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AN ANALYTICAL HIERARCHY PROCESS (AHP) APPROACH FOR SELECTION OF OFFSHORE SUPPLY BASES: KEMAMAN VERSUS TOK BALI IN MALAYSIA

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ABSTRACT

This paper explores and identifies a key element in the offshore supply chain and the oil and gas industry, the offshore logistic system, which includes offshore supply bases. This shore supply base is the logistics hub for all drilling and oil and gas activity. It functions as a central warehouse and a forward base for supplying cargo and needed supplies to offshore installations, and it offers critical services to facilitate offshore operations. Because of its advantageous position in Southeast Asia, Malaysia has become a prominent participant in the worldwide oil and gas sector. The nation's offshore supply bases, with oil and gas platforms operating in different locations along the eastern shores have become crucial centres for the sector. This study aims to identify the key factors in supply base selection by oil and gas operators by performing a comparative analysis of two significant offshore supply bases in Malaysia, specifically Kemaman and Tok Bali. The Analytical Hierarchy Process (AHP) has been used for stakeholders to make multi-criteria decisions. The method will prioritise four main criteria for supply base selection: Geographical location of offshore supply base, infrastructure and facilities, services provided and charges, and regulatory considerations were used with 12 sub-criteria to ascertain which supply base is most favourably situated to meet the increasing demands of the oil and gas industry in the region, all of which determine the operational efficiency and cost-effectiveness of offshore operations. The analysis revealed that the geographical component is the most significant, followed by facilities and infrastructure, service and costs, and regulatory, respectively. Based on the score, the attribute with the highest level of importance is the distance to MTJDA and MVCAA (northern section) of the oil and gas platform. This is followed by service, berth facilities, distance to the oil and gas platform at Terengganu water (southern section), outsourced/inland area, warehousing, storage facilities, crew change, customs, charges, port authority, and ISPS compliances in that order. The findings of this study will aid oil and gas companies and players in making informed decisions regarding the selection of onshore supply bases. By examining the factors influencing the choice of supply base and their respective advantages, companies can make informed decisions that contribute to their overall success in a competitive global market.

Introduction

The exploration and production (E&P) activities in the offshore oil and gas industry necessitate robust logistical support to ensure the smooth and efficient operation of various tasks such as seismic surveys, drilling, pipeline installation, platform installation, and production operations. Central to this logistical framework are offshore supply bases, which serve as critical hubs for the

transhipment of essential materials, equipment, and personnel between onshore facilities and offshore units (Hassan, 2013; Syuhaida, 2019; Syuhaida, 2020). These bases play a pivotal role in maintaining the continuity and productivity of offshore operations by providing a wide range of services and facilities tailored to the needs of the oil and gas sector. In Malaysia, two prominent supply bases, Kemaman Supply Base (KSB) and Tok Bali Supply Base (TBSB), exemplify the strategic importance of such facilities. KSB, located on the east coast of Peninsular Malaysia is the region's largest fully integrated oil and gas supply base, offering comprehensive logistical support, and various specialised services.

In contrast, TBSB, situated on the northeast coast, serves as a newer, yet increasingly vital, supply base catering to the North Malay Basin, the Malaysia-Thailand Joint Development Area (MTJDA), and the Malaysia-Vietnam Commercial Arrangement Area (MVCAA) as shown in Figure 1. Several factors, including geographical location, infrastructure and facilities, services offered, and regulatory compliance influence the selection of an appropriate supply base. These factors collectively determine the operational efficiency, cost-effectiveness, and overall success of offshore oil and gas operations.

The existing research on the oil and gas industry largely focuses on the problem with offshore platform vessel planning at the supply base. An example of an integrated approach for facility location and supply vessel planning with time windows (Amiri *et al*., 2019), Optimal fleet composition and mix periodic location-routing problem with time windows in an offshore oil and gas industry: A case study of National Iranian Oil Co. (Amiri *et al*., 2018). Even the research by Duffy (1979) surveyed the Northern North Sea offshore oil and gas supply base. Moreover, most research concentrates on developing the port logistics service quality and customer satisfaction (Le *et al.*, 2019).

There is a limited number of studies about offshore supply bases in Malaysia and researchers have published a limited number of articles. Further, the motivations of this study are the notion that understanding the dynamics of supply base selection is crucial for energy companies aiming to optimise their logistical chains and enhance productivity in a competitive global market.

This article identifies the key factors in the supply base selection by the oil and gas operator and company. Furthermore, it aims to explore the functions and significance of offshore supply bases, focusing on KSB and TBSB. By examining and identifying the factors influencing the choice of supply base and their respective advantages, this review provides insights into the strategic considerations that underpin effective offshore logistics management.
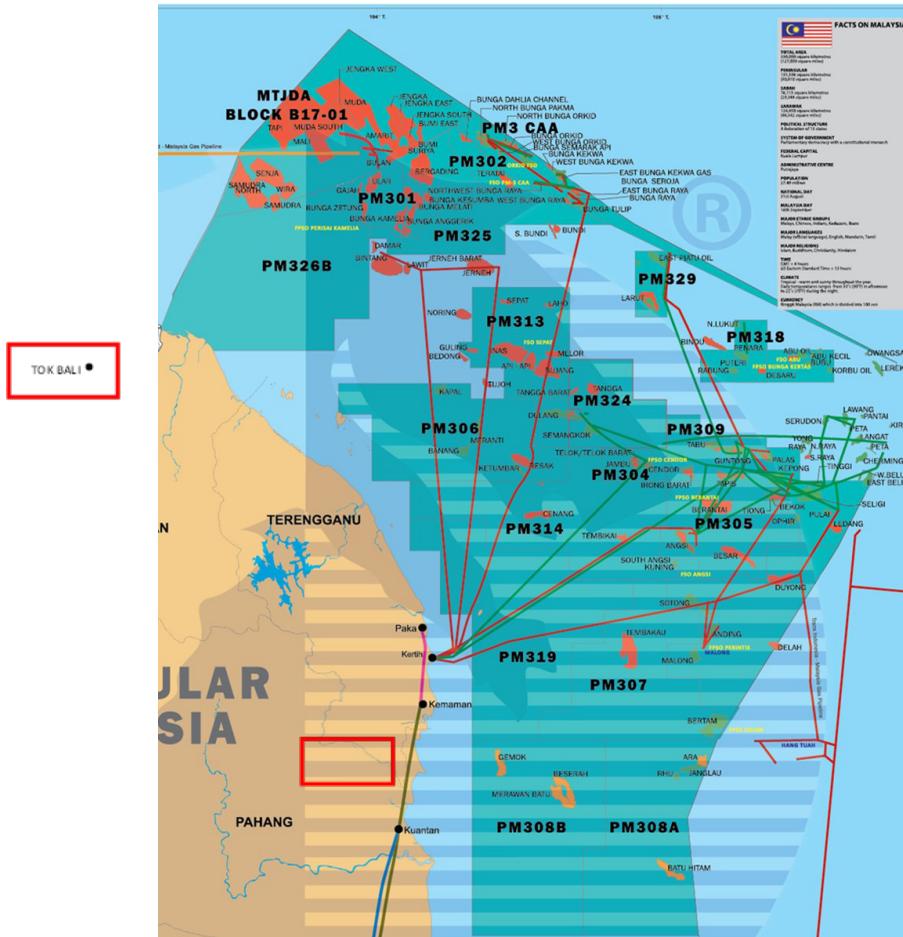
Figure 1: Overview of oil and gas location in East Coast Peninsular Malaysia
Source: MSGOC

Literature Review
Offshore Supply Base

An offshore supply base is the onshore logistical hub for various offshore exploration and production (E&P) activities, including seismic surveys, drilling, pipeline installation, platform installation, and production operations. The offshore support facility is a transhipment point for various items such as tools, equipment, mud, cement, manpower, consumables, water, fuel, and more. In simpler terms, "in other words" refers to a crucial component of the logistics system.

