RESEARCH ARTICLE

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AHP Application to Select Logistical Location in Upstream Oil and Gas Operation: A Case Study

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ABSTRACT

The objective of this research is to select the best logistics operation location for supporting multi-production field operations in an upstream oil and gas working area in Indonesia (Company XYZ). Company XYZ will have several upcoming production fields in the future, which are in different locations along the working area and far from the existing logistics operation location. Existing storage occupancy also becomes another consideration in preparation for the logistics operation plan to support multi-production fields. Some locations are examined as alternatives for upcoming logistics operation locations. The selection process will go through the Analytical Hierarchy Process (AHP) method as part of the Multi Criteria Decision Making (MCDM) tool. Three decision criteria used in this research refer to company XYZ's strategic pillars, which are Financial, HSE (Health, Safety, and Environment), and Production. The sub-criteria are selected from previous research that is relevant to the study. Some experts are involved in providing professional judgment for the available options to result in the alternative location with the highest priority as a business solution.

Keywords: Analytical hierarchy process, decision-making, logistics operation, upstream oil and gas.

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I. Introduction

Logistics play an important role in supporting the oil and gas industry, from the upstream sector to the downstream sector. According to Jubiz-Diaz *et al.* (2021), infrastructure, including land roads and ports, is one of the requirements that can influence logistics operations performance. Availability of infrastructure can increase transportation alternatives, frequency of transportation, and volume of products delivered. For the upstream oil and gas industry, infrastructure availability is critical for effective logistics operations to support oil and gas production. An optimal logistics location will help to achieve production targets by providing the required goods and services at the right time, place, quantity, and cost.

XYZ is an energy company that operates in the exploration and exploitation of the oil and gas sector in Indonesia. XYZ's operational area is located in the Madura Strait, East Java, Indonesia, and operates under a Production Sharing Contract (PSC) with the Indonesian Government through the Special Task Force for Upstream Oil and Gas Business Activities (SKK Migas), Ministry of Energy and Mineral Resources. XYZ started production from field A in 2017. Field A has an average gas production of around 110 million standard cubic feet per day (MMSCFD), and along with the gas production, it also produces condensate of around 6,000 barrels of oil per day (BOPD). To increase the production volume, XYZ plans to produce other prospective fields ahead. 5 additional fields will be produced by XYZ, which are Field B, C, D, E, and F. As XYZ's working area stretches along Madura Strait, those fields are spreading within this area from the left side until the right side of Madura Strait (as shown in Fig. 1). Storage occupancy of the existing warehouse also becomes another consideration to support upcoming multi-production field operations. Currently, the existing storage (shore base), which is in Sampang regency, East Java, and used to store the materials to support field A, has been occupied more than 50%. To support upcoming multi-production field operations, it is required to develop an optimum logistics operation scenario by choosing the location where the logistics operation will take place, such as a warehouse for the material storage and a port for the supply vessel will load and unload the cargos, and the crew boat will mobilize and demobilize passengers to and from the offshore facilities. Some relevant criteria need to be considered in the selection process of logistics operation location. There are also alternatives for the location to be selected. To reduce the complexity, the Analytical Hierarchy Process (AHP) is used in this study as part of Multi-Criteria Decision Making (MCDM) that can break down the problem into a hierarchy and provide the weight of each element which will result in one best option as a business solution.

II. Literature Review

Offshore oil and gas operation is a complex and challenging process that involves various activities. Laik (2018) mentioned that offshore oil and gas operation is

Fig. 1. Future XYZ production fields in Madura Strait.

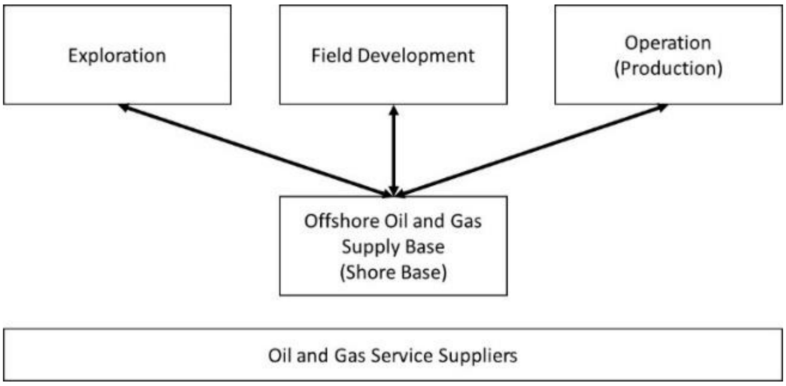


Fig. 2. Shore base role for offshore oil and gas operation.

