supply and demand patterns shifting, new infrastructure being built, and geopolitical events influencing the transit of gas across borders. The trade involves pipeline gas and LNG, which is critical to meeting global energy demand and supporting economic development. Global demand for natural gas and LNG has expanded due to increased gas power generation and LNG simply supplementing pipelines. Many factors, including income, weather, and consumer choices, generally determine demand for natural gas. Trade by pipelines accounts for 49.5% of total gas shipped in 2021, with the biggest exporting countries being the Russian Federation, Norway, the United States, Canada, Turkmenistan, and Algeria. They all shipped roughly 78.9% of global pipeline exports. In 2021, Europe, the United States, Mexico, China, and Canada were among the top importers of pipeline gas, accounting for 82.7% of total imports. On the other hand, the share of LNG demand is increasing over time; whereas demand for LNG was 41.3% of total gas needed globally in 2011, it grew to 50.5% in 2021, growing at a pace of 22.3%. China, Europe, Japan, South Korea, India, and Taiwan were the leading LNG consumers in 2021, accounting for 85.9% of all LNG consumed globally.

4.2 The Transportation Model

Moved Quantities

Our model comprises sixteen-by-sixteen matrices illustrating the volumes of LNG transported in 2021 between the sixteen producing regions and the sixteen consuming regions globally (See Table 1).

Table 1
Quantities of LNG in Billion cubic meters delivered from Sources to Destinations in the American Market

	Japan	China	S. K	India	Taiwan	Spain	France	Turkey	Pakistan	Italy	Belgium	U. K	Brazil	Argentina	Kuwait	Chili	**Total Supply**
Qatar	12.3	12.3	16.1	13.6	6.5	2.4	0.7	0.3	8.1	6.5	3.2	6	0.9	1.4	3.6		**93.9**
Australia	36.3	43.6	12.9	0.4	8.6	0.1											**101.9**
Malaysia	13.9	11.7	5.3	0.1	0.7												31.7
USA	9.6	12.4	12.1	5.6	2.4	5.8	4.3	4.5	1.2	1	0.2	4	8.7	2.2	0.9	3.4	78.3
Nigeria	1.2	2.1	0.9	2	0.8	4.3	3.5	1.5	0.2	0.3			0.1		1.3		18.2
Russia	8.8	6.2	3.9	0.6	2.6	3.3	4.7				1.9	3					35
Indonesia	2.6	6.6	3.3		1.6												14.1
Trinidad		0.6	0.1	0.4	0.2	1.1		0.2		0.2		0.2	0.3	0.1	0.2	0.7	4.3
Oman	2.6	2.2	6.3	1.7	0.6										0.4		**13.8**
Algeria		0.3		0.1		2.1	4.5	6.1		1.3	0.1	0.7			0.1		**15.3**
UAE	1.8	1	0.4	4.9	0.1				0.3						0.3		**8.8**
Egypt						0.4	0.2	1.3		0.3	0.1	0.3					**2.6**
Bruni	5.8	0.9	0.3		0.1												**7.1**
Angola		0.6	0.2	1.4		0.4			0.8				0.1		0.1		**3.6**
Papua New Guiea	4.8	4.5	0.3		2												**11.6**
Peru	0.7	0.2	1.2			0.1	0.1					0.8					**3.1**
Total Demand	**100.4**	**105.2**	**63.3**	**30.8**	**26.2**	**20**	**18**	**13.9**	**10.6**	**9.6**	**5.5**	**15**	**10.1**	**3.7**	**6.9**	**4.1**	443.3

The total amount of liquified natural gas demanded in the American market was about 18 million cubic meters, chiefly by three countries: Brazil, Argentina, and Chili. It was supplied by five countries: Qatar, the United States, Nigeria, Trinidad, and Angola, as shown in Table (1-a).

