Research Article

LNG Portfolio Diversification Optimization Model of Thailand

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Abstract
With the increase of reliance of LNG for Thailand, tons of liquefied natural gas (LNG) are imported, however there is no report that describes the engagement by a mathematical model. This study constructed a mathematical model to analyze LNG supply of Thailand. Based on the outcome in 2022, the offered LNG supply pattern, which reduced the total LNG price, risk of politics and risk of maritime, exhibited that Malaysia, Brunei, and Australia are LNG exporter of Thailand. Additionally, when the demand of LNG in Thailand increase, the demand from Qatar does not increase due to the low competitiveness. Moreover, in the study of diversification, the details suggested the raking of suppliers that Thailand should import. The rank is as follows: Brunei, Malaysia, Australia, USA, and Trinidad & Tobacco. The study of the objective factors on the decision of Thailand shows that the risk associated with shipping is ineffective to Thailand's LNG supply due to the geographical closeness of the supplier countries. However, the risk connected to the political of supplier nations is influenced by the decision of the supply. Furthermore, this study revealed the limitation of the research associated with the LNG supply of Thailand. Hence, the finding of this study not only presented the alternative policy of Thailand but also consolidated Thailand's energy security.

Keywords: Liquefied Natural Gas (LNG), Portfolio, Optimization, Linear programming

1 Introduction

According to Fuel report: Gas 2020, the effects of the Covid-19 crisis hampered the demand increase for major Asia gas importers in the first quarter of 2020, despite the fact that these importers accounted for the majority of the region's gas imports. As developing countries recover economically and benefit from falling gas costs, it is anticipated that the region's consumption would revive and increase over the next several years. Asia-Pacific will be the primary driver of global demand growth between 2021 and 2025, mostly due to China's strong demand growth. Consequently, the concentration of the LNG market, particularly in Asia-Pacific, will quickly expand.

Thailand, a nation in the Asia-Pacific region, understood that the occurrence would coincide with the depletion of its natural gas reserves, from Department of Mineral Fuel: Annual report 2018. Gas plan 2018, which is Thailand's natural gas policy, will be released in November 2020 in order to provide a strategy for addressing impending issues. Thailand intends to become the regional LNG hub of the Asia-Pacific area and will primarily meet its future natural gas demand via LNG imports as a buyer and dealer. In the meanwhile, the International Monetary Fund (IMF) estimates that the Henry Hub price would rise steadily from $2.65 per MMBtu in 2014 to $4 per MMBtu in 2030.

According to Energy Statics of Thailand 2022 and EGAT annual report 2021, 4,395 MMSCFD of natural gas was supplied to sectors of Thailand in 2021, especially energy generation. 2,603 MMSCFD of natural gas, or 56.47 percent of the total resource used for power production, was primarily employed for electricity generation. The volume demonstrated that natural gas is Thailand's principal resource. According to DMF annual report 2021, Thailand's known natural gas reserves are 3,449.64 billion cubic feet. Therefore, the natural gas reserves are roughly sufficient to meet the demand for three years. However, Thailand continues to rely on natural gas. As mentioned in detail, to efficiently drive the plan, The planning for the management of LNG supply is needed for Thailand.

With the unchangeable energy structure of Thailand, Thailand intends to increase its reliance on natural gas from imported LNG to fulfill future local demand. Therefore, Thailand's necessary tons of LNG will be supplied by spot trading while they are at the correct price. With the situation, Thailand will be hanged on the uncertainty of the market. The cost of electricity production will be sharply swung when the natural gas price is with the high variance, which affects the economics of Thailand. In the worst situation, the cost of energy production is too high to be affordable. Therefore, the unpredicted affair affects not only the economy but also the security of Thailand. To manage the situation, The LNG supply in Thailand should be studied. One of the effective tools that can contribute to the solution is portfolio optimization.

Portfolio selection analysis or portfolio optimization is the process of selecting asset distribution in order to create the most optimal portfolio, taking into account the static components of anticipated return and risks from asset standard deviation. Therefore, the optimization approach frequently serves as an instrument for investment planning inside a commercial industry. The approach may also be applied to more research on energy, particularly resource supply planning.

