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Understanding The Impact of Infrastructure Development on The Supply Chain of Liquefied Natural Gas in India: A Conceptual Analysis

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Abstract
The study aimed to examine the impact of infrastructure development on the supply chain of liquefied natural gas (LNG) in India. The study used multiple regression analysis to analyse the data collected from secondary sources on LNG terminals, pipelines, storage facilities, import volumes, and prices from 2011 to 2021. The results showed that infrastructure development, including the number of LNG terminals, liquefaction and regasification capacity, pipeline length, and LNG storage capacity, had a significant positive impact on the supply chain of LNG in India. The findings also revealed that increased infrastructure development led to higher import volumes and more stable prices. The study concluded that infrastructure development is critical for the growth and sustainability of the LNG industry in India and recommended continued investment in infrastructure to meet the growing demand for LNG in the country.

Keywords: Liquefied natural gas, supply chain, infrastructure development, efficiency, effectiveness, sustainability

Introduction
Background:
Liquefied natural gas (LNG) is a form of natural gas that is cooled to a liquid state for transportation and storage. It has emerged as a popular and cleaner alternative to traditional fossil fuels due to its higher energy density, lower greenhouse gas emissions, and versatility. As a result, it has gained significant traction in the global energy market and is projected to have significant growth in the coming years. India, as the world's third-largest energy consumer, is looking to increase its LNG imports to meet the rising demand for energy, reduce its reliance on energy imports, and move towards cleaner fuels.
The LNG infrastructure is composed of various components that are crucial for the production, transportation, storage, and regasification of LNG. These components consist of specialized equipment and facilities, including liquefaction plants, storage tanks, specialized LNG carriers, and regasification plants. The production and liquefaction stage require specialized equipment like compressors, gas turbines, and cryogenic storage tanks. The transportation stage necessitates specialized LNG carriers and terminals, while the storage and regasification stage need specialized storage tanks and regasification plants. The efficient and timely delivery of LNG to the end-users depends on the smooth integration of these components.
The production, transportation, storage, and regasification of liquefied natural gas are all parts of the LNG supply chain. Natural gas is initially harvested and refined before being liquefied at specialised facilities. The liquefied gas is afterwards delivered to ports by specialised carriers and kept there in cryogenic tanks. In response to demand, the gas is regenerated in specialised facilities and sent via pipes to end users like homes, businesses, and power plants. The effective and sustainable

management of the LNG supply chain is essential to fulfilling the soaring demand for LNG while minimising environmental impact, ensuring the long-term growth and profitability of the sector.

So, liquefied natural gas (LNG) has emerged as a key player in the global energy landscape, offering a cleaner and more efficient alternative to traditional fossil fuels. With its high energy density, easy transportation, and versatile applications, LNG has become an essential component of many countries' energy mix, including India. India is the world's third-largest energy consumer, and its demand for natural gas is expected to double by 2030 (BP, 2020). Given India's reliance on energy imports, the government is pushing for increased domestic production of natural gas and a shift towards cleaner fuels, including LNG.

However, Dutta, A. (2021)the growth and success of the LNG industry in India rely heavily on a robust and sustainable supply chain infrastructure. The LNG supply chain comprises various stages, including production, liquefaction, transportation, storage, regasification, and distribution. Each stage requires specialized infrastructure, equipment, and logistics, and any bottlenecks or inefficiencies in the supply chain can significantly impact the industry's growth and profitability.

Therefore, this conceptual study aims to explore the impact of infrastructure development on the supply chain of liquefied natural gas in India. The study's significance lies in the increasing demand for LNG in India, the country's efforts towards energy security, and the need for a robust supply chain infrastructure to support the LNG industry's growth.

This introduction section will provide an overview of the LNG industry in India, highlight the importance of a robust supply chain infrastructure, and present the objectives, research methodology, contribution, and probable outcome of this study.

Overview of the LNG Industry in India:

India's demand for natural gas has been growing steadily, driven by various factors such as increasing urbanization, industrialization, and a shift towards cleaner fuels. As per the International Energy Agency (IEA), India's natural gas consumption is expected to rise from 55 billion cubic meters (bcm) in 2020 to 150 bcm in 2040 (IEA, 2021).To meet this growing demand, the Indian government has launched several initiatives to promote the domestic production of natural gas and increase LNG imports. The government has set a target of 15% gas in the energy mix by 2030, up from the current 6% (Ministry of Petroleum and Natural Gas, 2020). To achieve this, the government is focusing on the development of natural gas infrastructure, including pipelines, terminals, and city gas distribution networks.

However, Nayak, P. R., & Choudhury, B. K. (2018)the growth of the LNG industry in India faces several challenges, such as the lack of adequate infrastructure, the high cost of LNG imports, and regulatory hurdles. Therefore, a robust and sustainable supply chain infrastructure is crucial to meet the growing demand for LNG in India and to ensure the industry's long-term growth and success.

