Sustainability Key Performance Indicators for Thailand's Upstream Oil and Gas Industry

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Abstract

This article aimed to study and propose key performance indicators and sustainability models for Thailand's upstream oil and gas industry. This propose is based on a literature review and a survey of academicians and industry experts to achieve sustainable operations. The analytical hierarchy process adopted prioritizes indicators based on triple bottom line aspects.

The oil and gas exploration and production industry is one of the most important for driving a nation's economy. Additional income is generated through royalty payments, special remuneration benefits, petroleum income tax, and revenues from joint development. However, the business carries high risk, including the uncertainty of unproven geological reserves; high cost of production; high intervention and maintenance costs; dependency of production capability on the weather; price fluctuations; and cost of treatment of waste and spills. Therefore, the industry makes efforts to be more sustainable by causing less harm to the environment and society while making profits, building relationships with partners and investors, and enhancing its competitive advantage for long-term benefits to the bottom line.

Even in times of low energy demand, the momentum and intensity to measure sustainability in the upstream oil and gas industry are maintained. As we move towards a more sustainable future, the upstream oil and gas sector should be considered a sustainable indicator to verify overall performance and measurable. Moreover, the oil and gas industries in Thailand's upstream sector are increasingly challenged to maintain business integrity. To ensure national energy security, the proposed sustainability KPIs and sustainability model could be used as guidance.

Keywords: Sustainability Key Performance Indicators; Exploration and Production; Analytical Hierarchy Process; Oil and Gas

Introduction

Global energy demand is gradually declining due to the role of hydrocarbons. However, the overall share of energy consumption, oil and natural gas are significant proportions compared to the others(BP, 2022). Currently, fossil fuels are the major consumption ratio, but the tendency of renewable energy is to increase rapidly. For these reasons, the upstream oil and gas sectors are increasingly challenged in their responsibility to ensure less environmental impact on society and that appropriate technologies are used to improve their safety and production performance. Even in low hydrocarbon demand, the momentum and intensity of sustainability in the upstream oil and gas industry are maintained. As we move towards an ever more sustainable future, the upstream oil and gas sector should be considered a sustainable indicator to verify overall performance in all aspects.

Over three decades, the exploration and production (E&P) sector has had one of the greatest business impacts on Thailand's economy, society, and environment. This industry has strictly followed government rules and regulations not only to comply with the law but also to improve business sustainability and its impact on society. Thailand still relies on petroleum as a primary energy source, especially natural gas, which accounts for 43% of the primary commercial energy; 69% of its natural gas comes from domestic resources (DMF, 2020).

Organizations follow several key performance indicators (KPIs) to establish business sustainability and address different challenges. This study aimed to develop KPIs for the upstream oil and gas (O&G) industry in Thailand, using the triple bottom-line approach (profit, people and the planet) at the organizational level and integrating the three dimensions; economic, social, and health, safety, security, and environment (HSSE), a regulatory requirement for petroleum companies into the proposed sustainability conceptual model.

This study differs from previous research in this field in three ways. First, it focuses on a specific country, while the previous studies focused on KPIs for sustainable production for the oil and gas sector in general (Elhuni & Ahmad, 2017). While Thailand can produce and supply oil and gas from indigenous sources, it remains a net energy importing country (Leesombatpiboon & Joutz, 2010). Second, the interviews were conducted by various experts linked to the upstream O&G field in Thailand and were not limited to employees in E&P companies. Finally, to the best of our knowledge, it is the first study to propose a sustainability model for Thailand's upstream O&G, as a guideline to ensure national energy security.

Research Objectives

1. To propose a key performance indicator for sustainability in Thailand's upstream O&G industry using the triple bottom line approach, and
2. To propose a sustainability model for Thailand's upstream O&G sector.

Literature Review

Exploration and production (E&P) businesses in upstream oil and gas are known to be high-risk, high-return, the latter depending upon geological characteristics of the sites, reserves, and market demand. They need high investment and are more complex than other phases (Barata et al., 2014).

The United Nations Development Programme (UNDP), the International Finance Corporation (IFC), and the International Petroleum Industry Environmental Conservation Association (IPIECA) developed a report titled "Mapping the oil and gas industry to the SDGs: An Atlas" in 2017 (UNDP, 2017) in order to collaborate with the O&G industry and ensure its ability to achieve the relevant goals.

The sustainable development of upstream oil and gas relates to environmental concerns, such as oil spills, hydrocarbon pollution, and greenhouse gas emissions(Gurumo & Lixin, 2011). Some nations incorporate environmental considerations into the technical qualification portion of auctions (Gurumo & Lixin, 2011). Most environmental damage is caused by unsafe or unsustainable practices that could result in a serious accident. For example, the largest oil spill in the Gulf of Mexico was the Deepwater Horizon spill; an oil release of approximately 4.6 million barrels 87 days before the well was capped resulted in severe air pollution and consequent health impacts(Beland & Oloomi, 2019). These major events have an impact not only on health and the environment, but also on the industry's social and financial stability and reputation. Consequently, the combined effect of health, safety, and environment (HSE) is a crucial indicator for ensuring the long-term integrity of assets in the industry.

In addition, HSE indicators are included in a company's sustainability report, which is an essential method for achieving business requirements and stakeholders' expectations (Orazalin & Mahmood, 2018). International Oil and Gas Producers Association (IOGP), American Petroleum Institute (API), and International Petroleum Industry Environmental Conservation Association (IPIECA), with additional indicators from the Global Reporting Initiative (GRI) (Schneider, 2013).

