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Literature Review on LNG Supply Chain Risk Mapping

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Abstract

Purpose – This study aims to identify and map potential risks in the Liquefied Natural Gas (LNG) supply chain, particularly in the context of global energy transition goals set by the 2015 Paris Agreement. With increasing reliance on LNG as a primary energy source to replace coal, understanding risks that may disrupt its supply is critical for power generation systems.

Methodology – A Systematic Literature Review (SLR) was conducted by collecting and screening relevant journal articles from the Scopus database. The risk identification and classification were based on the SCOR (Supply Chain Operations Reference) model, which categorizes supply chain processes into Plan, Source, Make, and Deliver. The PRISMA protocol was applied to ensure transparency and rigor in document selection and content synthesis.

Findings – A total of 21 risk factors were identified and mapped across the SCOR model. The highest concentration of risks (11 out of 21) occurs in the "Deliver" process, including supply disruptions, delivery delays, demand uncertainties, and overreliance on LNG as a primary energy source. These interconnected risks can trigger ripple effects such as increased electricity production costs and even the collapse of power grids due to imbalances in supply and demand.

Originality – This study contributes to the literature by systematically integrating risk factors in the LNG supply chain with the SCOR framework and highlighting the vulnerabilities in the delivery stage. It offers practical insights for stakeholders in the LNG and power sectors to develop mitigation strategies, particularly in anticipation of future energy crises linked to LNG shortages.

Introduction

The 2015 Paris Agreement established emissions targets by formulating a net-zero emissions agenda, the Net Zero Emissions (NZE) target, under which most countries must reduce greenhouse gas emissions to zero percent by 2050-2060 (Afifi et al., 2023).

Considering this target, some countries still rely heavily on coal-fired power plants, which dominate the primary energy mix for electricity generation and contribute significantly to greenhouse gas emissions (Kimura et al., 2023). Therefore, high dependence on coal-fired power plants must be eliminated by exploring alternative primary energy sources for electricity generation, while renewable energy is still under development before the Net Zero Emissions (NZE) target deadline of 2040-2060.

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The natural gas-generated power generation mix is projected to grow consistently by 6.4% per year, making LNG (Liquefied Natural Gas) the second-most dominant energy mix by 2050 (Hashimoto & Lee, 2021).

Consequently, there is an urgent demand for LNG supply as the primary energy source for power generation in accordance with the NZE energy transition which requires the use of primary energy with lower emissions compared to coal, however considering the demand for natural gas which includes LNG to offer a transition energy mix and the need to ensure sustainable supply to meet demand, LNG supply is projected to face obstacles as current LNG projects will shrink (Danyer & Tanfield, 2009).

Therefore, considering the projected difficulties in LNG supply, a risk mapping is needed to respond to this case which outlines what risks will be faced from the perspective of LNG suppliers for gas-fired power plants. In this study, the SLR (Systematic Literature Review) methodology will be used to identify and map supply chain risks based on the SCOR (Supply Chain Operations Reference) supply chain process mapping (Tarei et al., 2020; Venkatesh et al., 2015).

Literature Review

Supply Chain Risk

Supply chain risks occur along the flow from suppliers to end consumers, encompassing everything that supports or serves as the foundation for business continuity (Handfield et al., 2020; Chowdhury et al., 2019). Mitigation techniques appropriate to some risks can be funded through human, material, and intangible resources within an organization (Bier et al., 2020). Mitigation can then be provided to detect and analyze risks by estimating the probability and impact of their occurrence (Gunasekaran et al., 2015). In general, supply chain risks are divided into operational and disruption risks, which can arise from artificial, natural, and human-made causes (Heckmann et al., 2015; Kauppi et al., 2016). Uncertainty in cost performance, supply, demand, cultural and geographical boundaries add to operational hazards (Bier et al., 2020). Environmental conditions, technological breakthrough shifts, and political and economic uncertainty all contribute to disruption risks, which can be assessed by assessing the likelihood and impact of occurrence (Gunasekaran et al., 2015; Juttner, 2005; Garvey et al., 2015). This study focuses on the issue of disruptions largely caused by LNG product shortages.

Many studies have revealed various risk elements, such as risks caused by the supply chain network itself, the emergence of risks created by organizational errors, and environmental disruptions (Manuj & Mentzer, 2008; Balakrishnan & Nadarajah, 2016); Operational errors, supply and demand disruptions all pose risks (Kumar, 2018).