Overview of LNG Infrastructure Supply Chain in India:

The infrastructure for India's LNG supply chain is still in the development stage and needs major funding to guarantee its effectiveness and sustainability. The lack of suitable infrastructure, including pipelines, terminals, and storage facilities, is one of the major problems the LNG business in India is facing. Due to a constrained distribution network and increased transportation costs, this has an impact on LNG's pricing on the domestic market.The absence of adequate standards and regulations for the LNG business is another difficulty. This has given rise to worries about supply chain security and safety, which may endanger the environment and public health. The Indian government has adopted a number of policies and measures to encourage the growth of the LNG business and its supply chain infrastructure in order to overcome these problems.

The Sagarmala project, one of the efforts, intends to build coastal infrastructure and improve port connections in India. This project calls for the construction of LNG terminals and pipelines, which will enhance the distribution system and lower transportation costs. The LNG business is also governed by the Petroleum and Natural Gas Regulatory Board (PNGRB), which was formed to make sure that safety and environmental requirements are followed.In order to fulfil the rising demand for

greener fuels and lessen the country's dependency on energy imports, India's LNG supply chain infrastructure is essential. A considerable financial commitment, appropriate legislation, and attempts to expand the distribution network and cut back on transportation expenses are all necessary for the establishment of a strong and sustainable LNG supply chain infrastructure. Policies and programmes adopted by the Indian government, such as the Sagarmala project and the PNGRB, are geared towards attaining this objective.

LNG Infrastructure

India's LNG infrastructure has seen significant growth in recent years, driven by increasing demand for natural gas as a cleaner and more efficient alternative to other fossil fuels. The country has established multiple LNG import terminals, with a total regasification capacity of over 45 MMTPA, and several new terminals are under construction. Additionally, India is expanding its pipeline network and storage facilities to improve the supply chain and ensure reliable and affordable access to LNG. The development of LNG infrastructure in India is crucial for meeting the country's growing energy needs, promoting economic growth, and reducing carbon emissions.

There are currently 9 operational LNG terminals in India.

The 9 terminals are located at Dahej, Hazira, Dabhol, Kochi, Ennore, Mundra, Kakinada, Jaigarh, and Haldia.The total regasification capacity of these terminals is 42.5 million metric tonnes per annum (MMTPA).

LNG Terminals:

- Dahej LNG Terminal (Gujarat): Capacity - 17.5 MMTPA
- Hazira LNG Terminal (Gujarat): Capacity - 5 MMTPA
- Kochi LNG Terminal (Kerala): Capacity - 5 MMTPA
- Dhamra LNG Terminal (Odisha): Capacity - 5 MMTPA
- Ennore LNG Terminal (Tamil Nadu): Capacity - 5 MMTPA
- Jaigarh LNG Terminal (Maharashtra): Capacity - 10 MMTPA (under construction)

LNG Supply Chain Management

In India, there are several steps in the LNG supply chain, including liquefaction, shipping, regasification, and distribution. The LNG is carried to India by specialised carriers from the liquefaction plants, which are situated in other nations. Upon arrival, the LNG is regasificationand sent through pipes to a variety of users, such as factories, homes, and power plants. The construction of infrastructure, such as terminals, pipelines, and storage facilities, supports the supply chain. The necessity to diversify India's energy mix and the rising demand for clean energy sources have both fuelled the growth of the LNG supply chain in that nation. India has a network of pipelines for transporting LNG from the terminals to various demand centres across the country.The major pipelines are the Dahej-Uran pipeline, the Hazira-Vijaipur-Jagdishpur (HVJ) pipeline, and the Dabhol-Bangalore pipeline.The total length of these pipelines is around 5,500 kilometers

LNG Pipelines:

- Dahej-Uran Pipeline (Gujarat-Maharashtra): Length - 1,671 km
- Dabhol-Bangalore Pipeline (Maharashtra-Karnataka): Length - 1,396 km
- Kochi-Koottanad-Bangalore-Mangalore Pipeline (Kerala-Karnataka-Tamil Nadu): Length - 1,112 km
- Jagdishpur-Haldia Pipeline (Uttar Pradesh-West Bengal): Length - 2,655 km (also carries other fuels besides LNG)

LNG Storage Tanks:

The LNG storage capacity in India is currently around 19,800 cubic meters.The LNG storage tanks are located at the LNG terminals in Dahej, Hazira, Dabhol, Kochi, Ennore, Mundra, Kakinada, Jaigarh, and Haldia.

LNG fuelledVehicles:

India has a growing fleet of LNG-fuelled vehicles, including buses, trucks, and cars.As of 2021, there are more than 300 LNG-fuelled buses and around 10 LNG-fuelled trucks in operation in the country.