The major empirical findings (Andreassen, 2017) indicate that the IPIECA/API/OGP oil and gas sustainability reporting guidelines influence production safety disclosure more than the GRI global sustainability reporting guidelines. Due to the fact that IPIECA specializes in providing recommendations for sustainability reporting to the oil and gas industry, their standards emphasize a variety of safety issues pertinent to oil firms' production processes. These guidelines encourage oil companies to include issues of particular significance to the industry in their annual reports. The global GRI guidelines emphasize the significance of mainstreaming sustainability reporting. Because they are intended to capture general business activity as opposed to industry-specific issues, the guideline does not contain recommendations for oil companies regarding specific production safety issues. In addition, (Hourneaux Junior et al., 2017) utilizes GRI to determine the connection between a company's strategy and its sustainability aspects.

Balancing all these aspects is key to ensuring sustainability. Key performance indicators (KPIs) are recognized as effective tools for assessing and evaluating the overall performance of a business. Some studies have proposed a set of sustainability KPIs that focus on potential environmental contamination caused by on-surface oil spills from offshore oil and gas installations(Crivellari et al., 2021), while some others have identified key indicators that reflect reputation loss in oil and gas pipeline failure (Chen et al., 2019). One study proposed six key HSE performance indicators in petroleum industries (Yan et al., 2017). Another proposed a set of KPIs for evaluating sustainable production in the petroleum sector using the analytical hierarchy process (AHP) and found the most important indicators for evaluating sustainable production in the oil and gas sector based on the triple bottom line of sustainability in economic, environmental, and social factors are net profit, flaring gas, and preventing corruption (Elhuni & Ahmad, 2017).

There haven't been many studies on sustainability KPIs in the upstream oil and gas industry, especially in Thailand. The linked study that was discovered looked into KPIs for long-term production in the oil and gas industry in general(Elhuni & Ahmad, 2017).

In conclusion, there has been limited research into sustainability KPIs in Thailand's upstream oil and gas industry. It is very vital for Thailand's upstream oil and gas sectors to be prepared and secure its energy security in the future. Table 1 illustration of how sustainability indicators are used in the oil and gas industry, and the information source is shown in Table 2.

Table 1 The example of sustainability indicators used in the O & G industry

	The information's source																							
Indicator	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Income or financial performance related		✓														✓					✓			
Unit Cost per barrel		✓	✓													✓								
Daily Sales or Production Volume		✓	✓								✓													
Return on investment							✓																	
Return on asset																✓					✓			
Maintain Reserve to Production ratio		✓	✓							✓														
Cost optimization program, CAPEX and OPEX program		✓	✓																					
Workforce/ Workforce training and development/ Working conditions	✓		✓								✓	✓			✓						✓			
Value to society	✓	✓	✓																					
Psychosocial/ HSE risk	✓													✓										
Gender equalities and Diversify	✓																							
Partner and Stakeholder engagement	✓														✓		✓							
Anti-corruption	✓																✓				✓			
Governance & management system	✓														✓		✓							
Lost Time Injury Frequency Rate		✓									✓		✓		✓		✓				✓			
Total Recordable Incident Rate		✓									✓		✓		✓		✓							
Loss of Primary Containment		✓											✓											
Fatal Accident Rate											✓		✓				✓							
Oil spills/ spills		✓			✓						✓		✓				✓	✓			✓			
GHG, CO2 emission Sustainable emissions reductions		✓	✓							✓	✓	✓	✓				✓	✓			✓	✓		
Hazardous waste, waste reduction and waste management		✓	✓	✓							✓	✓	✓		✓			✓			✓			
Baseline study for onshore-offshore areas/ Marine environment		✓	✓		✓	✓																✓		
Big data or Digital Transformation		✓	✓						✓														✓	✓
Robotics and Artificial intelligence		✓	✓					✓	✓										✓	✓				
Boost contingence resource			✓	✓																				

Table 2 The information's source.

No.	Authors / Sources	No.	Authors / Sources	No.	Authors / Sources
1	IPIECA	9	(Longlong & Yifei, 2012)	17	(Anis & Siddiqui, 2015a, 2015b)
2	Company best practice	10	(Martchamadol & Kumar, 2012)	18	(Frank et al., 2016)
3	Expert advice	11	(Infante et al., 2013)	19	(Shukla & Karki, 2016b) and (Shukla & Karki, 2016a)
4	(Watson, 2020)	12	(Yusuf et al., 2013)	20	(Koroteev & Tekic, 2021)
5	(Gulas et al., 2017)	13	(Schneider, 2013)	21	(Elhuni & Ahmad, 2017)
6	(Gurumo & Lixin, 2011)	14	(Vestly Bergh et al., 2014) and (Bergh et al., 2018)	22	(Abdulrahman et al., 2015)
7	(Sheikhzadeh et al., 2012)	15	(Barata et al., 2014)	23	(Desai et al., 2021)
8	(Anisi & Skourup, 2012)	16	(Sharma, 2013)	24	(Mohammadpoor & Torabi, 2020)

A total of twenty-one literature sources related to sustainability KPI in upstream oil and gas. Moreover, three data sources from expert advice, company best practice and IPIECA are included.

Conceptual Framework

The conceptual framework of this study illustrated in Figure 1.

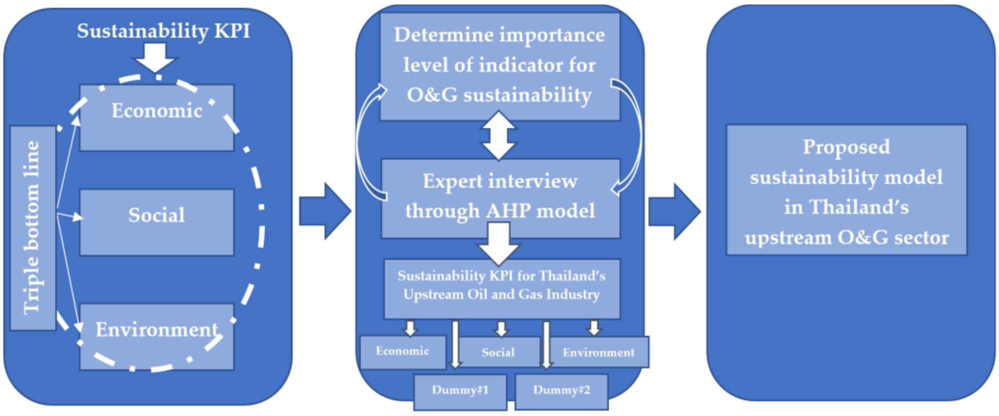

Figure 1 Conceptual Framework.