Supply Risk

Disruptions in the upstream supply chain that contribute to the flow of commodities into an organization are categorized as supply risks because they may impact the overall supply chain performance (Parast & Subramanian, 2021; Um & Han, 2021; Sreedevi & Saranga, 2017; Nooraie & Parast, 2015; Duong et al., 2022; Pham et al., 2022). Companies may face uncertainties that affect their response to client demand, which are driven by upstream supply chain anomalies (e.g., raw material price fluctuations, delayed deliveries, substandard quality, raw material shortages) (Um & Han, 2021; Sreedevi & Saranga, 2017; Nooraie & Parast, 2015; Wu & Olson, 2010; Hancerliogullari et al., 2016). The upstream supply chain will disrupt the entire supply chain system downstream (Boon-itt & Wong, 2011).

Demand Risk

Downstream disruptions, such as unexpected changes and volatility in market demand, are characterized as demand risks, where developing the right supply for demand through market forecasting is challenging (Sreedevi & Saranga, 2017; Pham et al., 2022; Wagner & Bode, 2008). Demand risks can be created by inaccurate market predictions, defective products,

different client groups, customers' inability to settle payments, rivals in the market, and misinformation (Parast & Subramanian, 2021; Sreedevi & Saranga, 2017; Bevilacqu et al., 2020). Such disruptions lead to higher product prices due to shortages resulting in companies being obliged to increase their costs, which can harm their profitability, and even produce bullwhip and ripple effects (Wagner & Bode, 2008; Pujawan & Mahendrawathi, 2017; Page et al, 2021).

SCOR Model

The Supply Chain Council established the Supply Chain Operations Reference (SCOR) model, which serves as a strategic planning tool for decision-makers to simplify complex supply chain procedures (Venkatesh et al., 2015). This model separates four supply chain processes: sourcing, manufacturing, shipping, and planning. Supply chain processes are classified into four categories, therefore the LNG supply chain is defined by how LNG is sourced, how natural gas is refined into LNG, how it is supplied to power plants, and how the entire supply chain infrastructure is built.

Research Methods

Searching Strategies

The systematic literature review (SLR) method begins by defining the search scope. The search scope is limited to keywords in the title LNG and Natural Gas. The search scope is developed from the scope of research focused on the LNG business. To find reputable journal publications, a search was conducted using the Scopus database.

Searching Srings

The search string formulation is based on the SCOR model dimensions, with each search string representing at least one dimension (i.e., Plan, Source, Make, Deliver) (Venkatesh et al., 2015). The supply chain scope is used as the search string, which is categorized in the SCOR model dimensions (described in column Y in Table 1) (Bhattacharyya & Jha, 2017). The supply chain scope is used for scope purposes during the search procedure. The addition of the LNG sector scope leads to the identification of risks caused by supply shortages. Thus, inclusion criteria are formulated: risks caused by supply shortages and scope in the LNG industry. And exclusion criteria are formulated: language other than English, topic fields other than Business, Management, and Accounting, and publication types other than articles or conference papers. Therefore, the possible combinations are (X1 OR) OR TITLE-ABS-KEY (purchasing) OR TITLE-ABS-KEY (supply) OR TITLE-ABS-KEY (planning) OR TITLE-ABS-KEY (control) OR TITLE-ABS-KEY (production) OR TITLE-ABS-KEY (distribution) OR TITLE-ABS-KEY (return) AND TITLE-ABS-KEY (risk). Detailed keywords are listed in Table 1.

Tabel 1. *Strings* kata kunci pencarian Scopus

X		Y		Z	
Variabel	**Kata Kunci**	**Variabel**	**Kata Kunci**	**Variabel**	**Kata Kunci**
X1	Natural AND Gas	Y1	Supply AND Chain	Z1	Risk
X2	LNG	Y2	Logistic		
		Y3	Development		
		Y4	Procurement		
		Y5	Purchasing		
		Y6	Supply		
		Y7	Planning		
		Y8	Control		
		Y9	Production		
		Y10	Distribution		
		Y11	Return		

PRISMA Procedur and Content Synthesis

The PRISMA framework is used as a system to report the process from identification to inclusion of journal and conference papers retrieved and identified through the Scopus database. The framework includes identification, title and abstract screening, full-text eligibility screening based on inclusion criteria, and document inclusion for analysis and synthesis to generate risk mapping (Mu et al., 2021).

After the publication retrieval process has gone through the PRISMA process, the publications are reanalyzed to identify the risks identified in the research.

Results and Discussion

Based on the SLR PRISMA process framework, the identification stage identified 12,101 journal and conference publications using keywords combined with several strings from the Scopus database. In this process, exclusion criteria were directly applied during the publication search in Scopus. This resulted in 11,783 publications meeting the exclusion criteria, resulting in their exclusion.