divided into four major activities, which are exploration, drilling, production, and transportation. Speight (2015) stated that in offshore production operations, there are offshore facilities that need to be kept above sea level and undersea operations, which will provide serious operation challenges. In addition to the technical challenges involved in offshore oil and gas production, several environmental and safety concerns must be taken into account. Speight (2015) stated that there are risks that can arise from accidents in oil and gas production operations. Most of the risks are associated with the unexpected release of hydrocarbon and other hazardous chemicals and gasses, which can cause fire and explosion at offshore locations. The risks can get higher as the facilities are located in remote areas. These risks will impact humans, assets, and the environment. Speight (2015) also mentioned the environmental risks involved in offshore production operations are pollution and oil spills. Pollution can be caused by producing water during the production operation, and oil spills can be caused by accidents that happen on offshore platforms and during tanker operations. Rahmani *et al*. (2021) categorized the costs of accidents into several steps: (1) emergency action cost, (2) accident research cost, (3) investigation cost, (4) work and accident damage cost, (5) production cost, (6) restoring work reputation cost, and (7) resuming work activity cost.

However, the oil and gas industry has moved from a reactive approach to a proactive approach for safety (Crawley, 1999). To prevent the risks caused by potential accidents, risk mitigation is required in the form of a comprehensive operation plan before the execution, including the logistics operation that has critical parts in supporting the oil and gas production operation. In the context of offshore oil and gas production, logistics plays a key role in ensuring that the necessary equipment and personnel are available at the right time and place. Logistics operations take parts both for land support and marine support. For land support, the activities are concentrated at the shore base. According to Uthaug and Engelseth (2016), the offshore oil and gas shore base has the main function as a hub for material supply to and from offshore facilities in all operation phases (as shown in Fig. 2). For marine support, logistics operations are conducted to transport personnel and provide routine supplies as well as emergency support to recover from hazardous incidents (Rahman *et al.*, 2019). This will involve the use of specialized transport equipment and material storage in strategic locations, as well as the coordination of complex supply chains involving multiple related stakeholders. Sousa *et al.* (2015) described the material flow in offshore oil and gas operations into several steps: (1) treatment of requests, (2) picking, (3) packing, (4) ground transport, (5) port operation, (6) shipping, and (7) delivery.

There are multiple factors or criteria involved in selecting a location. In this research, to support fields offshore oil and gas production operation, the selection of logistics location becomes the key that will provide a direct impact on the operational performance. The logistics location can be a warehouse location, port location, or district location that can accommodate the port and warehouse requirements. The warehouse is required for material storage and handling from the supplier and to the desired location. The port is required to support the vessel operation in delivering the materials and transferring the personnel from the onshore location to the destination at the offshore location and vice versa. Demirel *et al.* (2010) stated that the main criteria for selecting warehouse locations are costs, labor characteristics, infrastructure, markets, and macro environment. According to Uysal and Tosun (2014), the criteria for selecting a warehouse location are costs, transportation, labor, environment, and geographical location. According to Hakim and Kusumastuti (2018), the criteria for selecting a warehouse location are costs, geographical location, infrastructure, proximity, and macro environment. According to Çetinkaya and Akdaş (2022), the criteria for selecting a warehouse location are costs, infrastructure, labor, market, and government. According to Singh *et al.* (2018), the criteria for selecting a warehouse location are infrastructure, government, and market. According to Chang *et al.* (2008), the criteria for port selection are geographical location, water draft, feeder connection, inland intermodal connection, port reputation, port dues, terminal handling charge, cargo volume, transhipment cargo volume, the possibility of a niche market, import and export cargo balance, cargo profitability, berth availability, service reliability, information technology ability, convenience of custom process, relationship between management and workers, acceptance of special requirements, easiness of communication with staff, calling of competitors, slot and exchange with cooperation lines. According to Sun and Yang (2014), the criteria for port selection are port location, port infrastructure condition, level of port information, port custom clearance conditions and bonded functions, hinterland and economic conditions, logistics industry policy, and distribution condition of port.