Research Methodology

This research framework can be divided it into four research design phases of 11 steps in Figure 2.

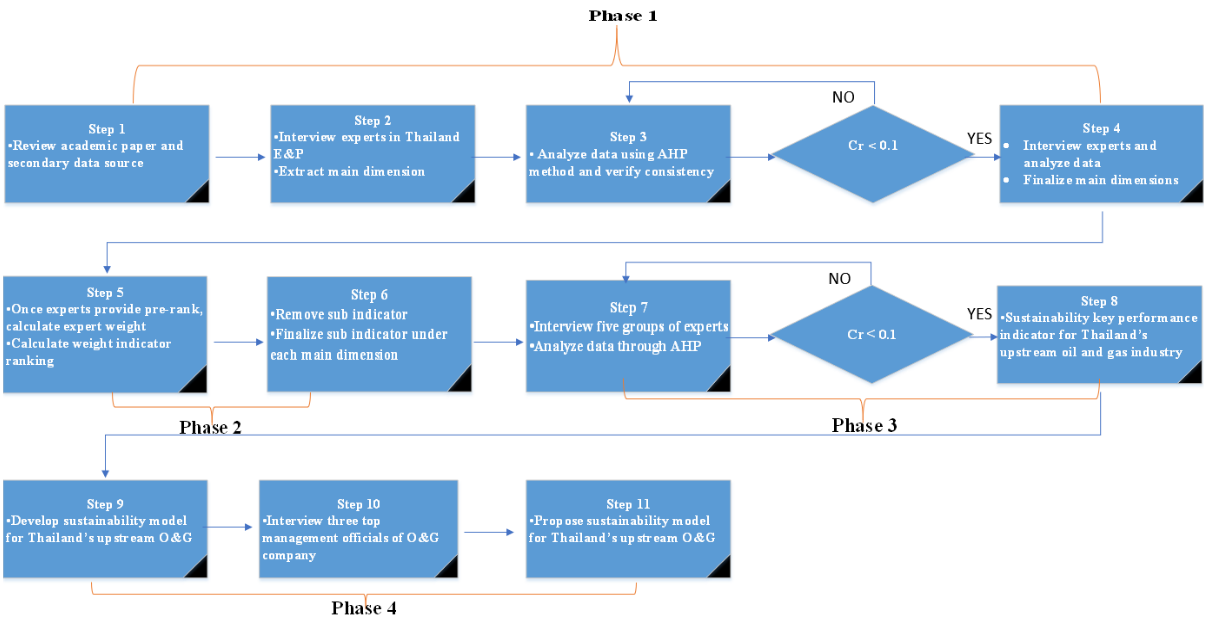

Figure 2 Research design by author

In Phase 1, academic papers, related primary data sources, and available published documentation were reviewed, and data were collected to compose draft sustainability KPIs and develop a questionnaire. The participants belonged to five categories: government officers, academics, employees of oil and gas companies, contractors with oil and gas companies, and employees of non-governmental organizations. In the preliminary session in Phase 1, 10 experts were interviewed to determine their opinions and thoughts about the main dimensions of the sustainability KPIs. The data were analyzed using AHP, after which the preliminary results on the main dimension were gathered to interview experts again and finalize the main dimensions. In Phase 2, the less important sustainability KPIs were eliminated using weighted indicator ranking. The sustainability KPI that received the highest ranking was included, and sustainability KPIs for the subdimension under the main dimension, called the sub-dimension, were selected. In Phase 3, 20 experts from the five groups were interviewed. The AHP approach was used to develop the model and construct a hierarchy together with the sustainability KPI's weight using a pairwise comparison questionnaire through the scale. The consistency ratio was then calculated. Finally, in Phase 4, the sustainability model for Thailand's upstream O&G was developed based on the Phase 3 results and interviews with three top managers with wide experience in the upstream oil and gas industry in Thailand.

Analytic Hierarchy Process (AHP)

AHP is widely applied by decision makers and researchers(Russo & Camanho, 2015). This method is developed by Saaty (1980). The general theory of measurement is the Analytic Hierarchy Process or AHP(Saaty, 1987) and widely used for researcher. These theory "measurement through pairwise comparisons and relies on the judgements of experts to derive priority scales"(Saaty, 2008). The level of hierarchies was constructed through AHP pairwise comparison(Saaty, 1990). The decision was structured in a hierarchy from ultimate goal, criteria, sub criteria and set of alternatives. After that set of AHP pairwise comparison matrix (A) or called judgment matrix were constructed as;

$$A = \begin{bmatrix} a11 & \cdots & a1n \\ \vdots & \ddots & \vdots \\ an1 & \cdots & ann \end{bmatrix} \qquad (1)$$

Pairwise comparison weight is normalized as

$$\tilde{a}ij = \frac{aij}{\sum_{i=1}^{n} aij} \qquad (2)$$

For *aij* mean a pairwise comparison between i and j. The priorities weight is obtained from paired comparisons. Table 3 illustrated the scale from 1 to 9 with explanation. Each of experts were asked to scale the number to compare relative importance between two elements with respect to another given elements.

Table 3 Scale of Relative Importance.