One of the portfolio optimizations for LNG supply appeared in [1], The Turkish researchers produced a methodology for Turkey's LNG portfolio selection based on three factors: importation cost, the marine danger of shipping roughness, and the risk of supplier countries that might impact their supply. The paper presents portfolio optimization as linear programming with the multi-objective. The model is developed to be a wider analysis in [2]. The model is developed to provide the solution for LNG supply in terms of spot trading. The model is applied not only to importers but also applied for exporters. In [3], Iran seeks optimum natural gas export plans by using portfolio optimization that takes non-systematic risks, the geopolitical risk index, and the natural gas dependence risk index into account. In addition, they assess resilience as six scenarios in order to handle the exceptional known natural gas reserves and robust global demand growth. However, in the case of Thailand, the study should be in terms of the importer to be suited for the recent natural gas structure.

For Thailand, the possible options for energy policy are studied in previous research, but none of the papers present an option that consolidates the current Thailand policy. Moreover, the papers associated with LNG supply using portfolio optimization for finding the alternative policy are not published. Therefore, in this study, portfolio optimization is used as a tool for providing an alternative policy of LNG supply in Thailand as the primal research.

With the limitation of the available data, the model should be based on the model from [1]. The nine exporter countries are considered to be the supplier by the historical supply. The analysis scope is focused only for LNG supply in 2022. Hence, all the input data should be based on 2022. To manage the risk of hanging natural prices, all traded LNG is from long-term contracts. Moreover, the parameters are adjusted for other studies as 4 scenarios with different purposes, which the details are presented in the next section. The objectives of this study are 1) to construct the portfolio optimization model of Thailand's LNG supply, 2) to study the decision of Thailand in terms of LNG supply when the demand increased, 3) to study the effect of the diversification value on the decision of LNG supply, 4) to study the sensitivity of the parameter associated with political risk and maritime risk to the decisions of Thailand's LNG supply and 5) to identify the limitations of the study associated with LNG supply using portfolio optimization. The finding of the paper provides an alternative policy that consolidated the current policy of Thailand, which makes the policy of Thailand more effective and less unpredictable risk. It also shows the decision of LNG supply when the demand in Thailand increased. Moreover, it identifies the limitations of studying for further study. This paper not only presents alternative policy but also makes Thailand stronger in energy security.

2 Materials and Methods

2.1 *Methodology of research*

The portfolio selection for Thailand's LNG procurement is created based on Thailand's present natural gas condition and the worldwide LNG market.

The raw data from the available source are converted to be usable before being programmed into a multi-objective optimization model, in order to deliver the optimum options. The mathematical model is comprised of goals about LNG supply-related components. The issue may be resolved using a weighted mechanism. Before they are merged to form an objective model, each goal must be weighted with a separate weight value.

For input data of the programming, raw data from the accessible source must first be translated into a parameter that can be used by the programming. Only then the raw data can be used. The specifics of the output are going to be shown in the following section.

The study is divided into 4 parts. For the first part, it is a historical comparison between the model's output and Thailand's present policy to notice the difference between them; the demand for this portion is based on current consumption, which may account for the programming's dependability. In the second part, it examines Thailand's choice if the demand for or proportion of LNG in Thailand's natural gas imports grew. In this research, the present demand is raised by 25 and 50 percent. In addition, for the sake of evaluating Thailand's potential choice, the consumption is assumed to be equal to the present maximum regasification capacity. Thirdly, the diversity of supplier countries is used to monitor the ranking of the supplier nations that should be selected as suppliers. Adjusting the diversity value to 1, 0.5, 0.34, 0.25, 0.2, and 0.17 ensures that the programming is diverse with respect to LNG importation providers. In the final section, the political and security risk is weighted differently as a sensitivity study to determine the resilience of LNG policy choices. However, since the weighting of Thailand's basic approach is not quantitatively described in any of the data sources, the sensitivity analysis result will be presented and debated as a perspective.

3 Mathematic Programming

The programming in this paper is based on the previous report [1]. The issue of LNG dispatching is modeled as a multiple-objective optimization in this investigation, and the programming is used to evaluate the relative importance of three factors: economics, politics, and security. The setup details are detailed below.

3.1 *Objective function*

The major objective of the programming is to choose the best portfolio for Thailand's LNG supply while reducing the function value of chosen elements covered in this research. The economic, political, and security risks are the forms of risk that influence the LNG supply. Programming has been conceptualized as a multi-objective issue due to the range of relevant factors. To answer this issue effectively, the evaluated components must be weighed. The goals are described in full below:

The primary goal is to decrease the price of LNG importing. The equation is equal to the volume of imported LNG from the supplier I multiplied by the normalized price of imported LNG from the supplier i (Equation 1).

