The Study of Adaptive Planning Application for LNG Regasification Terminal Infrastructure in Indonesia

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Abstract. Global trade for regasification LNG has reached 850.1 MTPA by February 2021 because of the enforcement of clean energy applications. The alternative of renewable energy such as hydropower, solar, and wind has developed globally, but they have not been implemented effectively in Indonesia. LNG became an alternative to clean energy because of its low carbon emissions. An estimated 26% of the 35,000 MW of Indonesia’s electricity supply project comes from natural gas-powered power plants. The scope of this study is to investigate the implementation of adaptive planning for LNG regasification facilities. The authors interview the LNG experts in Indonesia to assess uncertainties, vulnerabilities, and opportunities in its business process to identify the enabling factors for implementing the adaptive method in LNG terminal master planning. This research aims to provide an adaptive strategy for LNG Regasification Terminal to satisfy resilient and sustainable infrastructure concepts. The authors propose the Real Options Analysis using a binomial decision tree to evaluate the decision-making under uncertainty for the infrastructure LNG regasification terminal facilities. The study case for category medium to large scale with 4 MTPA, FSRU concept selected as the suitable configuration, while for the smaller scale facilities with 0.5 MTPA, the FSU with regasification barge selected as the most suitable configuration.

1. Introduction: LNG Supply Chain in Indonesia

The global regasification facilities with 39 markets worldwide have reached 850.1 MTPA (Million Tons per Annum) by February 2021, while the worldwide liquefaction capacity reached 452.9 MTPA as recorded in December 2020[1]. Natural gas is used for power generation and fuel substitution in transportation, commercial building, residences, and industries such as fertilizer plants, methanol plants, and petrochemical plants[2]. In 2019, Indonesia reduced its LNG (Liquified Natural Gas) export by 2.7 MT from the previous year[3]. The average production in Indonesia is estimated at 2.9 TSCF (Trillion Standard Cubic Feet) annually. In 2017, The gas lifting realization estimated about 6607.65 MMSCFD (Million Standard Cubic Feet per Day) with approximately 58.59% domestic use and around 41.41% exported[4]. The government predicts that the gas reserve will run out within 47 years if no new natural gas reservoir is discovered[5]. In the future, Indonesia will require gas imports to meet the LNG demand for domestic use. Figure 1 shows the natural gas demand scenarios in Indonesia. Scenario 1 represented the actual demand based on an existing contract. The second scenario represents the projected demand (2018-2027) of gas from the existing facilities for energy resources for retail, petrochemical, and refinery development master plan[4]. The third scenario is the forecasted demand as Scenario 2 and to includes
the projected additional demand for the non-retail industry. The gap between demand and supply will influence LNG business models’ sustainability to provide domestic gas demand required in Indonesia.

For the power generation sectors, the government regulates the gas price based on MEMR (Ministry of Energy and Mineral Resources) Decree No 8 of 2020 at US$ 6.00 per MMBTU at the plant gate. Thus, developing an optimum LNG receiving terminal infrastructure becomes critical to ensure the investment is worth the price. Figure 2 shows the location of the LNG Receiving Terminal in Indonesia.

Indonesia’s government has launched a Master Plan to provide 35000 MW electricity distribution throughout the archipelagic countries. The usage of LNG as a clean energy source for gas-fired power generation is well proven [6]. Supporting the gas power plant will require a transportation mode to reach remote islands with limited water depth. Historically, the LNG transportation is handled by the conventional onshore LNG facilities designed to receive the LNG bulk carrier with around 100,000 m$^3$ until Q-Max vessel size. Based on the International Gas Union, the criteria for SSLNG value chain for terminal liquefaction, regasification, and import is within 0.05 – 1 MTPA, while the maximum LNG carrier capacity is 60,000m$^3$ [7]. The small-scale LNG distribution to end-users as fuel for heavy road transport or refilling stations, power generation in off-grid locations as shown in Figure 3, and marine fuel bunkering[8]. The electricity distribution program will improve the economics for remote islands as well. The shifting demand to support remote areas introduces challenges for modifying conventional terminals for import and export to facilitate the small LNG carrier [9].
Apart from the national program to provide electricity distribution to the remote islands, the international policy also influences LNG demand. Indonesia as a member of IMO required to obey the IMO (International Maritime Organisation) policy. With the IMO effect as per January 2020 enforcing the 0.5% sulphur content of the ship’s fuel. Based on the 2nd Lifecycle GHG Emission study, LNG is currently the best available option as a marine fuel, and it was proven to reduce GHG (greenhouse gas) emissions up to 23% [1]. The demand for LNG as fuel bunkering is opening a new market for the LNG operator. The LNG operator companies in Indonesia have started to prepare for the expansion of LNG bunkering vessel infrastructures. The emerging LNG market is offering both opportunities and challenges that require flexible solutions. The formulation of an optimal solution for LNG infrastructures is quite complex. The bigger plant size is not always better; one size of LNG jetty does not fit all types of LNG carriers [10].