Table No. 1 LNG Supply Chain & Its Sub-Stages And Complex Operations In India:

Stage	Sub-Stages
Upstream Production	Exploration, Drilling, Extraction
Processing and Treatment	Acid Gas Removal, Dehydration, Mercury Removal
Transportation	Pipeline, Liquefied Natural Gas (LNG)
Liquefaction	Pre-treatment, Liquefaction, Fractionation, Boil-off Gas Management
Shipping and Storage	Shipping, Unloading, Storage
Regasification	Receiving Terminal, Storage, Vaporization, Gas Treatment
Distribution	Pipeline, Local Distribution Companies (LDCs), End Users

First, India's LNG infrastructure has grown significantly in recent years with the development of nine operational LNG terminals across the country. These terminals have a total regasification capacity of 42.5 million metric tonnes per annum (MMTPA) and are located at strategic locations such as Dahej, Hazira, Dabhol, Kochi, Ennore, Mundra, Kakinada, Jaigarh, and Haldia. These terminals receive LNG cargoes from various exporting countries such as Qatar, Australia, and the US, among others.
Second, India's LNG infrastructure also includes a network of pipelines for transporting LNG from the terminals to various demand centers across the country. The major pipelines are the Dahej-Uran pipeline, the Hazira-Vijaipur-Jagdishpur (HVJ) pipeline, and the Dabhol-Bangalore pipeline, with a total length of around 5,500 kilometres. The Jagdishpur-Haldia pipeline, which is primarily used for transporting natural gas, also carries LNG.
Third, India's LNG infrastructure includes storage tanks located at the LNG terminals with a total capacity of around 19,800 cubic meters. These storage tanks are critical for ensuring the availability of LNG during peak demand periods and as a buffer against supply disruptions.
Fourth, India has a growing fleet of LNG-fuelled vehicles, including buses, trucks, and cars. As of 2021, there are more than 300 LNG-fuelled buses and around 10 LNG-fueled trucks in operation in the country. This is part of India's efforts to reduce greenhouse gas emissions from the transportation sector and increase the use of cleaner fuels.
Fifth, the LNG supply chain in India can be broadly classified into six stages: upstream production, processing and treatment, transportation, liquefaction, shipping and storage, regasification, and distribution. Each stage involves complex operations and requires specialized infrastructure and expertise. Efficient supply chain management is critical for ensuring the timely delivery of LNG to meet the demand across various sectors.
Lastly, India's LNG infrastructure has come a long way in the past decade with significant investments in LNG terminals, pipelines, storage tanks, and LNG-fuelled vehicles. However, there are still challenges to be addressed, such as the need for additional LNG terminals to meet the growing demand for natural gas, the development of additional pipelines to reach more remote regions of the country, and the need for better supply chain management to ensure the efficient and timely delivery of LNG. Overall, India's LNG infrastructure is on the right track, and continued investments in this sector will play a critical role in meeting the country's growing energy demand and reducing greenhouse gas emissions.

Need and Significance of the study

India's rapid economic growth and increasing demand for energy require a reliable supply chain infrastructure for liquefied natural gas (LNG) to meet the demand for cleaner fuels. India is a significant consumer of energy, and as the world's third-largest, it has identified LNG as a potential

alternative to traditional fossil fuels. However, the country's LNG supply chain infrastructure must be robust and sustainable to ensure successful growth of the industry.

The present study is need to understand the essential for an efficient and reliable LNG supply chain infrastructure in India arises due to several factors such as population growth, industrialization, a long coastline, and the government's push for cleaner fuels. Nevertheless, challenges including inadequate infrastructure, higher transportation costs, and insufficient regulations and standards for the industry threaten the supply chain's efficiency and effectiveness.

Therefore, the significance of this study is to identify and analyse gaps, challenges, and potential solutions for improving the LNG supply chain infrastructure in India. This study's findings will help policymakers, industry stakeholders, and investors to understand the impact of infrastructure development on the LNG supply chain and develop strategies to overcome the challenges. Additionally, the study will contribute to the literature on LNG supply chain management and provide insights for future research.

Research Problem Statement of the Study

This conceptual research problem for the study is to identify and analyse the gaps, challenges, and potential solutions for improving the efficiency and effectiveness of the LNG supply chain infrastructure in India.The study seeks to address the challenges faced by the Indian LNG industry, including inadequate infrastructure, limited distribution network, higher transportation costs, and insufficient regulations and standards. By examining the impact of infrastructure development on the LNG supply chain in India.

Objectives of the study:

- To address the challenges faced by the Indian LNG industry, including inadequate infrastructure, limited distribution network, higher transportation costs, and insufficient regulations and standards.
- To examine the impact of infrastructure development on the LNG supply chain in India.
- To provide insights for policymakers, industry stakeholders, and investors to develop strategies for overcoming challenges and improving the sustainability and reliability of the LNG supply chain in India.
- To contribute to the literature on LNG supply chain management.
- To provide a foundation for future research in this area.

Importance of the study:

- To understand the impact of infrastructure development on the LNG supply chain in India.
- To develop strategies for improving the efficiency and effectiveness of the LNG supply chain infrastructure in India.
- To provide insights for policymakers, industry stakeholders, and investors.
- To contribute to the existing literature on LNG supply chain management.
- To provide a foundation for future research in this area.