The second purpose is to reduce the risk posed by supply nations. The equation is equal to the amount of imported LNG from the supplier I multiplied by the normalized risk value of supplier nation imports of supplier i (Equation 2).

The final purpose of objective 3 is to minimize the marine risk associated with rough seas. The equation minimizes the amount of imported LNG from the supplier I multiplied by the normalized risk value of shipping rough from the supplier i (Equation 3).

Each goal is assigned a unique weighting value. In the basic situation, the weight value of the LNG importation price function, the risk of supplier function, and the maritime risk of shipping are respectively 0.40, 0.50, and 0.10. Combining the weighted objective functions yields the model objective (Equation 4).

By the objective's detail, the assumption of the researcher is Thailand imports LNG from the source that is with the lowest impact, which is compounded by total LNG price, risk of politics, and risk of maritime, compared to all listed suppliers.

3.2 *Programming constraints*

Constraint equations were included within the programming in order to conform the outputs of the programming to the LNG supply practices. The constraint equations illustrated the disadvantages of genuine LNG value chain circumstances, such as the diversity of LNG supply, available amount of LNG exported, and demand.

3.2.1 Diversification of source of LNG supply

With the increasing concentration of the LNG market, the negotiating strength of the importing nations has diminished [3], particularly those with a low percentage of LNG imports, such as Thailand [4]. Therefore, importing nations should diversify their LNG supply sources to enhance energy security. In the basic scenario, the maximum ratio of LNG supply to demand has been set at one-fourth to guarantee that imports of LNG come from at least four distinct exporting nations.

Due to Thailand's long-term LNG contract and in order to obtain the model's output as closest as possible to the real decision, this equation must be made inaccessible if the volume of the long-term contract exceeds one-fourth of demand.

Diversification of sources equation: The maximum amount of LNG imports from the country I is always less than the nation j's demand, which is multiplied by 0.25 in the base scenario (Equation 5).

3.2.2 Available volume of LNG exporting country.

To ensure that the programming provided the maximum volume that an exporting nation may export to an importing country, an exporting country is permitted to export LNG based on the largest monthly proportion of LNG that it exports to an importing country.

Available volume of LNG exported equation: the volume of LNG shipped of exporting country I to j at time t is always lower than the volume of LNG supply of exporting country I at time t multiplied by the maximum percentage that exporting country that can export to a nation at the same time (Equation 6).

3.2.3 Demand of importing country

LNG is an essential energy supply for fulfilling demand. Therefore, for energy security, the LNG demand of the importing nation must be met, and the provided LNG must be evaluated for its appropriateness of consumption and collection for effective management.

The demand of an importing nation equation: The demand of an importing nation is always less than the sum of the volumes of imported LNG and LNG held at the preceding mouth that is deducted by the volume of LNG determined to be stored at mouth t (Equation 7).

3.2.4 Long-term contract.

For a long-term contract, to provide the most economic advantage and come near to the actual decision, Thailand would always import LNG from the nation with whom it has a long-term contract.

Long-term contract equation: imported quantity is always greater than long-term contract volume (Equation 8).

3.2.4 Regasification capacity.

For regasification capacity, ensuring that the imported amount does not exceed capabilities. This analysis determined that the overall number of imports from supplier countries cannot exceed Thailand's capability for regasification.

Long-term contract equation: imported volume is always below the capacity of regasification (Equation 9).

3.3 *Index*

$i \in I$ = Number of LNG-exporting countries. {*USA, TRI, OMA, QAR, ANG, NIG, AUS, BRU, MAL*}

3.4 *Decision variable*

$X_{(i)}$ = Volume of LNG imported from country *i* at time *t*.
$LP_{(i)}$ = Normalized imported LNG price from a country *i*.
$CR_{(i)}$ = Normalized country risks from a country *i*.
$MR_{(i)}$ = Normalized maritime transport risks from a country *i*.
$D_{(j)}$ = Volume of LNG demand of a country *j*.
$Con_{(i)}$ = Volume of signed long-term contracts of a country *i*.
$Maxp_{(i)}$ = Maximum percentage of LNG that a country *i* can export to an importing country.
$A_{(i)}$ = Total traded volume of exporting country *i*.
Rcap = Regasification capacity of Thailand.

3.5 *Weight*

we = Weight value for imported LNG price.
wc = Weight value for risk of supplier country.
wm = Weight value for maritime risk of shipping rough.