Figure 2 showing the overview of the offshore supply base logistics, which its main tasks involve the transportation of essential materials and supplies, as well as the return of used materials and equipment, between offshore units and an onshore supply base. These activities are carried out according to a predetermined delivery schedule (Aas *et al*., 2007; Amiri *et al*., 2018). Furthermore, an offshore supply base also comprising of at the very least, a jetty, lay-down areas, warehouses, and a range of support buildings which support cargo handling activities (Kaiser, 2010) and it serves as a hub for the coordination, organisation, and deployment of offshore supply vessels (A.-S. Milakovic *et al*., 2014).
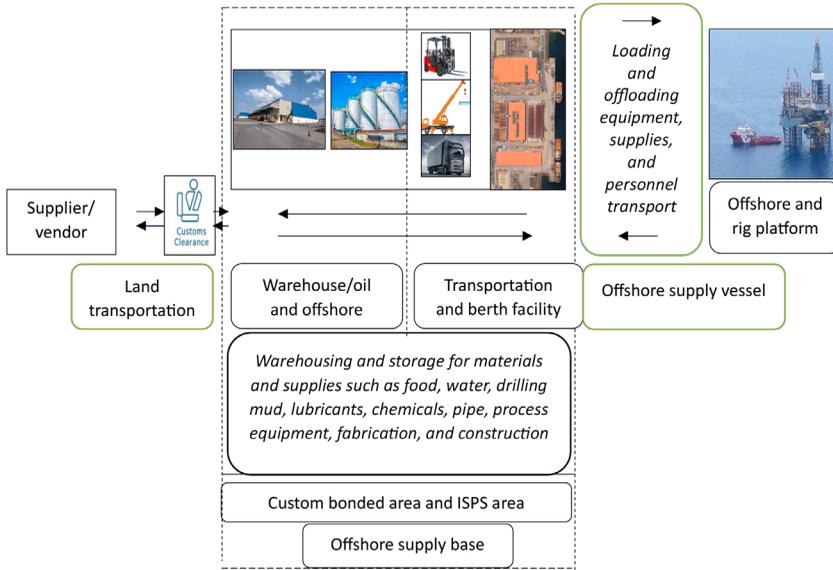
Figure 2: Overview of offshore supply base logistics
Source: Author

Kemaman Supply Base (KSB)

Kemaman Supply Base is situated on the east coast of Peninsular Malaysia. It is the largest fully integrated oil and gas supply base in Peninsular Malaysia and a one-stop shop for oil and gas companies operating in the region. It is important in supporting offshore oil and gas exploration and production activities. It is located in the Kemaman district of Terengganu, Malaysia. The base opened in 1982 and has since grown to 200 hectares, with an additional 60 hectares reserved for future expansion.

KSB is a privately owned port that operates under the jurisdiction of Kemaman Port and requires pilotage services from the Kemaman Port Authority. Clause 29A of the Port Authorities Act 1963 states that all vessels navigating within the Kemaman Port Pilotage District must be piloted. However, subject to terms and conditions, the Kemaman Port Authority may grant a pilotage exemption to a Master of Supply vessel and crew boat regularly calling at Kemaman Port.

Furthermore, International Ship and Port Facility Security (ISPS) compliance allows KSB to run its operations smoothly without

any disruption. The Royal Customs of Malaysia uniquely license the entire area of KSB under the Petroleum Supply Base scheme. This means that taxes and duties for imported oilfield equipment entering KSB and subsequently going to offshore locations are deferred. The Kemaman Supply Base is home to over 200 support service companies and Petroleum Arrangement Contractors (PACs) catering to various oilfield needs, offering various oilfield trade specialities. It supplies marine fuel products and lubricants at Kemaman Supply Base for Offshore Support Vessels (OSV) and power equipment on Oil and Gas (O&G) platforms in the offshore East Coast of Peninsular Malaysia.

KSB also provides berthing facilities for OSV. With a length of 360 meter, a maximum draft of 8.0 meter, and a maximum deadweight of 8,000, it can occupy a maximum of 10 vessels at one time with a double bend configuration, plus another two vessels at the finger jetty as shown in Figure 3. However, the maximum number of vessels that can carry out the cargo operation is only seven at a time. This operation will combine with the mooring and unmooring

Figure 3: Overview of KSB jetty facility
Source: Author

services and workforce for cargo operations. The Kemaman Supply Base is owned and operated by Pangkalan Bekalan Kemaman Sdn. Bhd. (PBKSB), a subsidiary of the EPIC Group.

Most of the companies KSB serve operate the platform in the area off Terengganu water. Voyage Distance from Kemaman Supply Base to the offshore rig platform in the Terengganu water is a shorter distance to Kelantan water, Malaysia-Thailand Joint Development Area (MTJDA) and Malaysia-Vietnam Commercial Arrangement Area (MVCAA) as shown in Figure 1. This can benefit the oil company that operates in Terengganu water in terms of travelling time and fuel costs.

Tok Bali Supply Base (TBSB)

Tok Bali Supply Base (TBSB) is located on the northeast coast of Peninsular Malaysia or more specifically in Pasir Puteh, Kelantan, which aims to provide a safe and professional one-stop centre for Production Sharing Contract (PSC) and services companies (Figure 4). TBSB was commercialised and officially operated by TB Supply Base Sdn. Bhd. in September 2014. The dominance shares have been owned by AZRB by its subsidiary, Matrix Reservoir Sdn. Bhd. (MRSB) is the owner of Tok Bali Supply Base (TBSB), which received full government approvals in January 2015 and commenced operation (Phase 1) in July 2015 as focusing for oil and gas sector.

TBSB has been licensed under the Malaysian Customs Act 1967 under Section 77B (Petroleum Supply Base). As a new emergence of the supply base in Peninsular Malaysia, they are focusing on three gateways of oil and gas exploration and production, namely the North Malay Basin (NMB), Malaysia-Thailand Joint Development Area (MTJDA), and Malaysia-Vietnam Commercial Arrangement Area (MVCAA).

To cater for the prolonged demand and become a successful supply base operator, they would accommodate and offer all necessities by creating opportunities and providing new service options covering downstream and upstream support, both local and foreign port users. Because it is ideally located to serve companies operating in the North Malay Basin, Malaysia-Thailand Joint Development Area and Commercial Arrangement Area (CAA) between Malaysia and Vietnam. Tok Bali Supply Base is expected to create savings for Production Sharing Contract (PSC) customers, especially those PSCs that are currently operating at the Malaysia-Thailand Joint Development Area (MTJDA) and Malaysia-Vietnam Commercial

Figure 4: Overview of TBSB jetty facility
Source: https://www.azrb.comoil-gas

Arrangement Area (MVCAA), due to shorter vessel voyage as compared to Kemaman Supply Base (KSB).