Table 1-a
Quantities of LNG in Billion cubic meters delivered from Sources to Destinations in the American Market

	Brazil	Argentina	Chili
Qatar	0.9	1.4	
USA	8.7	2.2	3.4
Nigeria	0.1		
Trinidad	0.3	0.1	0.7
Angola	0.1		
Total Demand	10.1	3.7	4.1

Conversely, European market demand surged to 82 million cubic meters in 2021, spearheaded by Spain, France, Turkey, Italy, Belgium, and the United Kingdom. Collectively, these nations accounted for approximately 18.5% of the total global demand. The supply to meet these demands originated from ten distinct countries, with Qatar, Australia, the USA, Nigeria, and Russia emerging as the key suppliers to this market (Table 1-b).

Table 1-b
Quantities of LNG in Billion cubic meters delivered from Sources to Destinations in the European Market

	Spain	France	Turkey	Italy	Belgium	U. K
Qatar	2.4	0.7	0.3	6.5	3.2	6
Australia	0.1					
USA	5.8	4.3	4.5	1	0.2	4
Nigeria	4.3	3.5	1.5	0.3		
Russia	3.3	4.7			1.9	3
Trinidad	1.1		0.2	0.2		0.2
Algeria	2.1	4.5	6.1	1.3	0.1	0.7
Egypt	0.4	0.2	1.3	0.3	0.1	0.3
Angola	0.4					
Peru	0.1	0.1				0.8
Total Demand	20	18	13.9	9.6	5.5	15

Finally, the aggregate volume of LNG requested in the Asian market stood at 343.4 million cubic meters and was predominantly imported by seven nations: Japan, China, South Korea, India, Taiwan, Pakistan, and Kuwait. Together, these countries represented approximately 77.5% of the global demand. The fulfillment of these requisites was sourced from 15 diverse locations, with Qatar, Australia, Malaysia, Russia, and the United States serving as the principal suppliers. These critical suppliers collectively met around 76.9% of the global supply (Table 1-c).

Table (1-c)
Quantities of LNG in Billion cubic meters delivered from Sources to Destinations in the Asian Market

	Japan	China	S. K	India	Taiwan	Pakistan	Kuwait	Total Supply
Qatar	12.3	12.3	16.1	13.6	6.5	8.1	3.6	72.5
Australia	36.3	43.6	12.9	0.4	8.6			101.8
Malaysia	13.9	11.7	5.3	0.1	0.7			31.7
USA	9.6	12.4	12.1	5.6	2.4	1.2	0.9	44.2
Nigeria	1.2	2.1	0.9	2	0.8	0.2	1.3	8.5
Russia	8.8	6.2	3.9	0.6	2.6			22.1
Indonesia	2.6	6.6	3.3		1.6			14.1
Trinidad		0.6	0.1	0.4	0.2		0.2	1.5
Oman	2.6	2.2	6.3	1.7	0.6		0.4	13.8
Algeria		0.3		0.1			0.1	0.5
UAE	1.8	1	0.4	4.9	0.1	0.3	0.3	8.8
Bruni	5.8	0.9	0.3		0.1			7.1
Angola		0.6	0.2	1.4		0.8	0.1	3.1
New G.	4.8	4.5	0.3		2			11.6
Peru	0.7	0.2	1.2					2.1
Demand	100.4	105.2	63.3	30.8	26.2	10.6	6.9	343.4

Source: bp-stats-review-2022-full-report

Kilometers traveled

The distances between the sources and demand destinations are assessed in nautical miles and converted into kilometers using the Sea-Distances.org application, as detailed in Table 2.

Table 2-a
Distances in Kilometers between Sources & Destinations in the American Market

	Brazil	Argentina	Chili
Qatar	8256	8626	13238
USA	8207	8207	5329
Nigeria	3397	4556	7165
Trinidad	3268	4516	3304
Angola	6094	8000	9300

Table 2-b
Distances in Kilometers between Sources & Destinations in the European Market

	Spain	France	Turkey	Italy	Belgium	U. K
Qatar	4657	4414	3840	4262	6277	6626
Australia	10067	9824	8918	9672	11466	11815
Malaysia	7045	6802	6228	6650	8665	9014
Russia	3086	3329	4167	4118	1310	1229