3.6 *The linear programming model*

Objective function:

$$min\ f_{optimal}^{LP} = \sum_i LP_i X_i \quad (1)$$

$$min\ f_{optimal}^{CR} = \sum_i CR_i X_i \quad (2)$$

$$min\ f_{optimal}^{MR} = \sum_i MR_i X_i \quad (3)$$

Model function:

$$min\ f_{optimal} = we(\sum_i LP_i X_i) + wc(\sum_i CR_i X_i) + wm(\sum_i MR_i X_i) \quad (4)$$

$$X_i \leq 0.25 D_j \ ; \forall i \quad (5)$$

$$X_i \leq Maxp_i A_i \ ; \forall i \quad (6)$$

$$\sum_i X_i \geq D_j \ ; \forall j \quad (7)$$

$$X_i \geq Con_{ij} \ ; \forall i \quad (8)$$

$$X_i \geq REGcap \ ; \forall i \quad (9)$$

4 Data

Due to the availability of reference sources, all the data for analysis in this research are based on data provided in 2022. Exporting nations are from the list of LNG exporting nations [4]. The study's scope includes nine exporting nations. The availability of data, such as total exporting volume, a distance of exporting port to Thailand, nation risk, and maritime risk, is the primary factor in selecting the countries. In addition, the other factor in country selection is supply potential, which is based on the exporting nations that supplied Thailand with LNG in 2021. To simulate the LNG market using a mathematical model, the nations are considered to be modules, as indicated in Table 1.

For this study, all parameters used for programming Thailand's LNG importation portfolio were encoded in GAMs using the XPRESS solver on an Intel® Pentium® CPU 4415Y @ 1.6 GHz and 8.00 GB.

Table 1: Detail of exporting countries and node representation

Supplier Country	Operator	Node Code
USA	Covepoint LNG LP	USA
Trinidad & Tobago	Atlantic LNG	TRI
Oman	Omam LNG	OMA
Qatar	Qatar Operation Company	QAR
Angola	Angola LNG	AGL
Nigeria	NLNG	NGR
Australia	BG Group and Santos Limited	AUS
Brunei	Brunei LNG	BRU
Malaysia	Petronas	MAL

4.1 *Importation cost*

The import price is derived from the actual cost of transporting LNG. The price is derived from the freight and natural gas costs. The charter charge, oil-off cost, and canal toll all add to the freight expense. The details are in Tables 2–4.

The computation of the parameter requires the distance of shipping roughly from suppliers to Thailand and the specifications of the LNG carrier in order to determine the trip day of Shipping. Thailand's Map Ta Put port providers' distances and approximate estimates come from [5]. In addition, to guarantee that the rough is as close as possible to real shipping, the rough is permitted to travel through Panama Canal and Suez Canal. In this research, the published report [6] is consulted for the LNG carrier's specifications. The carrier can contain LNG by 160,000 Cubic meters of LNG or 3.4 trillion BTU, and the carrier's speed is 17 knots or 408 Nautical miles/day.

Table 2: Detail of fright and importation cost from exporter to Thailand (A)

Supplier Country	Start Port Name	Port Code	Distance (Nautical mile)	ApproxiMated Voyage Day
USA	Baltimal	US BAL	11,545	28
Trinidad & Tobago	Point Fortin	TT PTF	11,496	28
Oman	Muscat (Qalhat)	OM MCT	3,889	10
Qatar	Ras Laffan	QA RLF	4,325	11
Angola	Luanda (Soyo)	AO LAD	7,889	19
Nigeria	Bonny	NG BON	8,707	21
Australia	Gladstone	AU GLT	3,875	9
Brunei	Lumut	BN LUM	947	2
Malaysia	Bintulu	MY BTU	911	2

Table 3: Detail of fright and importation cost from exporter to Thailand in USD/MMBtu (B)

Supplier Country	Node Code	Charter Fee	Boil-off	Canal Toll	Fright Cost
USA	USA	0.58	0.53	0.07	0.73
Trinidad & Tobago	TRI	0.56	0.51	0.16	0.81
Oman	OMA	0.20	0.24	-	0.23
Qatar	QAR	0.22	0.26	-	0.25
Angola	AGL	0.38	0.46	-	0.44
Nigeria	NGR	0.42	0.50	-	0.48
Australia	AUS	0.18	0.14	-	0.14
Brunei	BRU	0.04	0.03	-	0.05
Malaysia	MAL	0.04	0.03	-	0.05

Table 4: Detail of fright and importation cost from exporter to Thailand (C)