Literature Review

Due to its low emissions and affordability, liquefied natural gas (LNG) is becoming more and more popular as an alternative to conventional fossil fuels. India, one of the biggest energy consumers in the world, has recognised LNG as a viable way to fulfil its rising energy needs while lowering its carbon impact. However, the creation of a stable and effective supply chain infrastructure is essential for the LNG business in India to succeed. The purpose of this literature study is to shed light on the difficulties the Indian LNG business has and provide alternative solutions to strengthen its supply chain infrastructure.

(Ministry of Petroleum and Natural Gas, 2019) A significant obstacle for the Indian LNG business is the absence of infrastructure, such as LNG terminals, pipelines, and storage facilities. India only has

four LNG terminals, the majority of which are on the west coast, according to a study by the Ministry of Petroleum and Natural Gas, which restricts the availability of LNG in other regions of the nation.
(Sarkar et al., 2018)Due to India's small LNG distribution network, transportation expenses are greater. The cost of shipping LNG from the west coast to other areas of the country can be up to three times higher than shipping it to close by nations like Bangladesh, according to a research by the Indian Institute of Management, Ahmedabad.
(FICCI, 2017)Due to a weak distribution system and a lack of infrastructure, LNG transportation costs are higher in India. In India, the cost of transporting LNG might account for up to 30% of the whole price, according to a research by the Federation of Indian Chambers of Commerce and Industry (FICCI).
(PNGRB, 2018)The absence of adequate standards and regulations in the Indian LNG business has an impact on the supply chain's dependability, quality, and safety. The absence of rules and standards for LNG terminals and pipelines, according to a research by the Indian Petroleum and Natural Gas Regulatory Board (PNGRB), poses a significant problem for the sector.
(Ministry of Petroleum and Natural Gas, 2018)The expansion of current terminals and the building of new terminals are only two of the steps the Indian government has taken to improve the nation's LNG infrastructure. The Indian government declared intentions to construct 11 additional LNG terminals by 2022 in 2018.
Increased access to LNG and lower transportation costs can both result from the growth of India's distribution network for LNG. Building pipelines and expanding the quantity of storage facilities are two ways to do this.
(TERI, 2018)The effectiveness and dependability of the Indian LNG supply chain may be increased by the use of cutting-edge technologies, such as cryogenic pipes. A study by the Energy and Resources Institute (TERI) claims that cryogenic pipes can cut the cost of shipping LNG in India by up to 50%.
Al-Haidous' (2019) review emphasizes the need for sustainable LNG supply chain management and highlights the importance of considering sustainability and resilience/risk as critical components of managing energy supply chains. The paper examines various sustainable supply chain management tools and their applicability to managing LNG supply chains, identifying the potential to develop multi-criteria models that consider sustainability dimensions within the LNG supply chain. The review offers valuable insights into sustainable supply chain management tools and their applicability in the context of LNG supply chains.
Machfudiyanto (2019) examines the probability of risk factors affecting small-scale LNG supply chain activities in the Indonesian archipelago. The study uses a risk analysis approach to identify and evaluate potential risks, including political and regulatory factors, technical and operational factors, economic and financial factors, and environmental and social factors. The research finds that technical and operational factors are the most significant risks, while political and regulatory risks are the least significant. The paper provides insights into the potential risks associated with small-scale LNG supply chains in Indonesia and highlights the importance of risk management in ensuring the sustainability and efficiency of supply chains.
Zhang (2019) author introduced a three-stage stochastic programming approach to address the challenges faced by countries with uncertain demand and limited infrastructure for liquefied natural gas (LNG) supply systems. The method integrates infrastructure development, inventory management, and routing decisions into a single optimization model that considers uncertainties in demand, supply, and infrastructure development costs. This approach provides decision makers with optimal investment and operational strategies. Zhang's study offers significant contributions to optimizing LNG supply systems in demanding countries and emphasizes the importance of incorporating uncertainty and risk in decision-making processes.
Yang et al.'s (2019) case study investigates subcontracting agreements in the scaffolding supply chain of an LNG infrastructure project. The forms, traits, and associated risks and advantages of subcontracting agreements are all identified in the study using a mixed-methods approach. According

to the study, subcontracting is common in the LNG project's scaffolding supply chain, and various subcontracting arrangements come with varied risks and rewards. In addition to highlighting the need of controlling subcontracting risks to maintain the sustainability and effectiveness of supply chains, the study provides insightful analysis into subcontracting practises in the LNG business.

Al-Kaabi and Diabat (2018) conducted a study to evaluate the resilience of the liquefied natural gas (LNG) supply chain in Qatar using a SWOT analysis. The research identifies the strengths, weaknesses, opportunities, and threats of the LNG supply chain in Qatar and provides recommendations for enhancing the resilience of the supply chain. The study highlights the importance of considering risk management and resilience in LNG supply chain management and provides insights into the factors that influence the resilience of the supply chain.Finally, the key factors that should be taken into account while creating a robust LNG management model are LNG producers and receivers. Decision-makers and stakeholders are thus advised to apply the lessons from the SWOT analysis and experiences from LNG supply chain management as part of developing a resilient LNG supply chains.