In the next stage, screening based on title and abstract, two duplicate publications and 182 publications were found to be irrelevant to the topic. Consequently, 184 publications were excluded.

In the eligibility stage, 134 publications were screened based on their full text. This resulted in 54 publications being inaccessible for full text; 19 publications identified risks not caused by supply shortages; 13 publications covered fields other than Business, Management, and Accounting; and 11 publications covered areas other than the LNG industry. Therefore, 97 publications were removed based on these criteria. The final stage, the publication inclusion stage, aims to include publications in the analysis and synthesis to produce a risk mapping of the included publications.

From publications that meet the criteria, the risks identified in the research are analyzed and extracted. Some of the extracted risks are similar to those identified in other publications. Therefore, after the risk extraction process, these risks are synthesized with similar risks in other publications. However, publications are not limited to publications identified and filtered through the PRISMA process.

The risks extracted from these publications are then mapped based on the dimensions of the SCOR model. This aims to identify and quantify the risks present in a supply chain process (Table 2 shows the risks identified and mapped based on the SCOR model).

Based on the risks identified using the SLR method and mapped using the SCOR model, there are three risks in the planning process, three risks in the LNG exploration and procurement process, four risks in the LNG production or processing process for marketing, and 11 risks in the LNG marketing or delivery process to consumers.

From this mapping, it can be concluded that the greatest number of risks are in the LNG marketing or delivery process (i.e., delivery). Of the risks most prevalent in the delivery process, some risks require greater attention than other risks within the same supply chain process dimension, considering the discussion in the introductory chapter.

Considering the primary energy needs for the energy transition in response to the NZE target, which requires the use of primary energy with lower emissions, there are risks faced by power plants, as these plants will rely on LNG primary energy, which has lower emissions than coal.

These risks can create a ripple effect, creating a new risk, namely increased electricity costs. This becomes possible when power plants rely on LNG as their primary energy source. This dependence, when supply disruptions occur, will lead to decreased operational efficiency, requiring additional costs to offset these losses (Duong et al., 2022).

Tabel 2. Risk Mapping

SCOR	Risk	Reference
Plan	Investment cost risk	Resley & Reinsvold (2009); Shakhovskaya et al. (2018); Shaikh et al. (2016); Weijermars (2012a)
	Domestic regulatory risks	Chait et al. (2019); Weijmars (2012b)
	Risk policy	Weijermars (2012a); Chait et al. (2019)
Source	LNG price volatility	(Shakhovskaya et al. (2018); Chait et al. (2019); Xu & Lien (2020); Asenov (2018); Yukseltan et al. (2021)
	Single-supplier dependency	Basak et al. (2017)
	Miscalculation of natural gas consumption	Fagundes et al. (2021)
Make	Delays in upstream gas projects	Resley & Reinsvold (2009); Berle et al. (2013)
	Technology risks (technology obsolescence, *cyber-attacks*, information data breaches, and information system failures)	Stronzki et al. (2008)
	Inadequate transportation, storage, and infrastructure	Seconmadi (2010); McCreight (2019)
	Trade and operations mismanagement	Tan et al. (2020)
Deliver	Delivery delays	Stonzik et al. (2008)
	Poor delivery quality	Stonzik et al. (2008)
	Supply disruptions	Stonzik et al. (2008)
	Supplier failure: failure to meet contractual obligations and buyer expectations	Stonzik et al. (2008)
	Growth and fluctuations in electricity demand	Shakhovskaya e al. (2018)
	Power grid *collapses* due to lack of primary energy supply	Zani et al. (2010)
	Primary energy supply demand imbalance	Hibbard & Schatzki (20120
	Demand uncertainty	Weijermars (2012)

Rising electricity production costs will create a ripple effect. The inability to balance electricity production with demand due to dependence on LNG as the primary energy source for electricity production will lead to a power grid collapse if there is a supply disruption due to an imbalance between electricity production and consumer demand (Zani et al., 2010).

Conclusion

Based on the LNG supply chain risk mapping, it can be concluded that the greatest potential risks occur in the delivery process, based on the SCOR supply chain model. Of the risks in the delivery process, three risks require greater attention than others. This is because these risks are interrelated and can create a ripple effect, where the occurrence of one risk leads to other risks. These risks include the dependence of power plants on LNG as a primary energy source, which will increase electricity production costs and, furthermore, cause the power grid to collapse due to a shortage of primary energy supply. These results can be applied to the power generation industry and LNG suppliers in making strategic decisions based on the identified and mapped supply chain risks.

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