Exporting Country	Node Code	Importing Cost (USD/MMBtu)	Normalized Importation Cost
USA	USA	13.39	0.1082
Trinidad & obago	TRI	13.45	0.1082
Oman	OMA	16.46	0.1324
Qatar	QAR	16.50	0.1327
Angola	AGL	17.02	0.1356
Nigeria	NGR	16.84	0.1363
Australia	AUS	16.95	0.0835
Brunei	BRU	10.39	0.0816
Malaysia	MAL	10.21	0.0816

For finding the freight cost, charter fee, boil-off cost, and canal toll are calculated first. For the charter fee, the charter fee is calculated from voyage day and the day rate of shipping. The day rate is from [6], which is 70,000 USD/day. For boil-off cost, it is the cost of the fuel used for shipping. boil-off cost is calculated from the used fuel rate for shipping by 0.15 percent of inventory per voyage day. In this study, the LNG price of this study is based on [1]. For canal toll, the Panama Canal fee and Suez Canal fee are based on [7] and [8] respectively. On 1st June 2022, the fee for Panama Canal is 232,398.55 USD or 0.07 USD/MMBTU, and the Suez Canal fee is 570,808.06 USD or 0.16 USD/MMBTU.

4.2 *Maritime risk of a shipping rough*

Maritime risk is the possibility of becoming a victim of piracy or being involved in a hazardous occurrence when transporting an LNG carrier from exporter to importer. This analysis is based on the frequency and location of the incidence [9]. Each exporter's roughs to Thailand aggregated the number of events to determine their risk. Similar to the economic risk and import cost, the maritime risk is normalized prior to being included in the mathematical model. The details are in Table 5.

Table 5: The detail of maritime risk of shipping rough

Supplier Country	Node Code	Amount of Incidents	Normalized Maritime Risk ($MR_{(i,)}$)
USA	USA	7	0.02652
Trinidad & Tobago	TRI	37	0.14015
Oman	OMA	37	0.14015
Qatar	QAR	37	0.14015
Angola	AGL	43	0.14015
Nigeria	NGR	104	0.39394
Australia	AUS	4	0.01515
Brunei	BRU	0	0.00000
Malaysia	MAL	1	0.00379

4.3 *Risk of supplier country*

A supplier country's risk highlights the fragility or risk and vulnerability of each exporter in terms of economic, political, and social cohesiveness. The risk represents the availability of LNG from the exporter.

The risk may be determined by [10]. Similar to other risks, the national risk is formalized prior to being included in a mathematical model. The details are in Table 6.

Table 6: The detail of risk of supplier country

Supplier Country	Node Code	Fragile States Index	Normalized Country Risk ($CR_{(i)}$)
USA	USA	44.6	0.0895
Trinidad & Tobago	TRI	52.9	0.1061
Oman	OMA	50.4	0.1011
Qatar	QAR	44.1	0.0884
Angola	AGL	89	0.1476
Nigeria	NGR	98	0.1966
Australia	AUS	21.8	0.0437
Brunei	BRU	56.3	0.1129
Malaysia	MAL	56.9	0.1141

4.4 *Available volume*

To ensure that a supplier may export Liquefied Natural Gas (LNG) to Thailand, the available volume is the amount that a supply nation can dispatch to an importer country, which is based on the highest traded volume in 2020. The source of the data is referred to [4]. The data has been presented in Tables 7 and 8.

Table 7: The detail of available volume (A)

Exporting Country	Node Code	A Largest Importer Country	Largest Traded Volume (Billion Cubic Meter)	Total Traded Volume (Billion Cubic Meter)
USA	USA	China	12.4	95
Trinidad & Tobago	TRI	Spain	1.1	9.1
Oman	OMA	South Korea	6.3	14.2
Qatar	QAR	South Korea	14.1	106.1
Angola	AGL	India	1.4	4.7
Nigeria	NGR	Italy	4.3	23.3
Australia	AUS	China	43.6	108.1
Brunei	BRU	Japan	5.8	7.6
Malaysia	MAL	Japan	13.9	33.5

Table 8: The detail of available volume (B)

Exporting Country	Node Code	A Largest Importer Country	Total Traded Volume (Trillion BTU) ($A_{(i)}$)	Percentage of Largest Traded Volume ($Maxp_{(i)}$)
USA	USA	China	3,241.50	0.1305
Trinidad & Tobago	TRI	Spain	310.50	0.2222
Oman	OMA	South Korea	484.52	0.1329
Qatar	QAR	South Korea	3,620.24	0.5568
Angola	AGL	India	160.37	0.2979
Nigeria	NGR	Italy	795.02	0.1845
Australia	AUS	China	3,688.48	0.4033
Brunei	BRU	Japan	259.32	0.7632
Malaysia	MAL	Japan	1,143.05	0.4149

4.5 *Demand*

In the base assumption of this analysis, Thailand's demand is the total traded volume of LNG in 2021 from [4]. In 2021, Thailand purchased 7.5 billion cubic meters of LNG, equivalent to 313.91 trillion BTU. The volume represents 1.2 percent of the overall traded volume in worldwide commerce.