Among the services that TBSB offers are fuel and water, mechanical handling equipment, a bonded warehouse, customs and immigration, and office space. TBSB provides an integrated support service and facilities and can provide cost-efficient services to clients. Moreover, all-weather 473 meters of berthing facilities, with fuel bunker, potable water, liquid mud, and dry bulk off-take points conveniently slotted alongside the berth could accommodate five supply vessels and three crew boats at any one time. The land distance to MTJDA and CAA from Tok Bali Supply Base is only 160 km compared to 360 km from KSB. The shorter vessel voyage also translates to lesser fuel requirements and lower operational costs for the PSCs.

Factors Affecting the Selection of Supply Base

A supply base is a customised harbour designed specifically to meet the requirements of the offshore exploration and production business. In recent years, energy corporations have delegated numerous activities deemed secondary to their main operations such as logistics (de Wardt, 1990; Aas *et al.,* 2008). However, energy businesses still decide internally on the supply base selection rather than relying on sub-contractors like service companies, OSV operators, or freight forwarders. Kaiser (2010) has highlighted several crucial variables for supply base selection in the Gulf of Mexico, including distance to port, port capability and specialisation, transit time, and operator facilities.

Given the absence of any specific additional studies on the selection of supply bases, it would be advantageous to examine the broader literature on inter-port competition and port selection to assess its applicability to the choice of supply bases. The field of port literature has extensively examined many service-related and economic elements that significantly impact the decision-making process of shippers and ship owners. The conventional perspective on port selection focused mainly on the individual physical characteristics of a port such as its terminal infrastructure, equipment, efficiency, frequency of sailings, costs, quality of services, availability of value-added activities, and port security.

Additionally, it took into account the port's safety and environmental policies and the accessibility of its hinterland (Bruno & Guy, 2006). Recently, it has been acknowledged that the emphasis on individual physical characteristics of ports does not accurately represent the current state of global supply

chains. Ports are rapidly recognised as crucial connections within competitive global supply networks (Robinson, 2002).

Geographical Location of Offshore Supply Base

The geographical location of an offshore supply base significantly influences transportation costs and efficiency (Øyvind & Stein, 2009). For example, a supply base near the offshore rig installation results in lower transportation costs due to easier vessel access. Conversely, a supply base located far away may incur higher transportation and logistics costs. Furthermore, it can impact delivery lead times, affecting operational efficiency, productivity, and overall supply chain complexity (Koilo, 2023).

Additionally, the surrounding onshore area of the supply base is to be considered. For example, the industrial area nearby and local supplier resources. Access to the sources can help reduce lead times and improve overall operational efficiency. Furthermore, evaluating the infrastructure and transportation network in the surrounding area is essential to ensure smooth and timely delivery of materials and equipment to the offshore rig (Röben *et al*., 2008). By considering these factors, companies can optimise their supply chain operations and ultimately enhance productivity and cost-effectiveness in their offshore operations and overall logistics chain by choosing the right location for an offshore supply base.

Infrastructure and Facilities

The resources needed for a supply base include berthing space, cranes, loading/unloading equipment, storage facilities, and maintenance workshops. These resources should be efficient and accessible for the efficient movement of goods and personnel. Accessible transport links, including road, rail, and air, are essential for moving goods and personnel efficiently.

On-site accommodation, security measures, and facilities for waste management and environmental protection are also essential (Roben *et al*., 2010). A well-equipped supply base is essential for ensuring smooth operations in the oil and gas industry. The base must have a reliable supply of essential materials and the necessary infrastructure to support transportation and maintenance activities (Danish, 2019). Accessibility and security measures are also key considerations to ensure the safety and efficiency of operations. A supply base is very important in supporting the success of oil and gas operations by providing a range of services and facilities.

Service Provided and Charges

The supply base normally accommodates the vessel for berthing. This includes piloting services, vessel mooring and unmooring, crew change facilitation, and transportation services. Additional services may include bunkering, fresh water supply, and provision of necessary vessel supplies (Razack *et al*., 2018). With the efficient service provided, vessels can quickly and easily resupply and continue their operations without delay. This ensures that vessels can maintain their schedules and complete their voyages promptly.

The streamlined process of receiving essential services at offshore supply bases also helps to reduce downtime and increase productivity for shipping companies (Amiri *et al*., 2019). This comprehensive range of services contributes to smooth and efficient vessel operations in these areas. Understanding service charges is crucial for consumers as it directly impacts their willingness to pay. Consumers' perceptions of convenience, including transaction and access convenience play a significant role in their decision-making process (Leonard *et al*., 2002). The importance of convenience in services strongly correlates with consumers' willingness to pay, highlighting the need for businesses to understand, and address service charges to attract and retain customers (L. *et al*., 2004).

Regulatory Considerations

Ensuring regulatory compliance with local laws, environmental standards, customs clearance processes, and safety requirements on offshore supply bases is essential for safeguarding the

security of the transportation of products and persons. Implementing security measures is essential to adhere to regulatory standards like the ISPS code and others to guarantee the safety of operations within these facilities (Bichou, 2008).

Failure to adhere to these standards can result in serious consequences, including fines, legal action, and even the suspension of operations. Additionally, non-compliance with security measures can lead to reputational damage and loss of business opportunities.
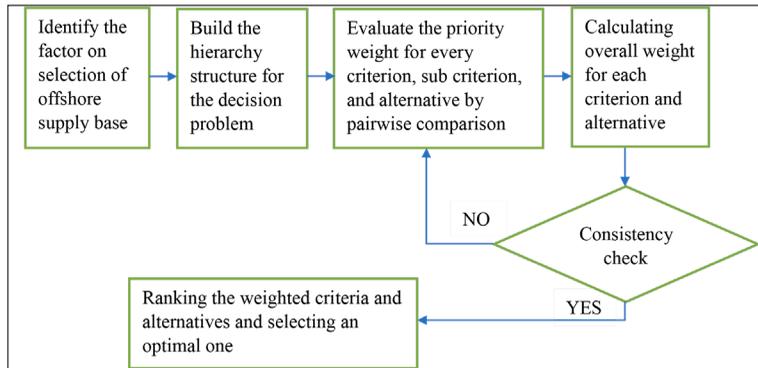

Figure 5: AHP method procedure

Therefore, offshore supply bases must prioritise regulatory compliance and safety to maintain the integrity and efficiency of their operations. By prioritising regulatory compliance, they can also build trust with their clients and stakeholders, ultimately enhancing their competitiveness in the industry.

Analytical Hierarchy Process

The Analytic Hierarchy Process (AHP) was developed by Saaty (1980) as a technique to address complex decision-making situations, including multiple criteria (Timor & Sipahi, 2005). It has been used for MCDM by stakeholders with varying preferences for transhipment port selection by global carriers (Lirn *et al*., 2004). An advantageous characteristic of this strategy is its ability to manage qualitative and quantitative data effectively (Kuo *et al*., 2002; Timor & Sipahi, 2005).

AHP is useful for decision-makers to analyse complicated problems, particularly those involving subjective judgment. It helps decision-makers comprehend the decision-making model's structure, enhancing their understanding of the challenges at hand. AHP is a method that breaks down a complicated

problem into a hierarchical structure consisting of goals, criteria, sub-criteria, and alternatives (Saaty, 1990; Triantaphyllou & Mann, 1995; Wang *et al*., 2004). The implementation of the AHP approach and method are shown in Figure 5 and will be discussed in the methodology.