Intensity of relative importance	Definition	Explanation
1	Equal importance.	Two activities contribute equally to the objective.
3	Moderate importance of one over another.	Experience and judgment slightly favor one activity over another.
5	Essential or strong importance.	Experience and judgment strongly favor one activity over another
7	Demonstrated importance.	An activity is strongly favored, and its dominance is demonstrated in practice
9	Extreme importance.	The evidence favoring one activity over another is of the highest possible order of affirmation.
2, 4, 6, 8	Intermediate values between the two adjacent judgments.	When compromise is needed.

Validation

The results of Pairwise comparison must be validated by using Consistency ratio (CR) in each matrix to verify judgments are consistent. The consistency ratio (CR) are acceptable once less than 0.1 or 10%(Saaty & Kearns, 1985) then this pairwise comparison is considered as consistent. To find Consistency ratio (CR) and consistency index (CI), start from calculate row averages from normalized pairwise comparison. After that, divide each element by their row average. Compute summary of each row and divide summation results by row average. Next, compute the average values. This value called $\boldsymbol{\lambda}$max. Lastly, Compute CR and CI by the following formula

$$CI = (\frac{\lambda max - n}{n-1}) \qquad (3)$$

And

$$CR = \frac{CI}{RI} \qquad (4)$$

The maximum eigenvalue of matrix called $\boldsymbol{\lambda}$max while n is matrix size. Random Consistency Index (RI) based on size of matrix(Saaty, 1994) is expressed in Table 4.

Table 4 Average Random Consistency Index (R.I.).

n	1	2	3	4	5	6	7	8	9	10
Random Consistency Index (R.I.)	0.00	0.00	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

AHP Model for upstream O&G in Thailand

The preliminary AHP model used in this research design is developed. Its three main dimensions are economic, social, and environment. This study might be found another main dimension. See Figure 3

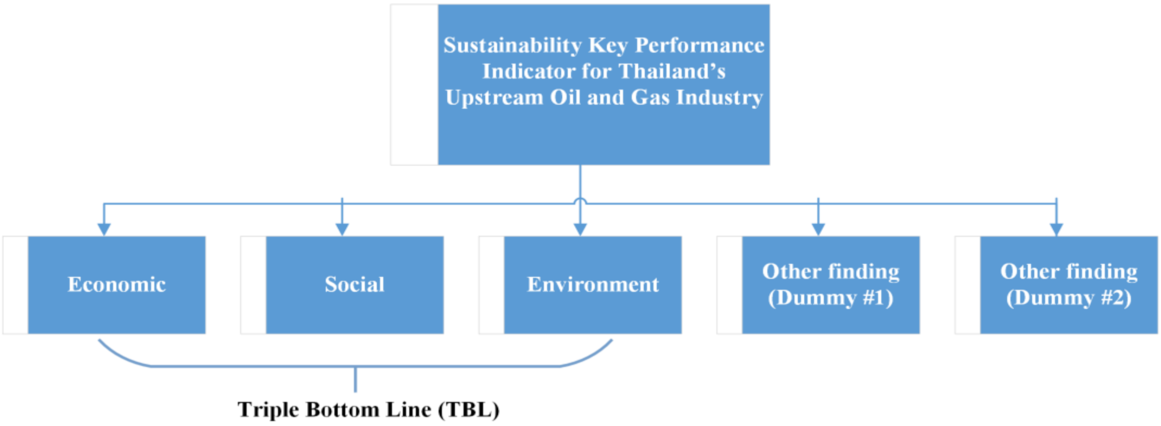

Figure 3 Preliminary AHP model for O&G

Research Results

Results for the Main Dimensions in Phase 1

The literature reviewed was categorized into five dimensions: social, economic, HSSE, innovation and technology, and long-term value creation. Experts recommended combining health, safety, and security with the environment into HSSE. Ten experts were interviewed through questionnaire, and the results are shown next. An AHP pairwise matrix was constructed using the five main dimensions. The average consistency ratio of the 10 experts was acceptable and 0.04886, or less than 0.1. The priority weights of the main dimensions were calculated; the economic dimension had the highest average priority weight, followed by social, HSSE, long-term value creation, and innovation and technology. The priority weights of the AHP and ranking are listed in Table 5.

Table 5 Consistency ratio and preliminary AHP results in Phase 1.

Expert	Consistency ratio	Priority weights				
		Factor level				
	Dimension level	Economic	Social	HSSE	Innovation & Technology	Long-term value creation
OG1	0.05005	0.32925	0.06987	0.35592	0.06410	0.18086
OG2	0.04169	0.37753	0.04926	0.15448	0.09469	0.32404
GOV1	0.00533	0.06215	0.16696	0.06554	0.34643	0.35893
GOV2	0.00455	0.27786	0.48361	0.13893	0.05051	0.04911
CON1	0.09516	0.58964	0.04081	0.14932	0.18132	0.03890
CON2	0.08873	0.42391	0.11813	0.32411	0.04350	0.09036
ACA1	0.08884	0.50208	0.25987	0.03591	0.08378	0.11836
ACA2	0.08966	0.08735	0.21543	0.13358	0.04505	0.51860
NGO1	0.01730	0.04670	0.12073	0.54440	0.24147	0.04670
NGO2	0.00727	0.21840	0.55324	0.10920	0.06139	0.05777
AHP results		**0.29149**	**0.20779**	**0.20114**	**0.12122**	**0.17836**
Ranking		1	2	3	5	4

OG= oil and gas companies, GOV= Government, CON= contractors, ACA= academicians and NGO= non-governmental organizations

The priority weight of the economic dimension is the highest value, or first rank compared to other main dimensions, followed by the social, HSSE, long-term value creation, and innovation and technology dimensions in that order. Four out of the ten experts pointed out that the last two dimensions have the lowest priority weight.