To further examine the decision if Thailand's demand quickly increases, the demand is raised by 25 and 50 percent of the current demand as research scenarios, resulting in a demand volume of 392.39 and 470.86 trillion MMBTU, respectively.

In the case of Thailand being an LNG hub, the demand is the maximum volume that Thailand can import or the storage volume of Thailand. Therefore, the demand in the case is based on capable of storage, which is from [11]. The nominal capacity of Thailand is 21 million tons per annual (MTPA) or 1,113.72 trillion Btu.

4.6 *Long-term contract*

According to [8], Thailand has contracts in 2022, one of which is signed directly with Qatar for 2 MTPA or 92.81 trillion BTU per year. Other contracts have been signed as a portfolio, making it impossible to determine a country's source. Therefore, in this analysis, Qatar is considered to hold the sole contract.

4.7 *Regasification capacity*

According to [8], Thailand will have two LNG facilities in 2022. The first terminal designation is LNG Map Ta Phut terminal 1, which has a regasification capacity of 11.5 MTPA. The second terminal is named LNG Map Ta Phut terminal 2 and has a regasification capacity of 7.5 MTPA. Thus, Thailand's regasification capacity is 19 MTPA, or 881.7 trillion BTU.

5 Result and Discussion

The portfolio optimization of Thailand's LNG supply offered an optimal solution, which concerned economic, political, and security risks in 2022. The output of the LNG supply was compared with the current policy to ascertain the reliability of the programming.

5.1 *Historical comparison*

In order to investigate the efficiency of the programming to the real supply, a comparison was conducted between the supply output and the current policy in Table 9 and Figure 1.

Table 9: The comparison of the result and the current policy for LNG supply in Trillion BTU

Exporting Country	The Current Policy		Demand of 2022	
	In Trillion BTU	In Percentage	In Trillion BTU	In Percentage
USA	17.0605	5.62%	0	0
Trinidad & Tobago	10.2363	3.37%	0	0
Oman	10.2363	3.37%	0	0
Qatar	122.8356	40.45%	92.81	29.57%
Angola	6.8242	2.25%	0	0
Nigeria	40.9452	13.48%	0	0
Australia	34.121	11.24%	64.147	20.43%
Brunei	10.2363	3.37%	78.478	25%
Malaysia	51.1815	16.85%	78.478	25%
Summary	303.6769	100%	313.913	100%

The results exhibited that the total volume of the LNG supply for the current policy and demand of 2022 is different by 10.2361 trillion BTU, which can be counted as a 3.37 percent of difference, but the supply pattern of both showed differently.

In real supply, the nine suppliers are chosen to import LNG. The volume of LNG from Qatar is the highest imported volume, which is 122.8356 trillion BTU or 40.45 percent of the total volume. Moreover, the remainder of the demand is satisfied by other countries. With the high volume from a single supplier country, it can be demonstrated that Thailand highly depends on the LNG from Qatar. The high dependency on LNG supply would consolidate the effect of political risk, which is a disadvantage for Thailand.

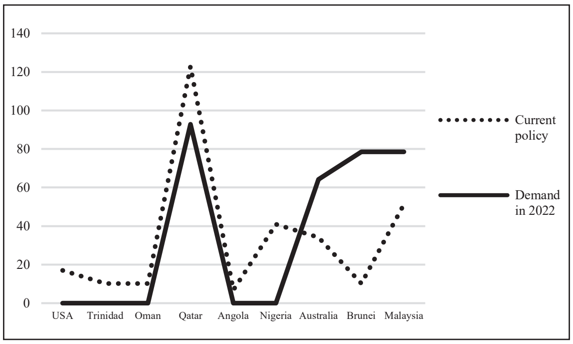

Figure 1: the detail of the result and current policy for LNG supply of Thailand in trillion BTU.