Methodology

The research methodology first involves reviewing the literature and interviewing the supply base operator to obtain information on the use of the AHP method in formulating and selecting the best factor for the selection of the supply base (Marzouk & Sabbah, 2021). To identify the factors in the selection of the supply base, interviews were conducted to obtain information related to each supply base, other than finding out from the online resources and literature for comparison, as shown in Table 2. After identifying the factor, a set of questionnaires was completed and answered by five experts from this sector. All interviewees have over 10 years of experience in the supply chain and oil and gas industry.

Table 1 shows the demographic profile of interviewees in this study. Based on the judgment of these experts, pair-wise comparisons were made between criterion groups and between sub-

factors in each group to determine their weights. A quantitative measure of their importance was obtained. Then, selecting the highest score will be the best option. This result is an "apples to apples", quantitative comparison of your choices (Munier & Hontoria, 2021).

Table 1: Interviewees demographic

Interviewee	Year of Experiences	Role in the Company	Country	Current Company
I1	14	Marine executive	Malaysia	Port operator
I2	16	Operation manager	Malaysia	Shipping agency
I3	15	Marine safety executive	Malaysia	Oil and gas operator
I4	20	Operation manager	Malaysia	Oil and gas operator
	18	Manager marine	Malaysia	Shipping company and oil and gas contractor

Step 1: Identifying the factors

The first step is to review the related literature studies and interview experts (Kuo *et al.,* 2002) to describe the decision problem with multiple criteria and attributes used for its solution.

Then, comparative development interventions for the two offshore supply bases were presented, as mentioned in Table 2.

Table 2: Comparative development interventions for the two offshore supply bases

Factor in Selecting Supply Base	Kemaman Supply Base (KSB)	Tok Bali Supply Base (TBSB)
Geographical		
Distance to rig platform	Approximately 360 km from MTJD and CAA (northern part) of the oil and gas platform	Approximately 160 km from the oil gas platform's MTJD and CAA area (northern part)
	Approximately 200 km from Terengganu water (southern part) of the oil and gas platform	Approximately 370 km from Terengganu water (southern part) of the oil and gas platform
Inland area	In the vicinity of Teluk Kalong industrial area	In the vicinity of Tok Bali Industrial Park
Infrastructure and facilities		
Berthing	All weather straight 360 m berth and two finger jetty can accommodate seven vessels at one time	All weather "U" shape jetty with a length of about 473 m can accommodate seven vessels simultaneously
Storage	Liquid mud plant, dry bulk plan, marine gas oil storage	Liquid mud plant, dry bulk plan, marine gas oil storage
Warehousing	Total 43 unit	A total of 12 units with 100% utilisation

Crew change	Completed with CIQ facilities	Completed with CIQ facilities
Service and charges		
Service	• Cargo loading and unloading • Pilotage and towage • Stevedoring-manpower • Material handling equipment • Weight bridge • Schedule waste management • Security - Provide round-the-clock security and also specific security services for individual client • Fresh water and fuel oil bunkering	• Cargo loading and unloading • Pilotage and towage • Stevedoring-manpower • Material handling equipment • Weight bridge • Schedule waste management • Security - Provide round-the-clock security and also specific security services for individual client • Fresh water and fuel oil bunkering
Charges	• Marine services such as pilotage, towage, port dues, harbour dues, and vessel dues as per Kemaman port tariff • Other charges are as per KSB tariff since they are private entities	• All the charges are under the Tok Bali tariff since they are private ports
Regulatory compliances		
Custom	Licensed under the Malaysian Customs Act 1967 under Section 77B (Petroleum Supply Base)	Licensed under the Malaysian Customs Act 1967 under Section 77B (Petroleum Supply Base)
Port authority	MSO 1952, Port Authority Act 1963 Kemaman Port	MSO 1952, Directly under Marine Department Malaysia
ISPS	In compliance with ISPS	In compliance with ISPS

Step 2: Develop the hierarchical structure of decision problem

The problem is divided into its criteria (level 1), as depicted in Figure 6, with each possible sub-criteria (level 2) arranged into many hierarchical levels (Ho, 2008). The criteria for evaluating location possibilities are determined based on information from relevant papers and the expertise of domain specialists. Numerous factors influence the decision-making process when choosing a site. However, specific criteria are deemed crucial because they are essential for correctly evaluating numerous location possibilities.

In this study, the evaluation of two potential supply bases takes into consideration the following criteria: Geographical location (C1), infrastructure and facilities (C2), service quality and charges (C3), and regulatory compliances
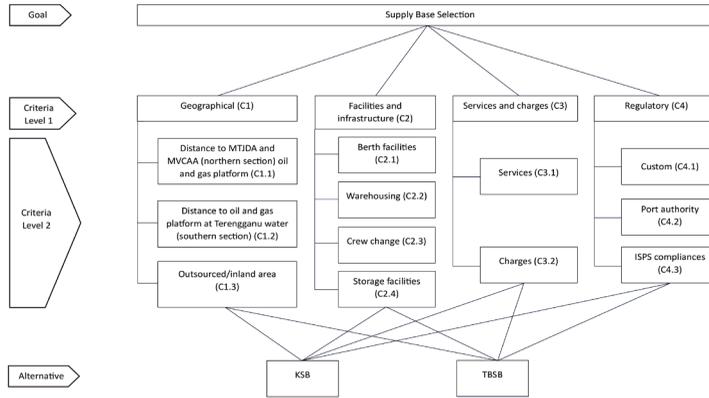
Figure 6: The hierarchical structure of supply base selection

(C4). Each entity is broken down into its individual properties. The attributes of the criterion "geographical" encompass the distance to the MTJDA and MVCAA (northern section) of the oil and gas platform (C1.1), the distance to the oil & gas platform at Terengganu water (southern section) (C1.2), and the outsourced/inland area (C1.3). The features of the criterion "infrastructure and facilities" include berth facilities (C2.1), warehousing (C2.2), crew change (2.3), and storage facilities (2.4). The attributes of the criterion "service and charges" are as follows: Service (3.1) and charges (3.2). The elements of the criterion "regulatory compliances" include custom (C4.1), port authority (C4.2), and ISPS compliances (C4.3).

Step 3: Evaluating the elements by pairwise comparison to obtain weights of elements

The weights of the AHP model's elements at each level are calculated by performing pairwise comparisons (Timor & Sipahi, 2005). Decision makers will compare the importance of the elements at each level in a pairwise fashion based on their prior knowledge or experience (H. Ho *et al.*, 2011). "For instance, every criterion in the second level is compared at each time concerning the goal while every attribute of the same criterion in the third level is compared at a time concerning the corresponding criterion" (Ho, W., 2008).

Furthermore, each pair of alternatives in the last level of the hierarchy is compared concerning the decision criterion and the sub-criterion. A questionnaire that allows for pairwise comparison of each pair of elements in the hierarchical model can be given to the decision-makers to determine the weight of the elements.

A rating scale called the Saaty Scale (Saaty, 1982) is used to measure the weights of the elements in the pairwise comparison. A questionnaire survey was designed to collect data from the decision-makers. The data collected were from the pairwise comparison of all the suggested elements in the hierarchical model. Five decision makers were gathered for an interview session and given the questionnaire survey to fill out.

Each question in the survey was a pairwise comparison of two elements at the same level. One example was "How important is Criterion 1 compared to Criterion 2?". This applied to all the criteria and sub-criteria. As for the alternatives, each was pairwise compared against one another to determine how well the first alternative met the sub-criteria against its pair. For example, "How well does Alternative 1 meet Criterion 5 compared to Alternative 2?" The pairwise comparison was done using the Saaty Scale (Saaty, 1982), as shown in Table 4. In this case, the average result from all the decision-makers was gathered to determine the relative weight of the factors. Table 3 shows the result of the interviewer's example of the relative weight scale for factor facility and infrastructure.