Selecting the logistics operation location will involve many attributes to be considered. To support the selection process, the multi-criteria decision-making (MCDM) method could be used. According to Munier *et al.* (2019), MCDM is a process to select one of the alternative solutions that need to meet several criteria. There are many methods of MCDM established in the literature. However, Lee and Yang (2018) stated none of the MCDM methods is suitable for all environmental conditions. Sometimes, a hybrid approach is performed to deal with complex conditions. Ishizaka and Nemery (2013) mentioned that there are several types of decision problems: (1) choice problem, (2) sorting problem, (3) ranking problem, (4) description problem, (5) elimination problem, and (6) design problem. Ishizaka and Nemery (2013) explained that a choice problem is choosing the best option or narrowing the field of choices, and the suitable MCDM method for the choice problem is the Analytical Hierarchy Process (AHP). AHP is one of the MCDM methods found by Thomas Saaty, which is useful for organizing complex problems. AHP breaks down the problem into a hierarchy, which helps simplify its complexity and displays the connections between various objectives (or criteria) and potential alternatives. The biggest advantage of this method is that it allows the inclusion of intangibles, such as experience, subjective preferences, and intuition, in a logical and structured way (Mu & Pereyra-Rojas, 2017). According to Mu and Pereyra-Rojas (2017), to perform the AHP analysis, a decision hierarchy needs to be developed. The decision hierarchy consists of the main objective at the top of the hierarchy and the criteria and sub-criteria arranged hierarchically, followed by the decision alternatives at the bottom of the hierarchy (as shown in Fig. 3).

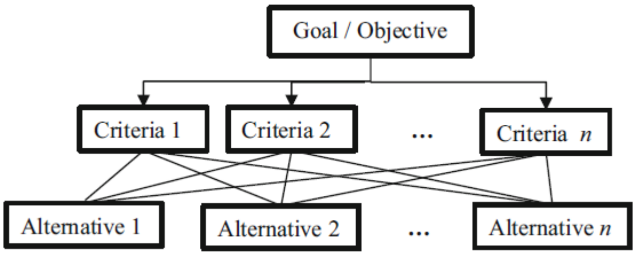


Fig. 3. AHP decision hierarchy.

After the hierarchy is developed, then continue to establish priorities. In this step, judgment is conducted through pairwise comparisons that are made between the criteria, sub-criteria, and alternatives to establish their relative importance or priority. A judgment or comparison is the numerical representation of a relationship between two elements that share a common parent (Saaty, 1994). Saaty (1994) also mentioned that the comparisons are made using a scale from 1 to 9 (1-The two elements are equally important, to 9-One element is extremely more important than the other). Once the pairwise matrix of the criteria is fully completed, then checking consistency amongst the pairwise comparisons is required to ensure the judgment is consistent and does not cause bias in the result. According to Saaty (1994), the Consistency Ratio (CR) is calculated by dividing the Consistency Index (CI) by the Random Index (RI). Random Index refers to Table I, while CI is a result of the following formula:

$$((\lambda \max - n)/(n-1))\,.^{(1)} \tag{1}$$

TABLE I: RANDOM CONSISTENCY INDEX

n	1	2	3	4	5	6	7	8	9	10
Random Consistency Index (R.I)	0	0	0.52	0.89	1.11	1.25	1.35	1.4	1.45	1.49

Using the priorities established in the previous step and after finding that the judgment is already consistent, weighted scores for each alternative are calculated. The weighted scores reflect the relative importance of each alternative. Based on the weighted scores, a final decision is made. The decision is based on the alternative with the highest weighted score.

III. Methodology

This research uses mixed methods to solve the business issue of selecting the logistics operation location in supporting multi-field production operations. This research uses both primary data and secondary data. Secondary data is collected through several ways, such as observing available XYZ data, taken from books, previous research or reports, or the internet, and mapping through the map in the application. Some data are available in XYZ from previous activities, such as strategic pillars, the cost for logistics operation, the distance between ports to XYZ field location, ports infrastructure condition, and jetty occupancy. Other data are available on the internet or other applications, such as available ports in selected regions or within XYZ operation area. Primary data used in this research are coming from the involved and credible sources in XYZ. The sources are the expert personnel who are directly involved and have direct concerns with logistics operations in supporting the production activities. There are 6 experts involved in this research to provide their professional judgments on pairwise comparison questionnaires as part of the AHP method to result in the business solution with the highest global priority among the available criteria and alternatives. The experts are the Manager of Logistics, the Manager of Regional Offices and Relations, the Manager of HSSE, the Sr. Head of BCDE Field Operations, the Head of D Field Operation, and the Head of Maintenance Support. All the experts have experience in oil and gas operations for more than ten years.