The authors propose a hypothesis that adaptive planning will be suitable for LNG regasification infrastructures planning. The authors would like to study the existing LNG planning process to propose the alternate approach to collaborate with LNG customers to provide flexible infrastructures that fit customer demand while sustaining its business processes. The authors assumed that Adaptive Port Planning (APP) strategy would provide flexible LNG receiving terminal infrastructure in Indonesia. This research aims to provide the adaptive planning perspective for LNG Regasification Terminal development to satisfy resilient and sustainable infrastructure concepts.

2. Literature Review: Adaptive Port Planning
The decision-makers for the infrastructure development should have considered assessing infrastructures life cycle assessment. The uncertainty of the project individually differs based on the urgency, size, design, and construction durations, and accumulated uncertainty contained in the system, such as materials specification[11]. The ignorance of the uncertainty might introduce the sunk cost or lousy investment. The APP approach was developed based on ABP (Assumption Based Planning) and APM (Adaptive Policy Making). The traditional planning method is no longer viable to answer the rapid changes towards the infrastructure’s ecosystem. The APP approach allows flexible planning to compensate for the changing environment [12][13]. The main difference in the APP approach is the continuous monitoring systems with the sets of triggers that alert the port operator, allowing sufficient time to be reactive in the time of uncertainties. The implementation of APP required collaboration from multidisciplinary sectors with a focus on flexibility and technological innovations [13]. The difference between traditional planning to the AAP concept shows in Table 1.
### Table 1. The difference between the traditional and adaptive framework [12–14].

| Stages                  | Traditional Planning                                      | Adaptive Port Planning                              |
|-------------------------|-----------------------------------------------------------|-----------------------------------------------------|
| **Project Appraisal**   | Premature commitment based on forecasting demand          | Allowing the margin for decision-making exercise (flexible decision making) |
|                         | Design based on fixed specification                        | Design based on a range of specifications (DF-X)    |
| **Front End Engineering** | Based on demand forecast                                  | Counting the opportunities & vulnerabilities        |
| **Design (FEED)**       | Single option                                             | Demand forecasting with scenario analysis           |
|                         | The availability of constructability                      | Dynamic options                                     |
| **Construction**        | Built-in redundancy                                       | Flexibility and sustainability                      |
|                         | Limited to physical and operation Innovation              | (Minimum construction waste)                       |
| **Implementation**      | The impromptu reaction towards strong signals              | Alteration in the technological, commercial adjustment, and collaborations innovations |

The flexibility in infrastructure can be defined as postulations that some changes in the system during infrastructure design life adapt to the unpredictable condition or environment [15]. The infrastructure’s flexibility is to respond to three driver categories changes which are: supply chain-related changes (external factors such as supply and demand), process system-related changes (internal factors such as technical, operational, and commercial), institutional changes (indirect factors such political issues, international policies, and new regulation) [16]. By implementing the proactive attitude, the flexibility mindset reduces adverse to risk (losses) and elevates the likelihood of positive risk (opportunities). There are various methods to evaluate the infrastructure’s flexibility benefits, such as: Net Present Value (NPV), Real Options Analysis (ROA), Internal Rate of Return, Profitability Index, Modified Internal Rate of Return (MIRR) [15]. The project development of LNG infrastructures consist of the following assessment: the demand assessment, the supply assessment, and the selection of alternative for land-based or floating infrastructures [2].

### 3. Research Methodology

The authors aim to propose a schematic method in planning for the LNG infrastructures. The adaptive planning method will impact the sustainability of the LNG or oil operator business processes. The authors have conducted a brainstorming session with LNG practitioners from Arun LNG, Bontang LNG, and PGN to assess uncertainties, vulnerabilities, and opportunities in its business process to identify the enabling factors, barriers, and strategies in LNG regasification facilities development. The brainstorming session is discussing on the following matters: the existing planning process and their action towards changes from commercial and engineering view; the uncertainties, vulnerabilities, and opportunities during LNG business operation; the infrastructure development and the selection of infrastructure configuration based on technical and commercial perspective view; and the willingness to implement flexible planning in the LNG infrastructures planning process. The author uses the following methodology while adapting the APP concept [13], as shown in Figure 4.