Table 3: Average relative weights by interviewers for sub criterion facilities and infrastructure C2

Criterion	C2.1-C2.2	C2.1-C2.3	C2.1-C2.4	C2.2-C2.3	C2.2-C2.4	C2.3-C2.4
I1	4	2	1	1	1	1
I2	6	1	2	0.333	1	3
I3	1	4	1	4	1	0.25
I4	4	2	1	0.5	1	0.5
I5	3	3	2	3	1	3
AVE	**3.6**	**2.4**	**1.4**	**1.7**	**1**	**1.4**

Table 4: 9-point intensity of relative weight (importance or well-being) scale

Definition	Scale	Significance
Equal importance/Equally good	1	Two preferences contributed equally to the decision
Moderate importance of one factor over another/Weakly	3	Experience and judgements slightly favour one preference over the other
Strong or essential importance/Strongly	5	Experience and judgements strongly favour one preference over the other
Very strong importance/Very strongly	7	A preference is strongly favoured and its dominance is demonstrated in practice
Extreme importance/Absolutely better	9	The evidence favouring one preference over the other is of the highest possible order of affirmation
Intermediate value between the two adjacent judgements	2, 4, 6, 8	Intermediate value between the two adjacent judgements
Reciprocals for inverse comparison		Reciprocals of the above nonzero numbers

Source: Adapted from Saaty (1982)

Pair-wise Comparisons

The elements of each level are compared pairwisely concerning the next upper-level element in terms of their importance. Moving from the top to the bottom of the hierarchy, the pairwise comparisons at a given level can be reduced to multiple square matrices.

$C= [C_{ij}]_{xnx}$ as is the following:

$$\begin{bmatrix} C_{11} & C_{12} & C_{13} \\ C_{21} & C_{22} & C_{23} \\ C_{31} & C_{32} & C_{33} \end{bmatrix}$$

The matrix which has reciprocal properties $R = \left[\frac{1}{C_{ij}}\right]_{xnx}$ are represented as:

$$\begin{bmatrix} \frac{1}{C_{11}} & \frac{1}{C_{12}} & \frac{1}{C_{31}} \\ \frac{1}{C_{21}} & \frac{1}{C_{22}} & \frac{1}{C_{32}} \\ \frac{1}{C_{31}} & \frac{1}{C_{32}} & \frac{1}{C_{33}} \end{bmatrix}$$

In AHP, Saaty (1980) suggested that a scale of relative importance from 1 to 9 is used to make subjective pair-wise comparisons (Table 4). First, all pairwise comparison matrices are formed. Then, the vector of weights $W=[W_1, W_2, \ldots, W_n]$, is computed based on Saaty's eigenvector procedure. The calculation of the weights involves two steps: (1) Forming a normalised pair-wise matrix and (2) creating a weighted matrix (Chen, 2006). The scale of the relative importance is defined in Table 4 according to the Saaty 1 to 9 scale for pairwise comparison.

After the pair-wise comparison matrix, $C= [C^{ij}]^{xnx}$ is done, the normalised by equation (1) (Chen, 2006), in which each element in the matrix is divided by its column total to generate a normalised pair-wise matrix (Bunruamkaew, 2012).

$$X_{ij} = \frac{C_{ij}}{\Sigma_{i=1}^{n} C_{ij}} \begin{bmatrix} X_{11} & X_{12} & X_{31} \\ X_{21} & X_{22} & X_{32} \\ X_{31} & X_{32} & X_{33} \end{bmatrix} \tag{1}$$

for all j = 1, 2, . . . , n.

Step 4: Calculating weights of all elements in the hierarchical model

The priority weight of criterion, sub-criteria, and alternatives is derived using the eigenvector approach mentioned before. Firstly, a matrix is generated to compare each criterion with one another, and then the resulting matrix is standardised to provide a consistent format. To ascertain the priority of a particular criterion (or sub-criterion or alternative), the relative weights are computed by averaging the pairwise comparisons of the pertinent values.

The weight of each element was determined using the eigenvector approach, as described by equation (2). This method involves dividing the sum of the normalised column of the matrix by the number of criteria employed (n) to obtain a weighted matrix (Bunruamkaew, 2012).

$$W_{ij} = \frac{\Sigma_{j=1}^{n} X_{ij}}{n} \begin{bmatrix} W_{11} \\ W_{21} \\ W_{31} \end{bmatrix} \tag{2}$$

for all i = 1, 2, . . . , n.

Step 5: Consistency check

In order to obtain a consistency vector, the pair-wise matrix is multiplied by the weights vector as equation (3):

$$\begin{bmatrix} C_{11} & C_{12} & C_{13} \\ C_{21} & C_{22} & C_{23} \\ C_{31} & C_{23} & C_{33} \end{bmatrix} * \begin{bmatrix} W_{11} \\ W_{21} \\ W_{31} \end{bmatrix} = \begin{bmatrix} C_{11} \\ C_{21} \\ C_{31} \end{bmatrix} \qquad (3)$$

Then, it is achieved by dividing the weighted sum vector by criterion weight (Bunruamkaew, 2012):

$$Cv_{11} = \frac{1}{W_{11}}[C_{11}\,W_{11} + C_{21}W_{21} + C_{13}W_{31}]$$

$$Cv_{21} = \frac{1}{W_{21}}[C_{21}\,W_{11} + C_{22}W_{21} + C_{23}W_{31}] \qquad (4)$$

$$Cv_{31} = \frac{1}{W_{31}}[C_{31}\,W_{11} + C_{23}W_{21} + C_{33}W_{31}]$$

There is a relationship between the vector weights, 9 and the pairwise comparison matrix, as shown in the following equation 5 (Chen, 2006):

$$C_W = \lambda_{max}W \qquad (5)$$

The value of $\lambda_{max}W$, the maximum eigenvalue of the comparison matrix (Mikhailov & Tsvetinov 2004), is an important validating parameter in AHP. It is used as a reference index to screen information by calculating the estimated vector's consistency ratio (CR) (Chen, 2006). λ is obtained by averaging the value of the consistency vector, formulated using equation (6) (Bunruamkaew, 2012):

$$\lambda = \sum_{i=1}^{n} Cv_{ij} \qquad (6)$$

In order to calculate the CR, the consistency index (CI) for each matrix of order n can be obtained from equation (7) (Chen, 2006):

$$CI = \frac{\lambda_{max} - n}{n - 1} \qquad (7)$$

The consistency ratio *CR* for the decision makers' judgements was calculated and checked using the equation (8):

$$CR = \frac{CI}{RI} \tag{8}$$

Where *RI* is the random consistency index obtained from a randomly generated pairwise comparison matrix. Table 5 shows the values of the RI for matrices of order 1 to 9 (Saaty, 1980). If the result of *CR* is < 0.1, the result of the alternative is considered valid. Any higher value at any level *CR* > .01 indicates that the decision makers' judgements warrant re-examination (Bunruamkaew, 2012); thus, the AHP procedure should be reviewed and revised.