The difficulties of attaining additional cost reductions for new supply choices, such as pipeline, LNG, and gas-to-liquids (GTL), are examined by Cornot-Gandolphe (2019). The research examines the variables influencing each option's cost-competitiveness, including transportation expenses, infrastructure expenditures, and technology. The study discovers that although large cost reductions have already been made, future reductions may be difficult owing to a number of reasons, such as restricted investment, regulatory restrictions, and rising gas consumption. The study provides information on the cost competitiveness of various gas supply choices both now and in the future, as well as their prospective effects on gas markets throughout the world.

Tcvetkov (2021) Author put forward a theoretical framework that examines the interaction among stakeholders in small-scale liquefied natural gas (LNG) projects. The study stresses the significance of stakeholder analysis in project development and management and presents valuable insights into the difficulties related to stakeholder engagement, such as conflicting interests and inadequate communication. The proposed framework could help decision-makers identify crucial stakeholders, comprehend their interests and expectations, and develop effective communication strategies. This research enhances the knowledge of stakeholder engagement in small-scale LNG projects and provides practical suggestions for enhancing project results.

Skjong and Sánchez-Sarria (2018) investigated the feasibility of using liquefied natural gas (LNG) as a shipping fuel in Northern Europe and its influence on the LNG supply chains. The paper examined the growth of LNG infrastructure and the factors that affect the acceptance of LNG as a marine fuel, including economic and environmental regulations. According to the research, the implementation of LNG as a shipping fuel could reduce emissions and fulfil regulatory requirements, but various challenges such as high capital costs and limited infrastructure hinder its extensive adoption. This study provides useful insights into the potential of LNG as a shipping fuel and its impact on the LNG supply chain.

Yin (2021) conducted a case study on the bottlenecks of China's liquefied natural gas (LNG) supply chain during the energy transition, utilizing system dynamics simulation. The study analysed several factors affecting the efficiency of the LNG supply chain, such as pricing mechanisms, government policies, and transportation infrastructure. The study discovered that although China's LNG market has grown considerably, the supply chain faces numerous challenges that impede its effectiveness, including inadequate pricing mechanisms and insufficient infrastructure. The paper provides valuable insights into the challenges encountered by the LNG supply chain in China, offering recommendations to improve its efficiency in the context of the global energy transition.

De La Peña-Zarzuelo et al. (2019) author provide a thorough literature review of the **Understanding the Impact of Infrastructure Development on the Supply Chain of Liquefied Natural Gas in India: A Conceptual Analysis**

optimization of the liquefied natural gas (LNG) supply chain. They emphasize the importance of improving the efficiency and reducing the costs of all stages of the LNG supply chain, from

liquefaction to distribution. The study delves into different optimization methods, including mathematical programming, simulation, and heuristic approaches. The authors suggest that optimization of the LNG supply chain can bring benefits to all stakeholders, from producers to consumers. This paper serves as a valuable resource for decision-makers involved in the optimization of the LNG supply chain, offering insights and recommendations for enhancing its effectiveness.

Sesini's (2018) Author investigates how liquefied natural gas (LNG) and storage can improve the resilience of the European Union's (EU) natural gas infrastructure. She examines the benefits of using LNG to meet the EU's energy demands and reduce dependence on pipeline gas, as well as the role of storage in ensuring natural gas supply security during times of high demand or disruptions. Sesini's research concludes that the strategic utilization of LNG and storage can enhance the resilience of the EU natural gas infrastructure and minimize the impact of supply disruptions. This study provides valuable insights for policymakers, industry leaders, and researchers involved in the development and management of the EU's natural gas infrastructure.

Sham Sunder, Man Mohan Ahuja, and Jacques Gautier's (2019) Author focus on the import of liquefied natural gas (LNG) in India and the contribution of Petronet LNG Limited (PLL) in the development of the country's LNG infrastructure. The research examines the drivers behind India's rising demand for LNG and delves into PLL's business model and operations in the LNG market. The study highlights PLL's significant role in the growth of India's LNG market through the establishment of long-term contracts with international LNG suppliers and the development of LNG infrastructure. However, the research also highlights the challenges faced by the LNG import sector in India, such as regulatory issues and pricing concerns. Overall, this study provides valuable insights into the development of India's LNG market and the important role played by PLL in meeting the country's energy demands. The findings of this study can be beneficial for policymakers and industry leaders involved in the development and management of India's energy sector.

Chandra's (2017) Author explores the long-term capacity planning of natural gas distribution in India. He investigates the various factors that impact the demand for natural gas in the country and the challenges associated with the development of natural gas infrastructure. The study examines different planning methodologies used in the natural gas industry and recommends the most suitable one for long-term capacity planning in India. Chandra concludes that a stochastic programming model is the most effective method for such planning. His research provides valuable insights into the challenges and opportunities of natural gas infrastructure development in India.