However, in contrast to the actual supply, by using programming, only four suppliers are chosen for importing the LNG. The selected countries are Qatar, Australia, Brunei, and Malaysia. Like the actual supply, LNG from Qatar is decided to be the highest volume by 92.81 trillion BTU or 29.57 percent of the total volume. However, in the output, the dependency on a single supplier is lower than the actual supply. Hence, the output offers the pattern of LNG supply that lowers the effect of political risk from the current policy. In addition, with the supplier's selection, the details demonstrated that the supplier considered the natural gas price. Hence, from the calculation of natural gas price, the total natural gas price of output is also lowered from the actual supply.

The details demonstrated that the model could offer the pattern of LNG supply in which the total volume is close to the actual supply and reduce the effect of political risk by lowering the dependency on a single supplier. Moreover, as the output, the total natural gas price is lower than the actual supply.

5.2 *Case of increased demand*

To manage further demand, the decision of Thailand is studied when the demand increases by 25% and 50%,

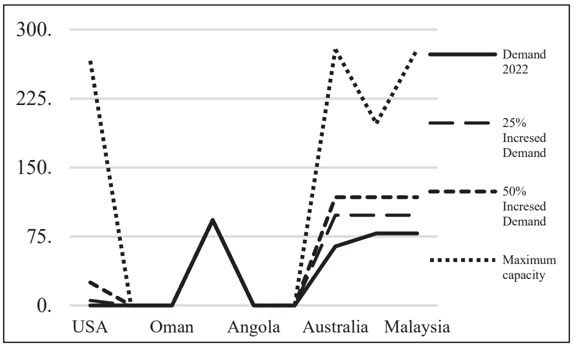

Figure 2: the detail of the result and current policy for LNG supply of Thailand in trillion BTU.

and it is increased to be the maximum capacity of LNG regasification of Thailand. The output is in Figure 2.

The result offered the decision that the growth in Thailand's LNG demand is satisfied by an equally increased volume from Malaysia, Brunei, and Australia. If demand increases, the production is also made available to the United States, the only other supply nation. Lastly, the amount from Qatar has not grown despite an increase in demand.

The detail demonstrated that Malaysia, Brunei, and Australia are selected to be suppliers for Thailand because the price of each is much more competitive compared with other suppliers. Hence, it reflected that Thailand should firstly import the gas from a supplier with a low natural gas price for economic advantages.

It is important to note, from the result, that the volume of LNG from Qatar does not increase when the demand increased. The detail demonstrated that because of the high LNG price of Qatar, in the increase of demand, Thailand imports natural gas from Qatar by only 122.84 trillion BTU how many equal to the signed contract.

5.3 *Distribution value adjusting analysis*

In order to investigate the effect of adjusting the diversification value to the decision of LNG supply. It is adjusted to be 1, 0.5, 0.34, 0.25, 0.2, and 0.167. The details are shown in Table 10.

The result exhibited that LNG from Qatar is always imported due to its long-term contract, and the same amount is imported regardless of the distribution values. The finding reveals that the programmer initially envisaged importing LNG from a Qatar-only long-term contract.

The volume from the source is imported till the volume equals the available volume or the ratio of diversification ratio, moreover, the remaining demand is satisfied by the supplier with the lowest impact or risk associated with importing. Furthermore, the selection is repeated until the demand is entirely met. The outcome demonstrates that the programming choice for this investigation prioritizes the indicated provider.

With the increase in the least number of providers, the model showed the prioritization of the suppliers that Thailand should import. The ranking of the suppliers is as follows: Brunei, Malaysia, Australia, USA, Trinidad & Tobacco.

Table 10: The detail of varying distribution value

Supplier Countries	Diversification Value (1/n), (n = least number of supplier)					
	1 (n = 1)	0.5 (n = 2)	0.34 (n = 3)	0.25 (n = 4)	0.2 (n = 5)	0.167 (n = 6)
USA	0	0	0	0	32.755	52.298
Trinidad & Tobago	0	0	0	0	0	11.911
Oman	0	0	0	0	0	0
Qatar	92.81	92.81	92.81	92.81	92.81	92.81
Angola	0	0	0	0	0	0
Nigeria	0	0	0	0	0	0
Australia	0	0	7.642	64.147	62.783	52.298
Brunei	197.903	156.957	106.73	78.478	62.783	52.298
Malaysia	23.201	64.147	106.73	78.478	62.783	52.298

5.4 *Sensitivity analysis*

To study the sensitivity of the factors associated with the LNG supply to the decision of Thailand, the weight of the objectives is adjusted for the study. The comparison was in Figure 3.