The second round of expert interviews found all ten experts also agreed that the last two dimensions, long-term value creation and innovation and technology, might be a part of the economic, social, and HSSE dimensions. The experts suggested re categorizing them because innovation and technology, and long-term value creation contribute to three existing dimensions. Moreover, the experts recommended removing them. The experts suggested categorizing them into three existing dimensions because innovation and technology contributes to the economic dimension. Utilizing technology, for instance, could reduce time and expense while increasing profit. In addition, it contributes to the social dimension by, for instance, implementing workforce training and development using data and digital resources.

Therefore, economic, social, and HSSE were finalized as the main dimensions of the KPIs for Thailand's upstream oil and gas industry. Therefore, big data or digital transformation, robotics, artificial intelligence, and boost contingence resources in Table 1 will be deleted in this section.

Results for Sub-dimensions in Phase 2

From phase one, three main dimensions consider as main dimension for Thailand's upstream oil and gas industry. Twenty-two sub dimensions were extracted from each main category. In Table 6, seven of sub dimension are under Economic and Social dimension while HSSE has eight sub dimensions. Moreover, the sub dimension in bold are come from innovation and technology, and long- term value creation. E7, S1 and S6 are from innovation and technology where as E6 and H8 are from long- term value creation.

In Phase 2, the top five sub-dimensions were selected, and the unimportant sub-dimensions removed. The experts pre-ranked the sub-dimension under each main dimension from 1 to 7 for economic and social and 1 to 8 for HSSE. The pre-rank score shows that the higher the number, the lower the importance. For instance, rank 1 in the HSSE dimension was defined as the most important, whereas rank 8 defines it as the least important. The score for rating the experts (in Table 7) was adapted from Chen (Chen et al., 2019) and Ramzali, Lavasani, and Ghodousi (Ramzali et al., 2015).

It is worthwhile to note that E6 and H8, which are Maintain Reserve to Production ratio and Baseline study for onshore-offshore areas, are come from long-term value creation. While E7, S1 and S6 from innovation and technology are the Cost optimization program, Capital Expenditure and Operating expenditure optimization, Workforce training and development and Anti- corruption program respectively.

Each expert's weight is shown in Table 8, calculated from their professional position, years of experience, education level, and age. Subsequently, the multiplied pre-rank score with the expert weight yielded the weighted indicator ranking (Chen et al., 2019). Finally, five of each sub-dimensions with the lowest weighted indicator ranking value were maintained.

Table 6 The sub-dimensions under each main dimension.

Indicator Code	Main dimensions	Sub-dimensions
E1		Net income or Net profit in MMUS$
E2		Unit Cost per barrel oil equivalent
E3		Daily Sales Production Volume
E4	Economic	Return on investment (ROI)
E5		Return on asset (ROA)
E6		Maintain Reserve to Production ratio
E7		Cost optimization program, Capital Expenditure and Operating expenditure optimization
S1		Workforce training and development
S2		Value to society (including local employment and local community relationships)
S3		Psychosocial
S4	Social	Gender equalities and Diversity
S5		Partner and Stakeholder engagement
S6		Anti- corruption
S7		Governance and management system
H1		Lost Time Injury Frequency Rate (LTIF)
H2		Total Recordable Incident Rate (TRIR)
H3	Health, Safety,	Loss of Primary Containment (LOPC)
H4	Security and	Fatal Accident Rate (FAR)
H5	Environment	Oil spills or hydrocarbon spills
H6		GHG, CO_2 emission Sustainable emissions reductions
H7		Hazardous waste and waste reduction
H8		Baseline study for onshore-offshore areas

Table 7 Weight criteria and details of the group of experts.

Constitution	Classification	Score	Expert 1	2	3	4	5	6	7	8	9	10
Professional position	Senior academic/ Management level	5		✓	✓		✓	✓	✓	✓		
	Junior academic / Team leader level	4										
	Engineer / Officer/ Analyst	3	✓			✓					✓	✓
	Technician	2										
	Worker	1										
Years of Experience	≥30 years	5										
	20–29	4		✓	✓			✓		✓		
	10–19	3	✓				✓		✓		✓	
	6–9	2										✓
	≤5	1				✓						
Education level	PhD	5			✓				✓	✓		
	Master	4	✓			✓	✓				✓	
	Bachelor	3		✓				✓				✓
Age range	≥50	5								✓		
	40–50	4		✓	✓		✓	✓	✓			
	35–39	3	✓			✓						
	31–34	2									✓	
	≤30	1										✓

Table 8 Estimation of expert weights.

Expert	Professional position	Years of Experience	Education level	Age range	Expert score	Expert weight
1	Engineer/ Officer/ Analyst = 3	10–19 = 3	Master = 4	35–39 = 3	13	0.088
2	Senior academic/ Management level = 5	20–29 = 4	Bachelor = 3	40–50 = 4	16	0.109
3	Senior academic/ Management level = 5	20–29 = 4	PhD = 5	40–50 = 4	18	0.122
4	Engineer / Officer/ Analyst = 3	≤5 = 1	Master = 4	35–39 = 3	11	0.075
5	Senior academic/ Management level = 5	10–19 = 3	Master = 4	40–50 = 4	16	0.109
6	Senior academic/ Management level = 5	20–29 = 4	Bachelor = 3	40–50 = 4	16	0.109
7	Senior academic/ Management level = 5	10–19 = 3	PhD = 5	40–50 = 4	17	0.116
8	Senior academic/ Management level = 5	20–29 = 4	PhD = 5	≥50 = 5	19	0.129
9	Engineer / Officer/ Analyst = 3	10–19 = 3	Master = 4	31–34 = 2	12	0.082
10	Engineer / Officer/ Analyst = 3	6–9 =2	Bachelor = 3	≤30 =1	9	0.061
Total score					147	1.000

To eliminate the less important sub-dimensions, 10 experts provide their pre-rank scores for Economic, Social, and HSSE. The lower the rank, the higher the importance. Based on the weighted indicator ranking, under the economic dimension, it was decided to remove return on investment (E4) and return on investment (E5) (Table 9).