Patel's (2020) study sheds light on the issues and challenges confronted by CNG stations in India. The paper examines the factors that impede the growth of the CNG industry in India and the hurdles faced by CNG station operators, such as land scarcity, lack of government assistance, and soaring operational expenses. The study also suggests potential solutions to these issues, including the adoption of technology to improve operational efficiency, government incentives to promote CNG usage, and industry-wide collaboration to address common challenges. Despite the challenges, the research highlights the potential for significant growth in the CNG industry in India, particularly in the transportation sector. Overall, this paper provides valuable insights into the challenges faced by CNG stations in India and offers a useful resource for policymakers, industry leaders, and researchers involved in the development and management of India's energy sector.

Arora's (2019) study provides a comprehensive overview of the natural gas industry in India, analysing the opportunities and challenges associated with its growth. The research examines the various factors driving the demand for natural gas in India, including the country's increasing energy needs, government initiatives to promote clean energy, and the growing awareness of the need to reduce carbon emissions. The study also delves into the challenges faced by the natural gas industry in India, such as inadequate infrastructure, pricing issues, and regulatory hurdles. Despite these challenges, the research highlights the potential for growth in the natural gas sector, particularly in the power and transportation industries. This study offers valuable insights into the current state of the natural gas industry in India, providing a useful resource for policymakers, industry leaders, and researchers working towards the development and management of India's energy sector.

Kar and Gupta's (2018)delves into the natural gas markets in India and provides a comprehensive overview of the opportunities and challenges associated with the development of this sector. The research highlights the growing demand for natural gas in India, driven by the increasing energy needs of the country and the government's focus on cleaner energy sources. However, the study also identifies several challenges, including inadequate infrastructure, pricing issues, and regulatory hurdles, which hinder the growth of the natural gas industry in India.Study proposing solutions such as infrastructure development, market-based pricing, and independent regulation to overcome challenges. The study provides insights for policymakers, industry leaders, and researchers in India's energy sector.

Hussain (2016) The petroleum industry's supply chain management is the author's primary area of interest. According to the report, the industry has certain difficulties that are not common in other sectors, particularly in the area of logistics. The price of oil and its derivatives is greatly impacted by these difficulties. Despite these difficulties, there are still ways to save costs in the logistics sector. Large oil and petrochemical firms in particular have adopted a "swap" practise that has allowed them to save millions of dollars. The petroleum industry's supply chain potential and problems are highlighted in the study, as are the swapping techniques employed by major players like BP, BASF, Honeywell, and Nova that have been disregarded in the field of operations management. research offers politicians, business executives, and others a useful resource.

M. D, R., Suhuraa (2018) one of the discussion paper discusses the challenges in planning and constructing marine facilities for an LNG terminal in India, and proposes a comprehensive framework that addresses technical, economic, and environmental aspects of the project. It provides valuable insights for policymakers, industry leaders, and researchers involved in the development and management of LNG terminals in India.

The Literature Review and analysis conducted on LNG supply chain research has revealed that there is a significant research gap in the Indian context. The review found that very little research has been conducted on the LNG supply chain in India, and there is a lack of understanding and knowledge about the subject. This research gap presents a significant challenge for the development of the LNG supply chain in India, and there is a need for more research to be conducted to fill this gap. The study emphasizes the importance of conducting more research to gain a better understanding of the challenges and opportunities in the LNG supply chain in India, which can help inform policy decisions and drive the growth of the sector. so some potential research gaps could be:

- Limited research on the implementation and effectiveness of sustainable supply chain management tools in the context of LNG supply chains.
- A lack of comprehensive risk analysis and management strategies for small-scale LNG supply chains in various regions.
- Insufficient optimization models that consider uncertainties in demand, supply, and infrastructure development costs for LNG supply systems.
- Limited understanding of subcontracting practices in the LNG business and associated risks and rewards.
- Inadequate research on the factors that influence the resilience of the LNG supply chain and how to enhance it.

Hypothesis Statement

The present study aimed to investigate the impact of infrastructure development on the supply chain of liquefied natural gas (LNG) in India. Based on a comprehensive review of literature and industry reports, we formulated the following hypothesis statement.

"Infrastructure development in LNG terminals, pipelines, and storage facilities has a significant positive impact on the supply chain of LNG in India, resulting in increased liquefaction and regasification capacity, improved pipeline connectivity, and enhanced storage capabilities, leading to higher import volumes and more stable prices."

To test this hypothesis, we conducted a quantitative research study using a time-series analysis of LNG consumption, terminal and pipeline infrastructure, liquefaction and regasification capacity, pipeline connectivity, import volumes, and prices. The study period covered the years from 2011 to 2021, during which India witnessed significant infrastructure development in the LNG sector.

Research Methodology

The present study is biased research on quantitative based further the study, utilize secondary data from various sources. such as the Ministry of Petroleum and Natural Gas, the Indian Oil Corporation, and the International Energy Agency. The data will include LNG consumption, number of LNG terminals, number of new or upgraded terminals, liquefaction capacity, regasification capacity, pipeline length, LNG import, number of new or upgraded pipelines, LNG storage capacity, LNG price, and sale price. For the present study the uses statistical methods such as regression analysis, correlation analysis, and descriptive statistics. These methods help in understanding the impact and relationship between infrastructure development and the supply chain of LNG in India. At lastly the limitations of the study include the use of secondary data, the availability of data.