In Figure 3, the result exhibited that an increase in the weight of the maritime risk does not affect the decision of the base strategy of the output. In those scenarios, the demand is met by LNG from the four primary suppliers, which are Qatar, Australia, Brunei, and Malaysia.

As a result, due to the geographical closeness of the supplier nations, the risk connected with the security of the shipping channel has no effect on the LNG supply strategy, as determined by the robustness test. The decision to modify LNG policy is influenced by

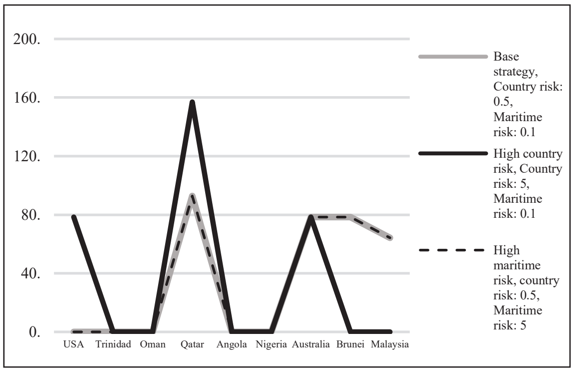

Figure 3: detail of sensitivity analysis in trillion BTU.

the growing significance of the political risk connected with supply nations. Consequently, the risk connected with the politics of supplier nations is influential in determining Thailand's LNG supply strategy.

With the mentioned detail, it demonstrated that the risk associated with the politics of supplier nations is influential in determining Thailand's LNG supply strategy. It also determines the preferred supplier country choice when assessing the further LNG supply security strategy.

6 Conclusions

As the outcome of the portfolio optimization for Thailand's LNG supply, it showed that the model is successfully constructed as a mathematical model. With the highly competitive LNG price for Thailand, Malaysia, Brunei, and Australia are selected to be the supplier of Thailand. Consequently, the decision affected the LNG supply pattern which reduced the total LNG price, risk of politics, and risk of maritime supply in 2022. From the investigation of the increase of demand, LNG from Qatar is not be increased. The detail demonstrated that with a couple of inadequate competitivity of the LNG price and the signed agreement, LNG from Qatar is imported by only an equal volume of the contract. As the study of the effect of diversification, the suppliers are prioritized for being the supplier of Thailand. The ranking is as follows: Brunei, Malaysia, Australia, USA, Trinidad & Tobacco.

From the investigation, the output showed the decision process for the LNG supply in Thailand. The volume from the source is imported till the volume equals the available volume or the ratio of diversification ratio, moreover, the remaining demand is satisfied by the supplier with the lowest impact or risk associated with importing. Furthermore, the selection is repeated until the demand is entirely met. The outcome demonstrates that the programming choice for this investigation prioritizes the indicated provider. Due to the geographical closeness of the supplier countries, the risk associated with shipping is ineffective to Thailand's LNG supply. Unlike the risk of shipping, the risk connected to the politic of supplier nations is influenced by the decision of the supply. Hence, for further policy planning, the political factor should be concerned.

According to the result and the conclusions, the possible adaptation of the model is a what-if analysis for studying cases of Thailand possibly faced in the present and future. For example, the operation decision if Qatar is not able to export LNG to Thailand, if any storage of Thailand is shut down, and other issues associated with Thailand's LNG supply system. However, this study had some limitations. Firstly, the LNG supply of Thailand is managed only by a state enterprise, therefore, any relevant data, e.g., the actual spot traded LNG price of suppliers, the price rate of regasification and storage, the actual injected LNG storage, etc. is inaccessible for the general public. Second, there were the unaffordable necessary data, the raw data, e.g. the predicted natural gas of each supplier country, have high-fee access. Hence, the studying associated with the natural supply of Thailand hugely needs economic support for the research by the general public. Finally, if this information were available, then not only could the model be improved, but also more studies could be undertaken that would prove beneficial for Thailand's LNG supply. For further expansion, the model is designed to be flexible for further needs associated with Thailand's LNG supply. Therefore, the model still needs more developments for specific studies. one example is the study of spot trading of LNG. The programming is developed not only to describe the natural gas supply but also to enhance the analysis of programming to be a more efficient decision provider.

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Author Contribution

N.T.: conceptualization, data acquisition, data analysis, methodology, writing an original draft, reviewing, and editing; S.M.: conceptualization, research design, project administration; C.U.: research design; L.L.: research design. All authors have read and agreed to the published version of the manuscript.

Conflicts of interest

The authors declare no conflict of interest.

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