Table 9 Weighted indicator ranking of sub-dimensions under the economic dimension.

Expert No.	E1	E2	E3	E4	E5	E6	E7
Expert 1	0.17687	0.26531	0.44218	0.61905	0.53061	0.35374	0.08844
Expert 2	0.10884	0.43537	0.21769	0.65306	0.76190	0.32653	0.54422
Expert 3	0.12245	0.61224	0.48980	0.85714	0.73469	0.24490	0.36735
Expert 4	0.29932	0.37415	0.44898	0.52381	0.22449	0.07483	0.14966
Expert 5	0.21769	0.65306	0.10884	0.54422	0.76190	0.32653	0.43537
Expert 6	0.65306	0.10884	0.54422	0.43537	0.76190	0.21769	0.32653
Expert 7	0.23129	0.34694	0.11565	0.69388	0.57823	0.46259	0.80952
Expert 8	0.12925	0.64626	0.51701	0.77551	0.90476	0.25850	0.38776
Expert 9	0.08163	0.24490	0.16327	0.57143	0.40816	0.48980	0.32653
Expert 10	0.12245	0.06122	0.24490	0.30612	0.42857	0.18367	0.36735
SUM	2.14286	3.74830	3.29252	5.97959	6.09524	2.93878	3.80272

Sub-dimensions psychosocial (S3) and gender equalities and diversity (S4) in Table 10 were deleted from under the social dimension.

Table 10 Weighted indicator ranking of the sub-dimension under the social dimensions.

Expert No.	S1	S2	S3	S4	S5	S6	S7
Expert 1	0.61905	0.35374	0.44218	0.53061	0.17687	0.26531	0.08844
Expert 2	0.54422	0.21769	0.76190	0.32653	0.43537	0.10884	0.65306
Expert 3	0.48980	0.61224	0.73469	0.12245	0.24490	0.36735	0.85714
Expert 4	0.14966	0.29932	0.07483	0.22449	0.52381	0.37415	0.44898
Expert 5	0.76190	0.21769	0.65306	0.54422	0.32653	0.43537	0.10884
Expert 6	0.54422	0.65306	0.21769	0.76190	0.43537	0.32653	0.10884
Expert 7	0.11565	0.23129	0.69388	0.57823	0.80952	0.46259	0.34694
Expert 8	0.38776	0.12925	0.90476	0.77551	0.51701	0.25850	0.64626
Expert 9	0.08163	0.16327	0.48980	0.32653	0.24490	0.57143	0.40816
Expert 10	0.18367	0.06122	0.42857	0.30612	0.12245	0.24490	0.36735
SUM	3.87755	2.93878	5.40136	4.49660	3.83673	3.41497	4.03401

Three sub-dimensions under the HSSE dimension, composed of the fatal accident rate or FAR (H4), oil spills or hydrocarbon spills (H5), and hazardous waste and waste reduction (H7), were eliminated (Table 11).

Table 11 Weighted indicator ranking of sub-dimensions under HSSE.

Expert No.	H1	H2	H3	H4	H5	H6	H7	H8
Expert 1	0.08844	0.44218	0.53061	0.17687	0.61905	0.26531	0.35374	0.70748
Expert 2	0.43537	0.32653	0.21769	0.76190	0.87075	0.10884	0.65306	0.54422
Expert 3	0.97959	0.12245	0.24490	0.73469	0.85714	0.48980	0.36735	0.61224
Expert 4	0.59864	0.44898	0.22449	0.29932	0.52381	0.07483	0.37415	0.14966
Expert 5	0.21769	0.32653	0.10884	0.54422	0.76190	0.87075	0.65306	0.43537
Expert 6	0.10884	0.21769	0.43537	0.76190	0.87075	0.32653	0.65306	0.54422
Expert 7	0.69388	0.80952	0.34694	0.92517	0.57823	0.11565	0.46259	0.23129
Expert 8	0.64626	0.51701	0.38776	0.12925	0.25850	1.03401	0.77551	0.90476
Expert 9	0.16327	0.08163	0.24490	0.48980	0.57143	0.32653	0.65306	0.40816
Expert 10	0.24490	0.18367	0.12245	0.42857	0.48980	0.30612	0.36735	0.06122
SUM	4.17687	3.47619	2.86395	5.25170	6.40136	3.91837	5.31293	4.59864

Results for main and sub-dimensions in Phase 3

The main and sub-dimensions from the preliminary results from Phase 1 and 2 were analyzed in Phase 3, using the AHP approach. For this, a second group of 20 experts, from O&G companies, government agencies, contractors, academia, and non-government organizations, was interviewed individually. The values of the consistency ratio in are acceptable by less than 0.1 (Saaty & Kearns, 1985). The average consistency ratio of the main dimension is 0.02365, while that of the sub-dimensions is 0.01061. The AHP results for the main dimensions for each expert is shown in Figure 4. The AHP results were classified into three representative dimensions from each of the five expert groups. The first rank for the economic aspect was provided by experts from oil and gas with 0.58685 while the social dimension from academician received the highest weight at 0.46134. The HSSE dimension received the highest weight from NGOs, 0.34776.

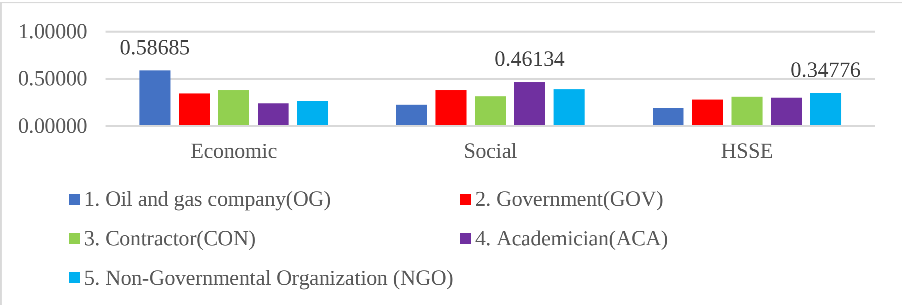

Figure 4 AHP results in main dimension level of each expert group.

