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Risk Assessment Frameworks for Large-Scale LNG Export Projects: Challenges and Financing Solutions

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Abstract: Background: The implementation of large-scale liquefied natural gas (LNG) exports involves a great deal of investment and entails various types of risks such as financial, technological and regulatory risks which can affect the sustainability of these projects in the long run. Even though there have been studies on the separate risk categories, there has not been enough information regarding an integrated connection between risk assessment frameworks and finance plans. This research paper investigates the joint impact of risk assessment and financing strategies on sustainability in large-scale LNG exports in the US. Methods: A quantitative cross-sectional survey involving 175 employees in companies of LNG exports, financial institutions, governmental organizations, and consulting firms was carried out through an online survey questionnaire. Results: The Financing Solutions scored the highest mean score (4.15), while Project Sustainability and Risk Assessment Framework ranked second and third with scores of 4.11 and 4.08, respectively. There were statistically significant positive correlations amongst all variables, with the highest correlation existing between Financing Solutions and Project Sustainability ($r = 0.769$, $p < 0.01$). It was originated from the regression analysis that the toughest predictors of Development Sustainability Financing Solutions ($\beta = 0.394$) and Risk Assessment Framework ($\beta = 0.312$). The modification clarified by the unchanged was 69.2%. ($R^2 = 0.692$; $p < 0.001$). Conclusion: An integrated method to risk calculation and effective financing will promote the sustainability of large LNG spread projects. Financial robustness, risk management, regulatory preparedness, and technology adaptation will facilitate sustainable development of LNG projects.

Keywords: Liquefied natural gas, Risk assessment, Financing solutions, Project sustainability, Energy infrastructure.



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1. Introduction

The fast-growing development of the LNG industry has had an effect on the world energy market and reinforced the importance of the role of the industry in providing energy security and assisting in the transition to cleaner energy sources [1]. The USA became one of the largest LNG exporters owing to the presence of shale gas resources, the use of efficient liquefaction technology and ongoing development of export infrastructure [2]. Huge LNG export projects help in economic development by increasing export revenues, creating jobs, developing industries, and international trade [3]. On the other hand, large LNG export projects involve huge investments, take much time for

development and occur in a business environment that is defined by regulatory risks, volatility of the energy market, technology challenges, and geopolitics [4]. Proper risk assessment becomes an integral part of project planning, finance management, and sustainability. The knowledge of the risks helps to enhance financial performance and resilience of projects [5].

Previous researches in the topic have focused on various dimensions of risk management related to the development of infrastructure for liquefied natural gas. Prior literature indicates that fluctuations in energy prices, construction delays, policy change, disruption in the supply chain and environmental risks can impact the performance and decision-making process of LNG projects [6]. Researchers have also highlighted the need for diversified funding models such as public-private partnership, export credit funding, syndicated loan, institutional financing and infrastructure financing among others to minimize financial risks and improve the feasibility of LNG projects [7]. While the prior research has been informative, it has generally focused on one category of risk in isolation from other dimensions and has failed to examine them in combination within a single framework. Another important deficiency in the prior literature is the lack of empirical information based on practitioners involved in LNG exportation projects in the United States [8].

As the complexity of the global energy market grows, it becomes evident that there is a necessity to develop an integrated approach to risk analysis that will take into account the financial, legislative, technological, and strategic challenges at the same time [9]. The implementation of LNG export projects is the result of cooperation between the government, investors, engineers, finance institutions, and energy companies, which makes it important to find ways to coordinate all of the processes properly. Otherwise, the risk analysis may prove to be inadequate, while the funding mechanisms will not provide proper results [10].

This study makes significant contributions to academics and practice through the empirical analysis of the main elements of risk and the financing solutions in one empirical framework. Through the survey research, carried out using data collected from 175 practitioners in the US via the online questionnaire, the research investigates the correlations between risk assessment framework, regulatory risks, financial risks, technological risks, financing solutions, and sustainability of the projects. These findings will add valuable contribution to the literature on energy infrastructure financing and will help policymakers, investors, financial institutions, and LNG developers in making better decisions and achieving sustainable projects. The main objective of the research is to investigate the efficiency of comprehensive risk assessment frameworks in the large-scale LNG export projects and the role of the financing solutions in the sustainability of the projects in the United States.

2. Materials and methods

Research Design and Online Survey

In conducting this research, a quantitative cross-sectional research design was used to examine the efficiency of the risk assessment framework and funding options in improving the sustainability of large LNG export ventures in the US. Data collection was done using online questionnaire surveys conducted via Google Forms, providing convenient access to participants in various states and organizations. The sample population comprised professionals involved in LNG export firms, energy consultancy firms, financial institutions, government agencies, and infrastructure financing organizations. Purposive sampling was used to ensure that respondents had practical experience in LNG projects development, risk assessments, and project financing [11]. The duration for which the survey was open lasted for about three months. A total of 180 questionnaires were sent to the selected individuals through professional email and LinkedIn accounts, with a total of 175 responses being recorded giving a response rate of 97.2%. Participation was voluntary, anonymous, and confidential while informed consent was electronically obtained prior to completion of the questionnaire.