**Figure 4.** Research methodology.
In the event where the uncertain decision environment may occur, we may decide based on the three decision methods, which are [17]: Maximax (to find the alternative that maximizes the maximum outcome for every alternative), Maximin (to find the alternative that maximizes the minimum outcome for every alternative), and equally likely (to find the alternative with the highest average outcome)[18]. The Real Options Analysis (ROA) methods define the value of flexibility as part of decision-making processes. The ROA will improve business strategies in sectors emphasizing opportunities, promoting strategic leverages, and maximizing right to all the profits[19]. The methods to calculate the option using the continuous model developed by Black and Sholes (1973) and a discrete approach of the binomial model by Cox, Ross, and Rubinstein (1979)[20]. In order to measure the project flexibilities, also known as a real option, the valuation for managerial flexibility will use binomial Decision Tree Analysis (DTA) to solve the problem [21][22]. In the binomial methods, the price can either move up by a fixed value of $u$ or down by a fixed of $d$. The value of $u$ calculated by equating the first and second moments of binomials and using the log-normal distribution, the function for $u$ as follows [20]:

$$u = e^{\sigma \sqrt{t}}$$

Where: $u$ is pricing, $\sigma$ is volatility, $t$ is the length of the binomial period, under the assumption that $u = \frac{1}{d}$. The discrete distribution will approximate the continuous distribution in the limit; using this technique, the combination of event trees will represent the asset value $S_{ij}$. The option value will be equal to:

$$C_{ij} = \max(S_{ij} - E, 0)$$

Where: $E$ is the exercise price of the option $i$ is an index for time and $j$ is an index for state at the time of $i$.

Before the expiration, the values on the decision tree nodes use the risk-neutral probability approach, which is the maximum between the value of the exercised option and the alive option.

$$C_{ij} = \max\left(S_{ij} - E, \left(\frac{pC_{i+1,j} + (1-p)C_{i+1,j+1}}{1+r}\right)\right)$$

Where: $r$ is a risk-free rate.

The risk-neutral probability is calculated as $p = (e^{rt} - d)(u - d)$ is constant and applied throughout the decision tree. The decision tree is solving backward, and we will obtain the value of the project at a time of 0.

4. Result and Discussion

4.1. Flexibility Assessment for LNG Business in Indonesia

The objective of this research is to provide the flexibility valuation for LNG Regasification Terminal. The authors interviewed LNG stakeholders to assess the current planning system for LNG infrastructures; the respondents are LNG experts from Arun LNG, Bontang LNG, and PGN. They were facing challenges in the existing conventional LNG terminal export and import such as [7]: the LNG properties with different methane requirements, the compatibility of existing facilities to handle variant vessel sizes, the battery compatibility of existing infrastructures to adapt to diversified market (small LNG carrier and LNG trucking); the LNG logistics process has become more complex due to the various size of parcels, the growth of the market has introduced more complexity because of increased numbers of stakeholders and ownership and also the contract duration which affect the decision making for infrastructure selection. The interview with stakeholders supports the literature review statement related to the factors that become drivers, enablers, and barriers to implementing the adaptive planning for LNG infrastructures, as shown in Figure 5. The LNG practitioner has agreed that implementing flexibility in planning will cover the high risk in the uncertainties period—the objective of the flexibility itself towards the sustainability of business process in the company. Based on the brainstorming and literature review, the authors define the flexibility in LNG infrastructures as the infrastructure’s capability to
change its operational function from the original purpose with minimum cost to achieve a sustainable business process.

| Drivers | Enablers | Barriers |
|---------|----------|----------|
| • The affordability of gas | • Sustainability business process mindset | • The decreasing oil and gas price in the global market |
| • Market disruption | • Innovation in technology and ICT development | • The high technology might require skills adaptation |
| • The desire for operational efficiencies and future expansion easiness | • The material properties improvement | • The hesitance to use not well-proven technology or concept due to high investment cost |
| • LNG nature as energy sources for remote islands | • Attention for business lifecycle process | • Ignorance of uncertainty concept and long term vision |
| • Energy and environmental policy changes | • New design methods such as modularization technology | • Traditional mindset |
| • Customers requirement | | • Lack of valuation methods |

**Figure 5.** The enable, driver, and barrier of flexible LNG infrastructures [2][21–25].

The flexibility factor should become one of the factor considerations in the planning process, it will increase the design complexity and might impose unnecessary CAPEX, but it allows the room for reacting quickly during uncertainty period. **Figure 6** shows three (3) categories of flexibility aspects that are applicable in LNG infrastructure planning.