Table 2-c Distances between Sources & Destinations in the Asian Market

	Japan	China	S. K	India	Taiwan	Pakistan	Kuwait
Qatar	6512	5845	6111	1300	5420	870	323
Australia	3919	3742	4131	5918	3704	6370	7089
Malaysia	2493	2069	2328	2878	1645	3330	4266
USA	5152	5708	5230	8165	5920	7978	10840
Russia	12204	11735	12001	7530	11310	7343	8461

Transportation Costs

The transportation costs between sources and demand destinations in the model are estimated using the Capra Energy Group's LNG freight cost calculator. These approximations are based on factors such as tanker capacity, distance traveled, average speed, and port fees. According to the calculations from the LNG freight cost calculator, the anticipated overall transportation costs per MMBtu, utilizing a tanker with a capacity of 160,000 m^3, from sources to demand destinations are projected to be $1,577 (Table 3).

Table 3-a

Transportation cost LNG freight calculator - LNG Total Freight Cost in the American Market ($/MMBtu)

	Brazil	Argentina	Chili
Qatar	6.15	6.15	10.34
USA	3.19	3.19	3.45
Nigeria	2.46	2.46	5.75
Trinidad	2.01	2.01	2.84
Angola	2.28	2.28	5.26

Table 3-b

Transportation cost LNG freight calculator - LNG Total Freight Cost in the European Market ($/MMBtu)

	Spain	France	Turkey	Italy	Belgium	U. K
Qatar	4.55	3.46	3.12	3.69	4.87	4.89
Australia	8.9	7.66	7.04	7.65	9.25	8.94
Malaysia	6.69	5.8	4.9	5.48	7.02	6.73
Russia	8.21	7.3	6.68	7.29	8.88	8.57

Table 3-c

Transportation cost LNG freight calculator - LNG Total Freight Cost in the Asian Market ($/MMBtu)

	Japan	China	S. K	India	Taiwan	Pakistan	Kuwait
Qatar	4.93	4.04	4.64	0.88	4.04	1.03	0.6
Australia	2.91	2.91	3.49	4.64	2.91	5.1	3.8
Malaysia	2.04	2.4	1.76	2.58	2.4	3.03	3.5
USA	7.3	7.93	8.24	6.38	7.93	6.54	6.74
Russia	0.88	1.16	0.89	4.3	1.16	4.46	5.25

Source: Data generated by the author.

5. Discussion of Findings

5.1 The General Model

The Northwest model was employed to ascertain the optimal resolution for the specified transportation quandary. The model's outcome identified the most cost-effective source for each destination, resulting in the lowest overall delivery cost of $1,161 per MMBtu (Table 4).

Table 4

Quantities Delivered & Shipping Cost

	Japan	China	S. K	India	Taiwan	Spain	France	Turkey	Pakistan	Italy	Belgium	U. K	Brazil	Argentina	Kuwait	Chili
Optimal cost = $1,161.22																
Qatar		19.4		30.8	26.2				10.6						6.9	
Australia	75.1	26.8														
Malaysia			31.7													
USA	18.8					20	18	1			5.5	15				
Nigeria										4.6			9.9	3.7		
Russia	3.4		31.6													
Indonesia		14.1														
Trinidad													0.2			4.1
Oman		13.8														
Algeria								10.3		5						
UAE		8.8														
Egypt								2.6								
Bruni		7.1														
Angola		3.6														
Papua New Guiea		11.6														
Peru	3.1															

Source: Data generated by the model.

5.2 The American Market Model

In the American market, the model's analysis reveals that instead of sourcing the entire demanded volume from the initial five suppliers, the needs can be met by just two sources, namely Nigeria and Trinidad. This strategic shift not only reduces the distances traveled but also minimizes transportation costs significantly (Table 4-a).