Measurement of Variables

The online questionnaire was divided into two primary parts. The first part included demographic data, such as gender, age, education, professional experience, and affiliation with

organizations. The second part was aimed at measuring six research constructs – Risk Assessment Framework (RAF), Regulatory Risk (RR), Financial Risk (FR), Technological Risk (TR), Financing Solutions (FS), and Project Sustainability (PS) [12]. These constructs were measured by means of four to five indicators based on the literature review of previous peer-reviewed publications about energy infrastructure, project finance, and enterprise risk management [13]. Each measurement item used a five-point Likert scale, varying from 1 = Strongly Disagree to 5 = Strongly Agree. Before administering an online survey, the questionnaire was pre-tested by academic and industry experts. Reliability was determined by means of the Cronbach's Alpha, whereas validity was tested using Composite Reliability (CR) and Average Variance Extracted [14].

Statistical Analysis

Data collected via survey were exported from Google Forms to Microsoft Excel for data cleaning prior to analysis using IBM SPSS Statistics 27 [15]. Descriptive statistics including frequency, percentage, means, standard deviation, minimum value, and maximum value were used to obtain respondent information and study variables' summary information [16], [17]. Correlation analysis using Pearson's approach was then performed to establish any relationship between independent and dependent variables as well as to determine multi-collinearity [18]. Multiple Linear Regression analysis was later performed to analyze the relationship between independent variables (Risk Assessment Framework, Regulatory Risk, Financial Risk, Technological Risk, and Financing Solutions) and dependent variable (Project Sustainability) and thus test the research hypotheses formulated earlier [19]. Statistical significance was assessed at 95% level of confidence ($p < 0.05$). Besides, model adequacy was measured using coefficient of determination (R^2), adjusted R^2 , F statistics, tolerance and Variance Inflation Factor [20].

3. Results

Demographic Characteristics of Respondents

The demographic distribution of the 175 respondents participating in the online survey conducted in the USA is presented in **Table 1**. The gender distribution showed a preponderance of males, accounting for 65.1%, and females made up 34.9%. The majority of the age range was 35-44 with 37.7%, and 45-54 made up 27.4% showing that the respondents were relatively mature professionally. With regards to education level, 46.9% of the respondents had a master's degree, and 32.5% had a PhD showing that the respondents were relatively educated. With regards to professional experience, the most common one was 11-15 years with 32.0%, and 16-20 years with 26.3%. In terms of organization, the most common respondents were LNG export companies, which made up 41.7%, and 22.3% belonged to the financial institution.

Descriptive Statistics of Study Variables

Descriptive statistics of the research variables have been presented in **Table 2**. It is clear from the results that generally there are high mean values, which show the positive perception by respondents on risk management and financing practices in large LNG projects. Financing Solutions have shown the highest mean score of 4.15 with a standard deviation of 0.56, which shows that there was general agreement on the significance of efficient financing approaches. Project Sustainability has shown second highest mean score of 4.11, followed by Risk Assessment Framework that has scored mean value of 4.08. Financial Risk and Regulatory Risk have mean values of 4.01 and 3.94, respectively, while Technological Risk has scored the least mean score of 3.87. Standard deviation scores between 0.54 and 0.67 show low variability and consistent responses from participants.

Agreement with Risk Assessment and Sustainability Statements

The agreement levels of the respondents towards risk assessment and sustainability factors in major LNG export projects as shows in **Figure 1**. As can be seen from the results, Financing Solutions gained the highest agreement level (82.1%), showing the high awareness of the respondents concerning the significance of proper finance strategies for the successful execution of the project. Moreover, the Risk Assessment Framework (78.4%) and Project Sustainability (76.5%) factors were

well recognized by the respondents. Moderate agreement was shown in the case of Financial Risk (74.6%). Regulatory Risk was found to be less accepted by the respondents (69.8%). The least agreement was shown by Technological Risk (63.7%), where the high number of neutral responses demonstrates the uncertainty of the respondents towards the risks associated with technologies.

Perceived Levels of Study Variables in LNG Export Projects

The perceived levels of the study variables among respondents are linked to the LNG exports in **Figure 2**. From the findings above, it is clear that all the main variables were rated high by respondents, showing their strong appreciation of their importance in ensuring successful implementation of the projects. Financing solutions received the highest percentage in the category of high-level perception at 65.7%, followed by Project sustainability (64.5%) and Risk assessment framework (62.3%). On the other hand, financial risk received a high perception level rating of 61.7%, implying that financial issues still form a significant issue in LNG projects. Nevertheless, regulatory risk and technological risk showed a higher moderate-level rating of 34.9% and 33.1% respectively.