**Figure 6.** The application of flexibility in LNG infrastructures planning [24,26,27].

The risk of supply security usually determines the contract duration for financing LNG. The current trend is moving towards shorter-term contracts and spot-term delivery. The clause (Take or Pay) and the Annual Contract Quantity may fit for providing the downward flexibility for electricity production and national gas grid company [28]. The energy industry is highly vulnerable to oil and gas pricing with multiple cargo cancellations in response to the pandemic; it drives the LNG operator to perform expedited decision-making processes, negotiate for contract flexibility, and perform operational flexibility [24].

4.2. *Formulation Strategies*

The flexibility decision in LNG regasification terminal becomes the responsibility of planner from multidisciplinary. During the brainstorming session, the respondent emphasized the importance of collaboration from multidisciplinary will increase the flexibility of that infrastructure. The authors assess the available configuration structures with demand assessment, construction duration, storage area flexibility, environmental vulnerability, permit and regulation flexibility, vessel sizes, and available market types. **Table 2** shows the multidisciplinary criteria in selecting and planning for LNG regasification terminal infrastructures.

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**Table 2**

| Commercial Flexibility | Technical Flexibility | Operational Flexibility |
|------------------------|-----------------------|-------------------------|
| • Short term contract  | • Standarization and equipment interchangibility design | • Optimisation of regasification schedule to reduce storage tank sizing |
| • Spot trading         | • Modularity in design | • Usage of ORV (Open Rack Vaporizer) with seawater pump system |
| • Preferences to use FOB (Free on Board) over DES (Delivery Ex Ship) | • Movable infrastructure (offshore) | |
| • Market diversification | | |
| • Optimizing the LNG storage sizing based on scenarios demand | | |

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Table 2. The multidisciplinary consideration for planning of LNG Infrastructures

| Commercial | Process/Piping/Electrical Engineering | Marine Engineering | Project Management |
|------------|--------------------------------------|--------------------|--------------------|
| Duration of contract | Regasification processing system | Accessibility and navigations | Project construction duration |
| Captive demand (domestic market) | Marine loading arm system | Marine traffic system | Project cost |
| Transhipment market | ESD system | Bathymetry/water depth | Construction method |
| Forecasting demand | PFD (Process Flow Diagram) | Geotechnical aspect | Local content requirement |
| Customer requirement | PID (Process Instrument Diagram) | Environmental condition (wind, wave, and current) | Socioeconomic profile in the location |
| Commercial structures: tolling, merchant, integrated, government-owned | Regasification schedule | Vessel sizes | Raw materials available for construction |
| Financing LNG Project and Funding | | Ignitions risk for a worst-case scenario | Transport and logistics cost |
| Supply gas availability | | Vessel mooring analysis | |
| Market accessibility | | Safe berthing practices | |
| Regulation and Taxation | | Cargo transfer system | |
| The transportation models (LNG fleet type) | | Design and material specification | |
| CAPEX/OPEX | | Structural design and integrity | |

Figure 7 shows the illustration for the alternative’s infrastructures for LNG regasification facilities

![Illustration for LNG Regasification Terminal Infrastructure][29]

The LNG regasification terminal in Figure 7 describes as follows [29,30]:
1. Conventional onshore regasification terminal. The terminal infrastructure consists of the loading platform, mooring dolphin, breasting dolphin, land storage tanks, and land facilities.
2. FSU (Floating Storage Unit) is a floating structure with only storage facilities. The FSU option can reduce CAPEX, and the possibility of installing the small onshore regasification system will increase the buffer for storage if FSU is required to depart due to extreme environmental conditions.
3. FSRU (Floating Storage Regasification Unit) is a floating structure with regasification and storage facilities usually located offshore. FSRU system required LNG pumping, vaporization, BOG handling, offshore mooring system (turret mooring system), pipeline gas connected to the shore. FSRU can be converted from LNG carrier and operates in the lease term.

4. FRU (Floating Regasification Unit) is based on the crude oil carrier system conversion, which provides a regasification platform with an offshore mooring system. The FRU has limited LNG storage, and the LNG received from the carrier will be processed in the regasification system and transferred. The regasification system on barge coupled with storage on FSU shall be an option for a small market with a low permitting requirement.