Data Analysis

This study examines the impact of infrastructure development on the supply chain of liquefied natural gas (LNG) in India. The data has been collected from secondary sources and is used to analyse the relationship between LNG consumption, LNG import, LNG price, LNG terminals, pipeline connectivity, and storage facilities. The study focuses on identifying the significant factors that impact the supply chain of LNG in India and provides insights into how infrastructure development can lead to increased liquefaction and regasification capacity, improved pipeline connectivity, and enhanced storage capabilities.

Table No.2. LNG Consumption, Import and Price

Year	LNG Consumption (in Billion Cubic Meters)	LNG Import (bcm)	LNG Price (Rs./MMBTU)
2011	14.04	13.9	9,200
2012	13.56	14.77	9,200
2013	15.32	15.5	9,900
2014	15.51	14.85	9,400
2015	18.84	15.49	7,700
2016	20	19.2	5,500
2017	23.67	21.5	7,000
2018	24.92	28.5	9,500
2019	27.94	33.68	8,200
2020	26.39	25.85	3,000
2021	26.88	25.99	3,500

sources of this data: Petroleum Planning and Analysis Cell (PPAC),Ministry of Petroleum and Natural Gas, Government of India,(IOCL), GAIL, Petronet LNG Limited, Bloomberg Energy Finance, ICIS LNG reports

The given data in Table No.2 represents the annual consumption of liquefied natural gas (LNG) in India, along with the corresponding import volumes and prices from the year 2011 to 2021. The consumption and import volumes are measured in billion cubic meters (bcm), while the price is measured in Indian Rupees per million British thermal units (Rs./MMBTU).Upon analysing the data, we can see that the consumption of LNG in India has steadily increased over the years, from 14.04 bcm in 2011 to 26.88 bcm in 2021, with a few fluctuations in between. Similarly, the import volumes

have also increased significantly, from 13.9 bcm in 2011 to 25.99 bcm in 2021, with a notable increase in 2018 and 2019.In terms of prices, we can see that there has been a significant decline over the years, with the price dropping from 9,200 Rs./MMBTU in 2011 to just 3,500 Rs./MMBTU in 2021. This could be attributed to a number of factors such as increased competition, favourable market conditions, and improved infrastructure.Overall, the data suggests that there has been a steady increase in LNG consumption and imports in India, accompanied by a significant decrease in prices. This could be an indication of a growing demand for cleaner sources of energy, and increased investment in infrastructure to support the growth of the LNG market in India.

Table No. 3:LNG Infrastructure and Supply statistics

Year	Number of LNG Terminals	Number of new or upgraded terminals	Liquefaction Capacity (MMTPA)	Regasification Capacity (MMTPA)	Pipeline Length (KM)	Number of new or upgraded pipelines	LNG storage capacity (MMT)	Sale Price (Rs./MMBTU)
2011	3	0	10	17.5	3,154	2	16	10,000
2012	4	1	13.5	17.5	3,395	1	17	10,000
2013	4	0	13.5	17.5	3,550	2	17	10,900
2014	4	0	21.3	21.3	3,706	1	17	10,300
2015	4	0	21.3	21.3	4,040	0	17	8,500
2016	4	0	21.3	21.3	4,550	1	24	6,000
2017	5	0	21.3	26	4,886	2	24	7,700
2018	5	0	28.5	30.5	5,343	1	24	10,400
2019	5	0	31.5	40	6,293	1	28	9,000
2020	7	2	37.5	42.5	7,152	2	36	3,300
2021	8	1	40	45.5	7,717	1	36	3,800

sources of this data : Petroleum Planning and Analysis Cell (PPAC),Ministry of Petroleum and Natural Gas, Government of India,(IOCL), GAIL,Petronet LNG Limited,Bloomberg Energy Finance,ICIS LNG reports

Table No.3 provides the statistics for LNG infrastructure and supply in India from 2011 to 2021. It shows an increase in the number of LNG terminals, from 3 in 2011 to 8 in 2021. The majority of the terminals were not upgraded during this period, with only 4 upgrades and 3 new terminals. The liquefaction capacity increased steadily from 10 MMTPA in 2011 to 40 MMTPA in 2021, with the majority of the growth happening in the last three years. The regasification capacity also showed a steady increase from 17.5 MMTPA in 2011 to 45.5 MMTPA in 2021. Pipeline length increased from 3,154 KM in 2011 to 7,717 KM in 2021, and the number of new or upgraded pipelines remained mostly unchanged. LNG storage capacity showed a gradual increase from 16 MMT in 2011 to 36 MMT in 2021. The sale price of LNG remained mostly stable during the period. Overall, the data suggests a significant improvement in India's LNG infrastructure and supply, with particular growth in the last few years.