After determining the *CR*, create an aggregate measure of the pairwise comparisons of all individuals involved in a decision problem, the individual assessments are averaged using equation (9):

$$C_{ij}^{hp} = \sqrt[q]{\prod_{q=1}^{q} C_{ij}^{q}} \tag{9}$$

Where C_{ij}^{q} is an element of matrix *C* of an individual q(q = 1, 2, 3, …,Q), and C_{ij}^{hp} is the average or the sum of a collection of numbers divided by the count (arithmetic mean) of all individuals C_{ij}^{q}. The group *CR* is calculated according to equations (7) and (8) (Saaty, 1982; Chen, 2006). Tables 6, 7, 8, 9, and 10 presents the results of the pairwise comparison, priority weight, and CR for the criteria and sub-criteria.

Table 5: Random index for N = 9

Random Index (RI)									
N	1	2	3	4	5	6	7	8	9
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45

Source: Saaty (1980)

Table 6: Pairwise comparison matrix and weights for the main criterion

Criterion	C1	C2	C3	C4	Priority Weight
Geographical (C1)	1	2.1	2.6	2.9	0.4209
Facilities and infrastructure (C2)	0.48	1	3	2.5	0.2946
Service and charges (C3)	0.38	0.33	1	3	0.1806
Regulatory (C4)	0.34	0.40	0.33	1	0.1039

CR: 0.0898

Table 7: Pairwise comparison matrix and weights for sub criterion geographical (C1)

Sub Criterion (C1)	C1	C2	C3	Priority Weight
Distance to MTJDA and MVCAA (Northern Section) oil and gas platform (C1.1)	1	2.0	1.6	0.4306
Distance to oil and gas platform at Terengganu Water (Southern Section) (C1.2)	0.49	1	1.4	0.2928

Outsourced/Inland Area (C1.3)	0.86	0.69	1	0.2766

CR: 0.0819

Table 8: Pairwise comparison matrix and weights for sub criterion facilities and infrastructure (C2)

Sub Criterion (C2)	C2.1	C2.2	C2.3	C2.4	Priority Weight
Berth facilities (C2.1)	1	3.6	2.4	1.4	0.4237
Warehousing (C2.2)	0.28	1	1.8	1	0.1959
Crew change (C2.3)	0.42	0.57	1	1.6	0.1875
Storage facilities (C2.4)	0.71	1	0.65	1	0.1929

CR: 0.0907

Table 9: Pairwise comparison matrix and weights for sub criterion service and charges (C3)

Sub Criterion (C3)	C3.1	C3.2	Priority Weight
Service (3.1)	1	4	0.8000
Charges (3.2)	0.25	1	0.2000

CR: 0.000

Table 10: Pairwise comparison matrix and weights for sub criterion regulatory (C4)

Sub Criterion (C4)	C4.1	C4.2	C4.3	Priority Weight
Custom (C4.1)	1	2.1	2.1	0.4977
Port authority (C4.2)	0.48	1	2.1	0.3099
ISPS compliances (C4.3)	0.48	0.48	1	0.1923

CR: 0.0510

Step 6: Calculating the final score for selecting the supply base

Table 10 summarises the priority weight assigned to each criterion, sub-criterion, and alternative in selecting a supply base, together with their corresponding scores. The utilisation of a pair comparison matrix determines the priority weight. In this analysis, two options are assessed based on their priority weight in terms of the number of decision elements, including criteria and sub-criteria. The priority weight for alternatives is determined based on the performance of each alternative relative to individual sub-criteria. As previously stated, the score for each sub-criterion is determined by multiplying the priority weights inside that sub-criterion. Subsequently, the values are consolidated into a comprehensive score by calculating the average of the total score

(T-score) for each choice, where the T-score is the score for each alternative by multiplying the priority weight of the main criterion with the sub-criterion and the weight of the alternative relative to the sub-criterion, to facilitate the decision-making process.

To calculate the overall score for KSB, use the following calculation.

[C1 PV x C1.1 PV x KSB C1.1 S] + [C1 PV x C1.2 W x KSB C1.2 S] + [C1 PV x C1.3 PV x KSB C1.3 S] + [C2 PV x C2.1 PV x KSB C2.1 S] + [C2 PV x C2.2 W x KSB C2.2 S] + [C2 PV x C2.3 PV x KSB C2.3 S] + [C2 PV x C2.4 PV x KSB C2.4 S] + [C3 PV x C3.1 PV x KSB C3.1 S] + [C3 PV x C3.2 W x KSB C3.2 S] + [C4 PV x C4.1 PV x KSB C4.1 S] + [C4 PV x C4.2 PV x KSB C4.2 S] + [C4 PV x C4.3 PV x KSB C4.3 S] = 0.679

Results and Discussion

The analysis of the offshore supply base selection criteria in Table 11 reveals that the component with the highest significance is "geographical" (0.4209). The three key criteria are "facilities and infrastructure" (0.2946), "service and charges" (0.1806), and "Regulatory" (0.1039). Based on the score, the attribute that holds the highest level of importance is the "Distance to MTJDA and MVCAA (northern section) of the oil and gas platform", accounting for (0.1812). The prioritised attributes are as follows: (2) Service (0.1445), (3) berth facilities (0.1248), (4) distance to oil and gas platform at Terengganu water (southern section) (0.1232), (5) outsourced/inland area (0.1164), (6) warehousing (0.0577), (7) storage facilities (0.0568), (8) crew change (0.0552), (9) custom (0.0517), (10) charges (0.0361), (11) port authority (0.0322), and last ranked (12) are ISPS compliances with the score of (0.0200). The AHP ranked KSB as the most suitable supply base to be selected with a weight of 0.679 presented of 68%. The other offshore supply base, known as the Tok Bali supply base has a weight of 0.321 presented at 32%. While KSB dominates the overall situation, not all elements are in its favor.

Analysing the distance variable, the MTJDA and MVCAA (northern section) of the oil and gas platform (C1.1) data indicates that TBSB has a higher weight of 0.8705 than KSB, which only weighs 0.1295. It was found that oil and gas operators in the northern section of the MTJDA and MVCAA sector selected TBSB as a logistical base for their offshore operations. This is due to the proximity of the location compared to KSB. It was discovered that operators in the southern region or the offshore area of Terengganu selected KSB as their target. This demonstrates the significant impact of the location distance factor and corroborates the findings of previous investigations.

Another contributing element to TSBS's victory over KSB is the difference in charges (C3.2), with TSBS having a weight of 0.6711 and KSB having a weight of 0.3289. It was discovered that a significant number of respondents preferred TBSB over KSB. This indicates that the potential rates charged by TBSB are more dependable and competitive. The other outcome in the selection of supply base between KSB and TBSB that can be compared based on the sub-criterion is displayed in Table 11.