As seen from Table 12, the AHP results shows the economic dimension had the highest rank with 0.36222, followed by social with 0.35257 and HSSE, with 0.28521. The AHP results for the sub-dimensions and the hierarchy of sustainability key performance indicators for Thailand's upstream oil and gas industry is illustrated in Figure 5. In the sub-dimensions, pairwise comparisons were arranged in each main dimension. In the economic dimension, net income is the most important indicator that affects the sustainability of upstream O&G in Thailand. This is followed by maintenance reserve and production ratio, cost optimization program, capital expenditure, and operating expenditure reduction, daily sales production volume, and unit cost per barrel oil equivalent, in that order. In the social dimension, value to society including local employment and local community relationships had the highest weight (0.2352), followed by anti-corruption program and zero non-compliance, workforce training and development, partner and stakeholder engagement, and governance and management systems, in that order. Lastly, for HSSE, total recordable incident rate was ranked first, with lost time injury frequency rate ranked almost the same, which were then followed by GHG, CO_2 emissions, sustainable emissions reductions, loss of primary containment, and baseline study for onshore and offshore areas in that order.

Table 12 AHP results of main dimension.

Rank	Main Dimension	AHP
1	Economic	0.36222
2	Social	0.35257
3	HSSE	0.28521

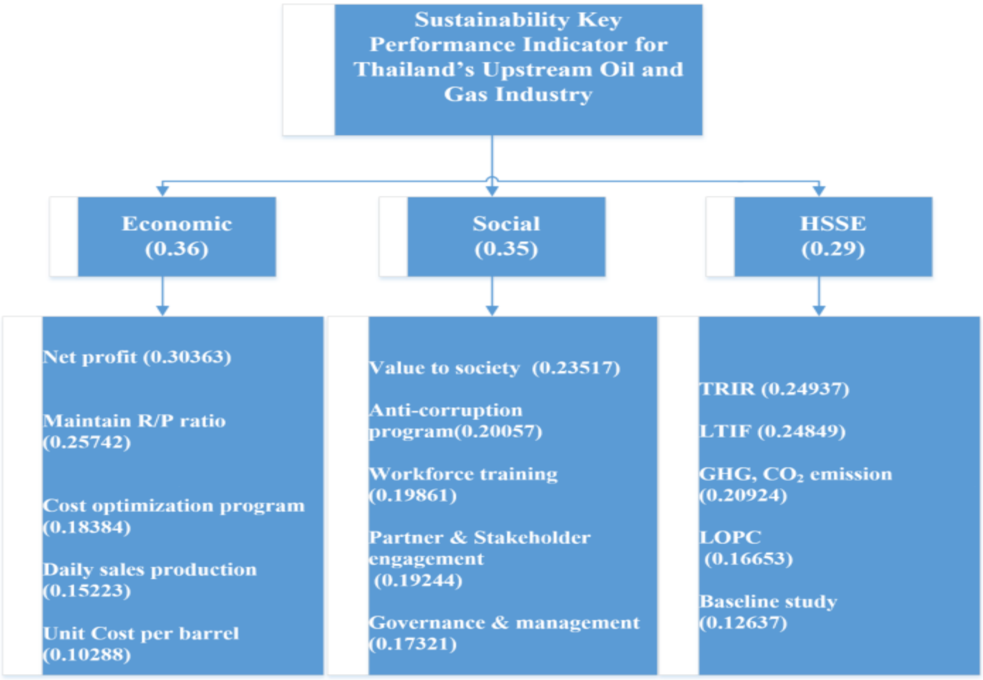

Figure 5 The hierarchy of sustainability key performance indicators for Thailand's upstream oil and gas industry.

Phase 4 Results: Proposed sustainability KPI Model for Upstream O&G in Thailand

The Triple Bottom Line, proposed by John Elkington (Elkington, 1998), has been used in business for over two decades and focuses simultaneously on economic, social, and environmental considerations. The four possible sustainability models proposed in the previous section are shown in Figure 6. Three top executives with more than 20 years of experience in the Thailand O&G industry were interviewed to select the best-fit model. As Figure 6 shows, the selected model (the last one) includes innovation and technology across its three pillars. Moreover, in terms of economic, social, and HSSE benefits, for instance, operation time reduction leads to cost saving and has a direct effect on the economy. These dimensions promote more safety in operation by using technological innovation and encourage more security for people and the environment at the same time. Finally, long-term value creation across three dimensions ensure sustainability in the long run and the balancing of each dimension.

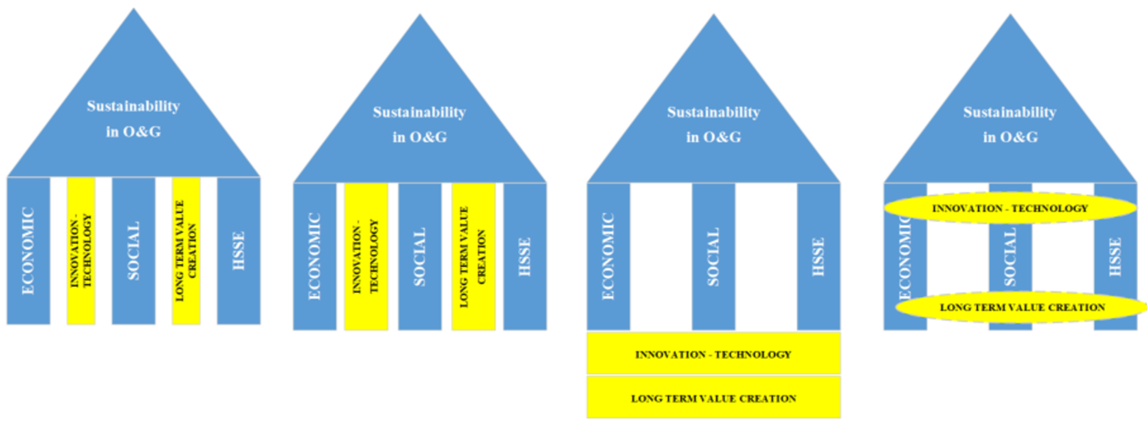

Figure 6 Proposed sustainability models for Thailand's upstream O&G.