Table 4-a
American Market Quantities Delivered & Shipping Cost –

Optimal Cost = $45.49 per MMBtu	Brazil	Argentina	Chili
Nigeria	9.9	3.7	
Russia			
Indonesia			
Trinidad	0.2		4.1

5.3 The European Market Model

The model suggests that rather than fulfilling the total demand from the initial ten sources, Europeans should procure all their requirements from just four sources: the United States, Nigeria, Algeria, and Egypt. This strategic adjustment is anticipated to lead to reduced transportation costs and shorter travel distances, as illustrated in Table 4-b.

Table 4-b
European Market Quantities Delivered & Shipping Cost

Optimal Cost= $206.03 per MMBtu	Spain	France	Turkey	Italy	Belgium	U. K
USA	20	18	1		5.5	15
Nigeria				4.6		
Algeria			10.3	5		
Egypt			2.6			

5.4 The Asian Market Model

The analysis of the model in the Asian market reveals that instead of sourcing the complete gas demands from the initial fifteen suppliers as previously identified, Asian nations can satisfy their total requirements by importing from twelve destinations, as depicted in Table 4-c. This strategic shift is expected to lead to reduced transportation costs and shorter travel distances.

Table 4-c
Asian Market Quantities Delivered & Shipping Cost

Optimal Cost = 909.429 per MMBtu	Japan	China	S. K	India	Taiwan	Pakistan	Kuwait
Qatar		19.4		30.8	26.2	10.6	6.9
Australia	75.1	26.8					
Malaysia			31.7				
USA	18.8						
Russia	3.4		31.6				
Indonesia		14.1					
Oman		13.8					
UAE		8.8					
Bruni		7.1					
Angola		3.6					
New G.		11.6					
Peru	3.1						

6. Implications, Limitations and Future Research Directions

The study's findings offer practical implications for the LNG industry by demonstrating the effectiveness of quantitative models, such as the Northwest model, in optimizing transportation costs and sourcing strategies. Implementing the solutions proposed by the models can lead to significant cost savings and operational efficiencies for companies involved in LNG transportation. By streamlining sourcing processes and focusing on key suppliers, the models provide a practical strategy for meeting gas requirements efficiently, which can benefit markets and countries by improving economic efficiency and environmental sustainability. These findings underscore the importance of data-driven decision-making in addressing complex transportation challenges within the energy sector.

In terms of theoretical implications, this study contributes to the theoretical understanding of SC optimization by showcasing the practical application of quantitative models in reducing transportation costs in the LNG. It also highlights the importance of strategic sourcing and SC optimization in enhancing operational efficiency and cost-effectiveness.

A key limitation of the study lies in the validation process, as highlighted in the examination of the differential effects of transportation in SC optimization modeling. While significant differences were found in the predictive abilities of the models, further research may be needed to address potential limitations in the validation process. Future research could explore the integration of carbon emission policies and uncertainty factors into multimodal transport path optimization models. Investigating how different carbon policies impact transportation costs and environmental sustainability could provide valuable insights for policymakers and transport enterprises seeking to optimize their operations while reducing carbon emissions.

7. Conclusion

This study utilized the Northwest model, the American market model, and the European market model to optimize transportation costs in the LNG industry. The findings suggest that by strategically selecting the most cost-effective sources for each region, significant cost savings can be achieved. The use of the QM for Windows software facilitated the evaluation of different scenarios and identified solutions that minimize transportation expenses. The models employed are effective in reducing transportation costs associated with sourcing liquefied natural gas. By consolidating the number of sources and selecting optimal suppliers, the models propose solutions that lower costs and reduce travel distances. This strategic approach is expected to benefit markets and countries by improving economic efficiency and environmental sustainability. The results indicate that implementing the proposed solutions can lead to a substantial reduction in transportation costs, with the model predicting a twenty-seven percent decrease compared to current practices. By streamlining the sourcing process and focusing on key suppliers, the models offer a practical strategy for meeting gas requirements efficiently. Overall, the study highlights the importance of utilizing quantitative models to optimize SC decisions in the LNG. By leveraging data-driven approaches and strategic analysis, companies and markets enhance their operational efficiency, reduce costs, and contribute to environmental conservation. The findings underscore the potential benefits of adopting a systematic and analytical approach to address transportation challenges in the energy sector.

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