Table 11: Priority weight and score for criterion, sub-criterion, and alternative

Criterion	Priority Weight	Sub-criteria	Priority Weight	Score (S)	Alternative	Priority Weight	T-score (S)
Geographical (C1)	0.4209	C1.1	0.4306	0.1812	KSB TBSB	0.1295 0.8705	0.0235 0.1577
		C1.2	0.2928	0.1232	KSB TBSB	0.8352 0.1648	0.1029 0.0203
		C1.3	0.2766	0.1164	KSB TBSB	0.8571 0.1429	0.0998 0.0166
CR for sub-criterion C1: 0.0819							
Facilities and infrastructure (C2)	0.2946	C2.1	0.4237	0.1248	KSB TBSB	0.8485 0.1515	0.1059 0.0189
		C2.2	0.1959	0.0577	KSB TBSB	0.8333 0.1667	0.0481 0.0096
		C2.3	0.1875	0.0552	KSB TBSB	0.7500 0.2500	0.0414 0.0138
		C2.4	0.1929	0.0568	KSB TBSB	0.8438 0.1562	0.0480 0.0089

		CR for sub-criterion C2: 0.0907					
Service and charges (C3)	0.1806	C3.1	0.8000	0.1445	KSB TBSB	0.8485 0.1515	0.1226 0.0219
		C3.2	0.2000	0.0361	KSB TBSB	0.3289 0.6711	0.0119 0.0242
		CR for sub-criterion C3: 0.000					
Regulatory (C4)	0.1039	C4.1	0.4977	0.0517	KSB TBSB	0.7500 0.2500	0.0388 0.0129
		C4.2	0.3099	0.0322	KSB TBSB	0.7222 0.2778	0.0233 0.0089
		C4.3	0.1923	0.0200	KSB TBSB	0.6667 0.2333	0.0133 0.0067
		CR for sub-criterion C4: 0.0510					
CR for main criterion = 0.0921							
FINAL SCORE					KSB TBSB	0.679 0.321	68% 32%

Conclusions and Implication

This study offers a comprehensive analysis of the offshore supply base. The text provides additional details on integrating offshore supply bases inside the oil and gas supply chain. The objective is to validate the efficacy of the AHP for selecting an appropriate offshore supply base in East Coast Peninsular Malaysia. The alternatives for evaluating the Analytic Hierarchy Process (AHP) approach were determined by analysing pertinent research on the criteria and sub-criteria in the hierarchical model, as well as utilising literature and interview data and have intended to show an expert's point of view for factors affecting the selection of supply base.

Offshore supply bases are essential elements of the logistics network that support the oil and gas sector's exploration and production (E&P) activities. These supply bases serve as crucial centres, enabling the smooth movement of materials, equipment, and personnel between facilities on land and platforms in the sea. From the findings and discussion, the literature study emphasises the crucial function these bases play in guaranteeing smooth operations and the significance of strategic base selection. The Kemaman Supply Base (KSB) and the Tok Bali

Supply Base (TBSB) in Malaysia exemplify the substantial improvement in operational efficiency that can be achieved through the integration and strategic positioning of supply bases.

KSB, the largest fully integrated supply base in Peninsular Malaysia, provides a wide range of services, strong infrastructure, and a strategically advantageous location for firms operating off the Terengganu coast. TBSB, while newer, provides critical support to operations in the North Malay Basin, MTJDA, and MVCAA offering logistical advantages due to its proximity to these areas. Its proximity to these locations gives it logistical benefits, location, infrastructure and facilities, service offerings, and regulatory compliance.

Having a supply base close to offshore installations can decrease transportation costs and transit times. Additionally, advanced infrastructure and extensive services guarantee streamlined and effective operations. Furthermore, adherence to regulatory requirements is essential for preserving operational integrity and mitigating legal and reputational hazards. Ultimately, the performance of offshore E&P activities heavily relies on

offshore supply bases such as KSB and TBSB. Energy organisations can achieve optimal logistical operations, increased productivity, and cost-effectiveness by thoroughly evaluating location, infrastructure, services, and regulatory requirements. Well-managed supply bases will continue to be crucial to operational success in the evolving offshore oil and gas industry.

However, this study may have constrained the criteria and sub-criteria used to assess offshore supply bases, neglecting other pertinent considerations such as environmental effects, technical improvements, and long-term sustainability. Relying solely on literature reviews and expert interviews can induce biases. The limited sample size and lack of diversity among the experts interviewed may restrict the applicability of the findings. Moreover, emphasising the East Coast of Peninsular Malaysia implies that the results may not be relevant to other areas of distinct geopolitical, economic, and environmental circumstances.

Furthermore, the dynamic character of the oil and gas business, which is affected by volatile oil prices, regulatory modifications, and technical progress could potentially affect the applicability of the study's results in the long run. Although AHP is a resilient method for making decisions, it largely depends on the discernment and coherence of the decision-makers. Variations in decision-making can impact the dependability of the outcomes. In order to conduct a thorough evaluation of offshore supply bases, future studies should consider a broader range of variables such as environmental sustainability, technical advancements, and long-term strategic advantages.

By employing a mixed-method approach that integrates quantitative data such as performance indicators and cost analysis, with qualitative insights, a more comprehensive understanding can be achieved. Enhancing the generalizability of the findings can be achieved by incorporating a broader and more varied selection of industry experts. Performing comparative analyses across several geographical areas can aid in identifying universal standards for selecting a supplier base

and highlighting region-specific aspects that impact decision-making.

Conducting longitudinal studies to monitor the performance of certain supply bases over time can offer valuable insights into the long-term effects of strategic supply base selection and the flexibility of the criteria employed. Integrating the AHP with other decision-making frameworks and advanced analytical approaches such as fuzzy logic and multi-criteria decision analysis can improve the strength and dependability of the evaluation process.

An examination of the impact of developing developments in the oil and gas sector such as the increasing use of renewable energy, digitisation, and automation, on the criteria for choosing offshore supply bases can offer valuable insights for the future. A more thorough understanding of the consequences of supply base selection can be obtained by incorporating input from a wider array of stakeholders such as regulatory authorities, local communities, and environmental organisations.

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Conflict of Interest Statement

The author declares that they have no conflict of interest.

References

Aas, B., Gribkovskaia, I., Halskau, Ø., & Shlopak, A. (2007). Routing of supply vessels to petroleum installations. *International Journal of Physical Distribution & Logistics Management*, *37*(2), 164-179. https://doi.org/10.1108/09600030710734866

Aas, B., Buvik, A., & Cacik, Dj. (2008). Outsourcing of logistics activities in a complex supply chain: A case study from the Norwegian oil and gas industry. *International Journal of Procurement Management*, *1*(30), 280-296.

Aas, B., Halskau, Ø., Sr, & Wallace, S. W. (2009). The role of supply vessels in offshore logistics. *Maritime Economics & Logistics*, *11*(3), 302-325. https://doi.org/10.1057/mel.2009.7

Amiri, M., Sadjadi, S., Tavakkoli-Moghaddam, R., & Jabbarzadeh, A. (2018). Optimal fleet composition and mix periodic location-routing problem with time windows in an offshore oil and gas industry: A case study of National Iranian Oil Company. *Scientia Iranica*. https://doi.org/10.24200/sci.2018.20412

Amiri, M., Sadjadi, S. J., Tavakkoli-Moghaddam, R., & Jabbarzadeh, A. (2019). An integrated approach for facility location and supply vessel planning with time windows. *Journal of Optimization in Industrial Engineering, 12*(1)*, 151-165. https://doi.org/10.22094/joie.2018.544109.1517

A.-S. Milakovic, S. Ehlers, & M. H. Westvik. (2014). *Offshore upstream logistics for operations in arctic environment* (pp. 171-178). CRC Press eBooks.

Berry, L. L., Seiders, K., & Grewal, D. (2002). Understanding service convenience. *Journal of Marketing*, *66*(3), 1-17. https://doi.org/10.1509/jmkg.66.3.1.18505

Bhattacharya, P., & Hutchinson, F. E. (2022, March 2). 2022/21 "Malaysia's oil and gas sector: Constant expectations despite diminishing returns". *ISEAS-Yusof Ishak Institute*, *2022*(21), 1-17. https://www.iseas.edu.sg/wp-content/uploads/2022/01/ISEAS_Perspective_2022_21.pdf

Bichou, K. (2008). Security and Risk-Based Models in shipping and ports. *OECD/ITF Joint Transport Research Centre Discussion Papers*. https://doi.org/10.1787/228863484281

Bruno, U., & Guy, E. (2006). Port selection and multicriteria analysis: An application to the Montreal – New York alternative. *Maritime Economics and Logistics*, *8*(2), 169-186.