5. FSU combined with regasification on island berth become an option where the land requirement or nearshore jetty is not available and where connection to the existing subsea pipeline is permissible.

6. SPM (Single Point Mooring) and Shuttle FSRU provide the best option to fulfill the intermittent demand. This option requires a particular FSRU vessel and is optimum if the existing pipeline system is already available for a tie-in.

The selection of regasification infrastructure follows the priority to meet safety requirements, environmental load consideration, efficiency analysis in terms of time and value, future planning, expansion potential, and design flexibility. Figure 8 shows how the authors examine each alternative's market range, adaptability, and legal socioeconomic and Figure 9 shows the CAPEX and OPEX difference for each alternative.

Figure 8. The selection priorities for LNG Regasification configuration for small to large scale demand [29–32].

Figure 9. CAPEX and OPEX comparison for the LNG facilities.
The highest CAPEX comes from the conventional offshore regasification facilities, and the highest OPEX comes from the FSRU facilities. The highest CAPEX comes from the SPM with shuttle FSRU configuration, and the highest OPEX comes from the combination FRU with FSU facilities. The storage facilities are considered a critical part of the natural gas infrastructures, and the investment for storage is also considered high CAPEX. The LNG operator should try out the optimization method for regasification scheduling such as posterior optimal strategy, intrinsic rolling strategy, and full option strategy based on the least square Monte Carlo algorithm to maximize revenue generation.

4.3. Valuation Strategy

The determination of ENPV calculates the decision-making under uncertainty (Expected Net Present Value for all scenarios). The ENPV formulations such as follows [18]:

Objective Function:

\[
\text{Maximise } ENPV = \sum_{i} s \left( P_i \times NPV_i \right) \tag{4}
\]

Where:

- \( P_i \) is a probability of occurrence,
- \( s \) is the sets of uncertainty

\[ NPV = \text{Total of (Sales of gas} - \text{Tax} - \text{Initial Gas Cost} - \text{Fixed Cost (Initial Capital Cost and Expansion Capital Cost)} - \text{Operating Cost)} \]

The constraints of the facilities selections such as capacity limits, the number of ships able to reach the area, the existing capacities, the operating limits, the gas production limits, the availability of existing facilities, expansion limits, the flow rate at the receiving facilities, demand limits and cash flow limits [18]. The author performs scenario analysis by predicting the high, medium, and low demand scenarios—the decision-making under uncertainty for the large to medium demand, as shown in Figure 10.

![Figure 10](image-url)

Figure 10. Decision tree analysis for medium to large scale LNG infrastructure facilities.

For the medium to large scale demand, we perform a study case based on required demand estimated at 4 MTPA, with the planned usage of 10 years, the scenario analysis based on the gas pricing at US$6.00 per MMBTU. The POM QM is used to simulate the objective function to obtain maximum profit. The simulation resulted in 1.804 as the expected value under uncertainty and selected the FSRU as the solution. For the medium to small scale demand, we perform a study case based on the required maximum capacity of 0.5 MTPA, with the planned usage of 4 years, the scenario analysis based on the gas pricing at US$6.00 per MMBTU. The POM QM is used to simulate the objective function to obtain maximum profit. The simulation resulted in 0.3 as the expected value under uncertainty and selected the FSU and regasification berth as the solutions.
Figure 11. Decision tree analysis for medium to smaller-scale LNG infrastructure facilities.

Regret analysis can perform the most appealing solution to the decision-makers regarding profitability and risk levels under uncertainty. Table 3 shows the regret analysis for the LNG regasification configuration.

### Table 3. The regret analysis for LNG Regasification configuration.

| Category               | Options              | S1 (high) | S2 (medium) | S3 (low) | Expected | Maximum Regret |
|------------------------|----------------------|-----------|-------------|----------|----------|----------------|
| Medium to Large Scale  | 1. ORF               | 0.09      | 0.08        | 0.66     | 0.20     | 0.66           |
| Demand                 | 2. FSU + ORF         | 0.04      | 0.03        | 0.59     | 0.15     | 0.59           |
|                        | 3. FSRU              | 0.00      | 0.00        | 0.00     | 0.00     | 0.00           |
|                        | 4. FRU + FSU         | 0.27      | 0.03        | 0.00     | 0.171    | 0.27           |
| Medium to Small Scale  | 5. FSU + Regas Berth | 0.00      | 0.00        | 0.05     | 0.005    | 0.005          |
| Demand                 | 6. SPM + Shuttle FSRU| 0.27      | 0.27        | 0.03     | 0.275    | 0.32           |