Table 13 shows the selected sustainability models (the last one) with an AHP of 0.55847, as ranked by three top executives.

Table 13 AHP results for sustainability models for Thailand's upstream O&G.

Proposed sustainability models for Thailand's upstream O&G					
Model	Top executives#1	Top executives#2	Top executives#3	AHP results	Rank
Model 1	0.27547	0.21949	0.29650	0.26382	2
Model 2	0.07430	0.05918	0.05332	0.06227	4
Model 3	0.13774	0.10974	0.09883	0.11544	3
Model 4	0.51249	0.61159	0.55134	0.55847	1

Discussions

Inseparable sets of health, safety, and security from the environment.

It is common knowledge that John Elkington's Triple Bottom Line, which has been used in business for more than two decades, simultaneously considers economic, social, and environmental factors. To ensure sustainability along supply chains, individuals associated with the upstream oil and gas industry must ensure their health and safety while maintaining a healthy work environment and community. This is one of the primary concerns. Managing security concerns associated with the oil and gas industry and safeguarding the environment are also essential. In the upstream oil and gas industry, health, safety, and security could not be separated from environmental dimensions. Last but not least, the three primary dimensions are economic, social, and health safety, security, and the environment.

Two identified dimensions overlap with the three main dimensions.

Although the research began with three dimensions, we discovered two more: innovation and technology, and the creation of long-term value. However, the specialists recommended classifying them into three existing dimensions. Innovation and technology contribute to the economic dimension. Using technology, for instance, can reduce time and expenses while increasing profit. It also contributes to the social dimension when, for instance, data and digital resources are used to implement workforce training and development. Long Term Value Creation contributes to the economic and health, safety, security, and environment (HSSE) dimensions, as investing current resources in infrastructure maintenance proves beneficial over time.

The two identified dimensions were incorporated into the economic, social, and HSSE dimensions due to their overlap with the three primary dimensions. In addition, after conducting AHP, it was determined that too many criteria rendered the AHP instrument ineffective. As a result, we have three primary dimensions.

In addition to the three main dimensions, the sub dimensions (Innovation and Technology and Long-Term Value Creation) account for one-third of all sub dimensions, a sizeable portion. Therefore, we must include them in the proposed sustainability model for the upstream oil and gas industry in Thailand. Using these dimensions, this study developed a prototype of a sustainability model for Thailand's upstream oil and gas industry. Moreover, this study developed a sustainability model for Thailand's oil and gas industry consisting of three main primary dimensions as pillars and two additional dimensions which also link and connect the three primary dimensions. These two additional or sub-primary dimensions integrate and bound the three primary dimensions, making them more robust and efficient.

Roadmap for sustainability key performance indicators for Thailand's upstream oil and gas industry.

The United Nations established 17 sustainable development goals (SDGs) with 169 targets for all countries to adopt and achieve by 2030. However, key performance indicators for Thailand's upstream oil and gas industry should be corrected, measured, evaluated, and closely monitored by the industry. In addition, the indicators are able to revise and adjust within a reasonable time to ensure sufficient information for data correction. This may lead to improving indicators and consequently to developing strict social and environmental policies which the industry should comply with.

Knowledge from Research

This study makes a significant contribution to the literature because the existing academic literature has focused on KPIs for the oil and gas industry in general, whereas this study focuses on Thailand’s upstream oil and gas sector. Moreover, findings of this study can be used by companies in Thailand’s upstream oil and gas industry to plan, design and implement strategies for responding to increasing pressure for environmentally and socially responsible activities as well because currently the industry’s focus remains on the economic part mostly. Finally, the proposed set of sustainability KPIs and the conceptual model may be utilized as guidelines for Thailand’s upstream oil and gas sector.

Conclusion

The challenge of the oil and gas business is not only balancing their financial, environmental, and social considerations, but the need to invest more in innovative technologies to ensure social and environmental performance improves in parallel with business growth. The proposed set of sustainability KPIs and the model could be utilized as guidelines for Thailand’s upstream oil and gas sector. All of the study's findings could be used to guide not only an industrial executive in assessing the sustainability performance of O&G businesses in Thailand but also a policymaker in establishing a criterion for achieving future sustainable development goals. Moreover, the outcomes of this study encourage not only related parties to explore more sustainability indicators but raise awareness of sustainability issues.

Although the business is dynamic and volatile, the organization is able to adjust to be appropriate on a case-by-case basis. Balancing every dimension is the foundation for sustainability in Thailand’s upstream oil and gas industry.

Suggestions

Further studies should focus on innovation and technology, and long-term value creation such as carbon capture utilization and storage (CCUS) that also contributes to reduction of GHG, and this might be a potential valuable topic. In addition, industries are encouraged to conduct more research on technology, which improves the indicators suitable for short- and long-term plans. Although experts agree that both long-term value creation and innovation and technology, should be considered as components of the economic, social, and HHSE dimensions. However, we should keep up to date because we are living in a data and technology-driven era, which may become a major pillar in the near future, they are vital and need further research for a re-evaluation of their contribution.

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