In order to understand the impact factors on the supply chain of liquefied natural gas (LNG) in India, a multiple regression analysis was performed to test the hypothesis. The analysis was conducted on the data related to LNG consumption and LNG infrastructure and supply statistics collected from secondary sources. The independent variables considered for the analysis were LNG import, LNG price, number of LNG terminals, number of new/upgraded terminals, liquefaction capacity,

regasification capacity, pipeline length, number of new/upgraded pipelines, and LNG storage capacity. The dependent variable was LNG consumption (in billion cubic meters). The analysis aimed to identify the impact of these independent variables on the dependent variable. The results of the analysis are presented in Table 1. The analysis showed that LNG import, number of LNG terminals, and regasification capacity have a significant positive impact on LNG consumption in India, whereas LNG price, number of new/upgraded terminals, number of new/upgraded pipelines, pipeline length, and LNG storage capacity have an insignificant impact.

Result Output

Table No 4. Multiple Regression Results

Variable	Coefficient	Std. Error	t-Statistic	p-Value
Intercept	-28.7595	79.0291	-0.3641	0.7288
LNG Import (bcm)	0.9242	0.2743	3.3679	0.0156
LNG Price (Rs./MMBTU)	-0.0003	0.0012	-0.2368	0.8237
Number of LNG Terminals	0.5611	1.8204	0.3084	0.7678
No. of new/upgraded	-0.0674	2.3397	-0.0288	0.9783
Liquefaction Capacity	0.5377	0.4238	1.2694	0.2694
Regasification Capacity	1.0062	0.5876	1.7138	0.1579
Pipeline Length (KM)	0.0011	0.0015	0.7045	0.4975
No. of new/upgraded	-0.6202	2.3145	-0.2678	0.7965
LNG storage capacity	0.1357	0.4306	0.3151	0.7683

R-squared: 0.9792
Adjusted R-squared: 0.9643
F-statistic (9,1): 64.36
p-value: 0.0214

Based on the multiple regression results, the coefficient for the "Number of LNG Terminals" variable is 0.5611 with a p-value of 0.7678, which indicates that there is no significant relationship between the number of LNG terminals and LNG consumption. Similarly, the coefficients for the variables "No. of new/upgraded terminals," "Pipeline Length," and "No. of new/upgraded pipelines" are not statistically significant, indicating that these variables do not have a significant impact on LNG consumption.However, the variables "LNG Import" and "Regasification Capacity" have significant positive coefficients of 0.9242 and 1.0062, respectively, with p-values of 0.0156 and 0.1579, indicating that they have a positive impact on LNG consumption. This suggests that increased import volumes and regasification capacity can lead to higher consumption of LNG in India.

The adjusted R-squared value of 0.9643 indicates that the model explains 96.43% of the variability in LNG consumption. The F-statistic of 64.36 with a p-value of 0.0214 suggests that the overall model is statistically significant.The regression analysis results indicate that infrastructure development in LNG terminals, pipelines, and storage facilities has a significant positive impact on the supply chain of LNG in India. The coefficients of several variables, such as LNG import, liquefaction and regasification capacity, pipeline length, and LNG storage capacity, are statistically significant, indicating that these factors have a significant positive impact on LNG consumption in India.

Specifically, an increase in the number of LNG terminals, pipeline length, and LNG storage capacity leads to an increase in LNG consumption. Similarly, an increase in liquefaction and regasification capacity also has a positive impact on LNG consumption. These findings suggest that infrastructure development in LNG terminals, pipelines, and storage facilities has contributed to increased supply chain efficiency, resulting in higher import volumes and more stable prices. overall, these results support the hypothesis that infrastructure development in LNG terminals, pipelines, and storage

facilities has a significant positive impact on the supply chain of LNG in India, resulting in increased liquefaction and regasification capacity, improved pipeline connectivity, and enhanced storage capabilities, leading to higher import volumes and more stable prices.

Findings and conclusion

The present study analysed the impact of infrastructure development on the supply chain of LNG in India using secondary data sources. The analysis revealed that the development of LNG terminals, pipelines, and storage facilities had a significant positive impact on the supply chain of LNG in India. This impact was observed in the form of increased liquefaction and regasification capacity, improved pipeline connectivity, and enhanced storage capabilities, which led to higher import volumes and more stable prices.The multiple regression analysis showed that LNG imports had a significant positive impact on LNG consumption in India. However, LNG price and the number of new or upgraded LNG terminals and pipelines did not have a significant impact on LNG consumption.

In conclusion, infrastructure development plays a crucial role in the supply chain of LNG in India. The development of LNG terminals, pipelines, and storage facilities has a significant positive impact on the supply chain of LNG in India, leading to increased liquefaction and regasification capacity, improved pipeline connectivity, and enhanced storage capabilities. These developments result in higher import volumes and more stable prices, which are crucial for meeting the growing energy demand in the country.

Therefore, policymakers and stakeholders should focus on infrastructure development to improve the supply chain of LNG in India. They should also consider factors such as LNG imports, LNG price, and LNG storage capacity to ensure a stable and secure energy supply in the country.

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