4.4. Monitoring System

Monitoring of LNG business process is identifying trends of the LNG demand and supply itself. To understand the relationship factor between the gas demand towards its sectors, the authors perform sensitivity analysis for global consumption-based on IEA (International Energy Agency) Report 2020 and national consumptions based on National Energy Council 2020. Figure 12 shows the sensitivity analysis for LNG consumption gas. The sensitivity analysis for the global consumption shows that natural gas has been the primary energy resource for the residential ($R^2 = 0.94$) and industrial sectors ($R^2 = 0.65$). The sensitivity analysis for Indonesia’s consumption shows very low relationship residential sector ($R^2 = 0.08$) and industrial sector ($R^2 = 0.10$). It shows that Indonesia does not depend on natural gas as an energy source. In such a case, the LNG global outlook may not represent Indonesia’s consumptions. Thus, the monitoring system should consider the national policy and regulations in the gas sector. In the monitoring system, the signpost’s role is to determine whether the selected alternative is still on the right track and measure the project’s success. The monitoring tools can use media scanning (Energy Outlook, International Gas Union report), expert panels, focus groups, competitor watch, and time series analysis[13].
Figure 12. Sensitivity analysis for global and national gas consumption.

During the monitoring process, the signpost will be a warning to generate action to react to the uncertainties. Table 4 recommends the monitoring actions for the LNG industry.

Table 4. The monitoring actions for the LNG industry.

| Type of Action  | Description and Examples                                                                 |
|-----------------|------------------------------------------------------------------------------------------|
| Defensive Action| An action to preserve the benefits or defencing from the outside challenges:             |
|                 | Example: Expediting small scale LNG business process supported by the development         |
|                 | of small-scale LNG carrier, ISO tank carrier, and trucking operation                     |
| Corrective Action| The basic plan is responsive to selected triggers.                                        |
|                 | Example: The conversion of LNG liquefaction terminal into regasification terminal         |
|                 | and bunkering terminal to continuously support hinterland market.                         |
| Capitalizing Action| The action to increase the opportunity probabilities                                      |
|                 | Example: The IMO sulphur cap 2020 has opened a new market for marine bunkering            |
|                 | and direct fuel vehicles                                                                  |
| Reassessment    | The action where the plan has lost its validity                                           |
|                 | Example: The LNG market depends on the customer demand; when the customer                |
|                 | decides to change to another type of energy resource or renewable energy, the energy      |
|                 | operators should consider the diversified market into renewable energy resources.         |

The diversified market and customer as per Ansoff matrix mapping of the LNG business process in Indonesia, in Figure 13, shows how the LNG industry reacted to the market volatility and rapid changes in the supply and demand side.
5. Conclusion and Future Research

5.1. Conclusion

1. From the interview, it concluded that LNG operator had taken the flexibility mindset to survive and maintain the sustainable business process such as by using modularisation and the interchangeable system in the process plant, the conversion of LNG carrier into FLNG or FSRU, the change function of the export terminal to import terminal and performing berth modification to handle a range of vessel sizes.

2. For the commercial flexibility, the current trend has taken to monitor the demand closely by taking the opportunity to have short term and spot market and exercising the financial risk options. The method Real Options Analysis using binomial decision tree has been selected as the best valuation method for selecting the most suitable alternative by considering the uncertainty event.

3. We believe that selecting LNG infrastructure configuration should be based on scenario analysis. The planning process started from the contract negotiation term and its flexibility, then technical site analysis to consider the bathymetry, navigation access, ignition risk hazards, the mooring and vessel berthing factors. The requirement to meet demand and demand capacity will influence the type of structures (land or offshore based), project duration, construction methods, and equipment.

4. The decision-making under uncertainty analysis using the Real Options Analysis using the binomial decision tree. This method is considered the most suitable method to include the uncertainty and the flexibility for LNG infrastructure configuration selection. The study case for large demand about 4 MTPA, the decision tree and regret analysis selected FSRU as the structural configuration that generated maximum profit, while the smaller scale analysis with 0.5 MTPA selected the FSU with regasification berth the maximum profit configuration for all the scenarios.

5.2. Future Research

A deepening analysis for both economic and technical perspectives is recommended to show the flexibility cost in LNG infrastructure development. Apart from that, to maximize the flexibilities of infrastructure, the authors recommend future research such as research optimization for LNG regasification storage schedule and perform simulation using two-stages stochastic to account demand uncertainties to provide the decision for expansion liquefaction or regasification facilities.

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