Bunruamkaew, K. (2012). *How to do AHP analysis in Excel* [PDF]. University of Tsukuba. https://giswin.geo.tsukuba.ac.jp/sis/gis_seminar/How%20to%20do%20AHP%20analysis%20in%20Excel.pdf

Chen, C. (2006). Applying the analytical hierarchy process (AHP) approach to convention site selection. *Journal of Travel Research*, *45*(2), 167-174.

Dalgic, Y., Lazakis, I., Dinwoodie, I., McMillan, D., & Revie, M. (2015). Advanced logistics planning for offshore wind farm operation and maintenance activities. *Ocean Engineering*, *101*, 211-226. https://doi.org/10.1016/j.oceaneng.2015.04.040

De Wardt, J. P. (1990). Drilling contracting in the nineties (Paper No. SPE 19902). Presented at the *1990 SPE/IADC Drilling Conference, 27 February-2 March 1990, Houston, Texas*.

Duffy, D. (1979). Northern North Sea offshore oil and gas supply base survey. *Trade Journal-Petroleum Review*, *33*(393), 30-49. https://www.scopus.com/record/display.uri?eid=2-s2.0-0018688493&origin=inward&txGid=0f31c14ed54ee5604148fd743b1b9995

Hassan, A. (2013). Review of the global oil and gas industry: A concise journey from ancient time to modern world. *Petroleum Technology Development Journal*, *3*(2), 123-141.

Ho, H., Chang, C., & Ku, C. (2013). On the location selection problem using analytic hierarchy process and multichoice goal programming. *International Journal of Systems Science*, *44*(1), 94-108. https://doi.org/10.1080/00207721.2011.581397

Ho, W. (2008). Integrated analytic hierarchy process and its applications – A literature review. *European Journal of Operational Research*, *186*(1), 211-228.

Islam, Y., & Siddiqui, D. A. (2019b). The effect of external factors towards the logistics performance in efficiency of material supply

for the pipeline construction based projects: Evidence from the Oil and Gas Industry in Pakistan. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3510617

Kaiser, M. J. (2010). An integrated systems framework for service vessel forecasting in the Gulf of Mexico. *Energy*, *35*(7), 2777-2795.

Kuo, R. J., Chi, S. C., & Kao, S. S. (2002). A decision support system for selecting convenience store location through integration of fuzzy AHP and artificial neural network. *Computers in Industry*, *47*(2), 199-214.

Le, D. N., Nguyen, H. T., & Truong, P. H. (2020). Port logistics service quality and customer satisfaction: Empirical evidence from Vietnam. *The Asian Journal of Shipping and Logistics*, *36*(2), 89-103. https://doi.org/10.1016/j.ajsl.2019.10.003

Lirn, T. C., Thanopoulou, H. A., Beynon, M. J., & Beresford, A. K. C. (2004). An application of AHP on transhipment port selection: A global perspective. *Maritime Economics and Logistics*, *6*(1), 70-91.

Randstad Malaysia (2024, February 21). Malaysia's oil and gas industry outlook and salary trends 2024. *Randstad Malaysia*. https://www.randstad.com.my/hr-trends/workforce-trends/malaysia-oil-gas-industry-outlook-salary-trends-2024/

Marzouk, M., & Sabbah, M. (2021). AHP-TOPSIS social sustainability approach for selecting supplier in construction supply chain. *Cleaner Environmental Systems*, *2*, 100034. https://doi.org/10.1016/j.cesys.2021.100034

Mikhailov, L., & Tsvetinov, P. (2004). Evaluation of services using a fuzzy analytic hierarchy process. *Applied Soft Computing*, *5*(1), 23-33.

Munier, N., & Hontoria, E. (2021). *Uses and limitations of the AHP method: A non-mathematical and rational analysis*. Springer.

Panayides, P., Borch, O. J., & Henk, A. (2018). Measurement challenges of supply chain performance in complex shipping environments. *Maritime Business Review*, *3*(4), 431-448. https://doi.org/10.1108/mabr-07-2018-0021

Razack, J., Nazir-Khaleel, I., Rampersad, S., Zambrano, A., Chandarjeet, S., & Choon, S. (2018). Shorebase Logistics for deepwater drilling operations in Trinidad, Guyana and Suriname. *Paper presented at the SPE Trinidad and Tobago Section Energy Resources Conference, Port of Spain, Trinidad and Tobago, June 2018*. https://doi.org/10.2118/191230-ms

Röben, S. A., Ottjes, J. A., Van Den Dool, A., & Lodewijks, G. (2008). *6th International Industrial Simulation Conference 2008, ISC 2008*. In Proceedings of the 2008 6th International Industrial Simulation Conference (pp. 288-292). [Conference presentation]. 6th International Industrial Simulation Conference, ISC 2008, June 9-11, 2008.

Roben, S., Ottjes, J. A., Lodewijks, G., & Van Den Dool, A. (2010). A design approach for asset supply logistics. *International Journal of Computer Aided Engineering and Technology*, *2*(4), 311. https://doi.org/10.1504/ijcaet.2010.035388

Robinson, R. (2002). Ports as elements in value-driven chain systems: The new paradigm. *Maritime Policy and Management*, *29*(3), 241-255.

S. Umeesh Kumar Suppramaniam, & Syuhaida Ismail (2020). Critical construction activities of the oil and gas projects in Malaysia. *Journal of Advanced Research Design, 64*(1), 14-22.

Saaty, T. L. (1980). *The analytic hierarchy process*. New York: McGraw-Hill.

Saaty, T. L. (1982). *Decision making for leaders*. New York: Lifetime Learning.

Tang, D. K. H., Leiliabadi, F., Olugu, E. U., & Dawal, S. Z. B. M. (2017). Factors affecting

safety of processes in the Malaysian oil and gas industry. *Safety Science*, *92*, 44-52. https://doi.org/10.1016/j.ssci.2016.09.017

Timor, M., & Sipahi, S. (2005). Fast-food restaurant site selection factor evaluation by the analytic hierarchy process. *The Business Review*, *4*(1), 161-167.

Triantaphyllou, E., & Mann, S. H. (1995). Using the analytic hierarchy process for decision making in engineering applications: Some challenges. *International Journal of Industrial Engineering*: *Applications and Practice*, *2*(1), 35-44.

Wang, G., Huang, S. H., & Dismukes, J. P. (2004). Product-driven supply chain selection using integrated multicriteria decision-making methodology. *International Journal of Production Economics*, *91*, 1-15.

Yang, H. (2014, June 16). *Identification of local environmental, geographical or cultural factors that may influence offshore operations and maintenance processes* (Master's Thesis, Faculty of Science and Technology, University of Stavanger). https://uis.brage.unit.no/uis-xmlui/handle/11250/2367025

Ye, L. R., Zhang, Y. J., Nguyen, D., & Chiu, J. (2004). Fee -based online services: Exploring consumers' willingness to pay. *Journal of International Technology and Information Management, 13*(1), Article 12. https://doi.org/10.58729/1941-6679.1248