Pearson Correlation Matrix

The Pearson correlation matrix of the variables under study is presented in **Figure 3**. The variables include Risk Assessment Framework, Regulatory Risk, Financial Risk, Technological Risk, Financing Solutions, and Project Sustainability. The results reveal significant positive correlations among all variables at 1% level of significance ($p < 0.01$). The highest correlation coefficient is that of Financing Solutions and Project Sustainability ($r = 0.769$), while the second highest correlation coefficient is that of Risk Assessment Framework and Project Sustainability ($r = 0.721$). The third highest correlation coefficient is that of Financing Solutions and Risk Assessment Framework ($r = 0.684$). The correlation coefficient ranges from 0.471 to 0.769 without indication of any multi-collinearity problem.

Hypothesis Testing Results

The outcomes of hypothesis testing regarding the variables affecting Project Sustainability in major LNG export projects in **Table 3**. As per the regression analysis results, it can be seen that all relationships tested were statistically significant and valid. From the set of variables considered for this research, the Financing Solutions were the most positively associated variable with Project Sustainability ($\beta = 0.394$, $p < 0.001$), emphasizing the importance of proper financial mechanisms for the sustainability of projects. The Risk Assessment Framework was another important determinant with a beta of 0.312 ($p < 0.001$), signifying the importance of risk identification and management in the process. Financial Risk, Regulatory Risk, and Technological Risk contributed significantly to the model, with respective beta values of 0.247, 0.181, and 0.159. Overall, the model accounted for 69.2% of the variance in Project Sustainability ($R^2 = 0.692$).

4. Discussion

In this study, there is enough insight given about the significant factors that determine the sustainability outcomes in large LNG export facilities in the US. It was found out that proper risk assessment mechanisms, financial strategies, and risk management processes have great significance in making the projects sustainable [21]. From the demographic information provided, it is evident that the respondents had a high level of experience since 46.9% of the respondents had a master's degree while 32.5% had a PhD degree. This means that the responses given were those of well-experienced people who worked in the LNG, financial, government, and consulting industry. The descriptive statistical data shows that the respondents placed significant emphasis on finance and sustainability factors [22]. Financing Solutions emerged to be the category with the highest mean score (Mean = 4.15, SD = 0.56). This implies that money availability, investments, and capital management have been identified as key ingredients in ensuring success of any LNG project. Just like Financing Solutions, Project Sustainability had a very high mean score (Mean = 4.11), implying that there is an increasing recognition of the importance of economic, environmental, and operational sustainability. From the analysis conducted, it is clear that in the current era, for successful implementation of any LNG export project, it is not enough to have the technical expertise alone; one must also be able to

plan properly financially [23].

The agreement analysis also validates the importance of financing and risk management processes. Financing Solutions had the highest level of agreement (82.1%), which means that the stakeholders agree on the importance of financial methods to ensure feasibility and sustainability of the project. Risk Assessment Framework had an agreement level of 78.4%, which shows the importance of having a systematic framework of assessing risks related to LNG projects. On the other hand, Project Sustainability had an agreement level of 76.5%, which reveals that stakeholders increasingly recognize the importance of sustainability as part of the project. However, Technological Risk had the lowest agreement level (63.7%), which implies that uncertainties related to technology and innovations are considered as important factors among the stakeholders. In addition, the perceived level analysis provides more evidence on the importance of different project aspects [24]. Financing Solutions had the highest perceived level (65.7%), followed by Project Sustainability (64.5%) and Risk Assessment Framework (62.3%). Conversely, Regulatory Risk had a considerably high moderate perception (34.9%), implying that policy changes, environment regulations, and governmental requirements pose some level of uncertainty for the developers of the projects. Therefore, LNG firms require appropriate regulatory strategies and mechanisms in order to avoid possible disturbances [25].

Moreover, the findings of correlation and regression provide additional evidence on the existing relationships among the research variables. The results of Pearson correlation analysis revealed significant positive correlations among all constructs, with the strongest association being found between Financing Solutions and Project Sustainability ($r = 0.769$, $p < 0.01$). In other words, stronger financing strategies are highly related to higher sustainability performance. The results of hypothesis testing showed that all proposed relationships were statistically significant [26]. Financing Solutions positively affected Project Sustainability to the highest extent ($\beta = 0.394$, $p < 0.001$) and, secondly, Risk Assessment Framework positively impacted it ($\beta = 0.312$, $p < 0.001$). The model accounted for 69.2% of the variance in Project Sustainability ($R^2 = 0.692$). The results generally indicate that there is a need for an integrated framework for sustainable LNG export development which includes financial resilience, risk assessment capability, regulatory preparedness, and technology adaptation [20], [27]. The study shows that investors, policymakers, and project managers must focus on comprehensive financing solutions and risk management approaches to ensure the success of their projects. Such insights are helpful for improving the process of decision making in the future.

5. Conclusion

This study attention to the importance of risk assessment frameworks, financing solutions, and risk management strategies in ensuring sustainability of large-scale LNG export projects in the USA. As the findings suggest, financing approaches and risk assessment framework are crucial factors for achieving sustainable project performance. Regression analysis revealed that Financing Solutions and Risk Assessment Frameworks were the most powerful predictors of sustainability performance. In general, successful LNG project development can be achieved through an integrated approach which includes financial resilience, regulatory preparedness, technology adaptation, and risk management.

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