IV. Data Collection

A. *Decision Criteria*

In defining criteria, this research uses existing XYZ strategic pillars as a reference for the criteria. XYZ strategic pillars become company targets that must be achieved by all company elements. Logistics operation, as part of XYZ operation as a whole, also shall refer to this company target. Based on XYZ's operation condition, there are three strategic pillars to be used as decision criteria related to logistics operations in supporting production fields. The decision criteria are HSE (Health, Safety, and Environment), production, and financial. The HSE aspect becomes the critical target for XYZ's operation. All XYZ operation activity, including logistics operation, shall put HSE as the priority because of its impact on people, company assets, environment, company reputation, and operation sustainability. The production pillar will relate to all the activities required to produce oil and gas, including its supporting activities. To support production operation and ensure all the logistical requirements are available when needed are part of the logistics scope in XYZ. All XYZ functions shall work together to succeed in the production activity and achieve the production target. Logistics operation shall be able to provide the required materials and services promptly without causing any delay to production activity. Logistics operation also relates to the financial pillar, as the logistics activity will incur costs that need to be managed as per the approved budget and to achieve XYZ's financial pillar target. XYZ's Financial target can be described as the expected income value generated in such a period. This value will be influenced by the operation costs. The operation costs need to be managed properly to ensure XYZ will have positive income and the financial pillar target will be achieved. The decision criteria for this research are described in Table II.

TABLE II: Decision Criteria

Criteria	Description
Financial	The money value that results from XYZ's business activity in producing oil and gas in the Madura Strait area
HSE (Health, Safety, and Environment)	All required action to minimize the potential hazards to prevent risks/accidents and properly handle the risks/accidents if they happen during XYZ production operation.
Production	All required actions to generate oil and gas from the reservoir and transport it to the buyer's location.

B. *Decision Sub-criteria*

After defining decision criteria, each criterion needs to be broken down into sub-criteria to get more detailed attributes. The sub-criteria for this research refer to previous research in terms of selecting logistical locations. The available sub-criteria in the previous research were then selected based on their relevance with the company operation condition and requirements, which has been discussed in the early stage of the operation preparation in XYZ. Table III shows the decision sub-criteria for this research.

TABLE III: Decision Sub-criteria

Criteria	Sub-criteria	Reference
Financial	Storage & Handling Cost	Çetinkaya and Akdaş (2022), Hakim and Kusumastuti (2018), Chang *et al.* (2008), Demirel *et al.* (2010)
	Transportation & Distribution Cost	Çetinkaya and Akdaş (2022), Hakim and Kusumastuti (2018), Demirel *et al.* (2010)
HSE (Health, Safety, and Environment)	Proximity to Field Location	Hakim and Kusumastuti (2018), Demirel *et al.* (2010)
	Port Infrastructure Condition	Sun and Yang (2014), Çetinkaya and Akdaş (2022)
Production	Vessel Berthing Availability at Jetty	Chang *et al.* (2008)
	Local Government support	Singh *et al.* (2018), Çetinkaya and Akdaş (2022), Demirel *et al.* (2010)

Storage and handling activities involve related costs that will differ between one location with other locations. Each alternative will be compared based on the cost of storage and handling that occurred for logistical operations in each location in 1 year. Storage and handling cost involves facility rental cost, heavy equipment rental cost, manpower cost,

Fig. 4. XYZ Production unit locations and alternative port locations.

other associated costs for storing and handling materials in the warehouse, and also associated costs for port handling. Besides storage and handling costs, transportation is a major component of logistics operations. Similar to storage and handling costs, the transportation and distribution costs are also calculated on a 1-year basis. Transportation and distribution cost involves fuel cost from vessel sailing activity, fuel supply cost, and freshwater supply cost.

In supporting oil and gas production operations, the proximity of the logistics operation location is required for supplying the materials and transferring personnel promptly, including in emergency conditions. The short distance between the logistics operation location and the field location will minimize the supply lead time. The distance also can affect personnel health, which short distance will lead to less fatigue personnel during personnel transfer. In an emergency, proximity to the field location can affect the medical evacuation and oil spill combat scenario. This scenario might require additional logistical support, such as air transportation or additional storage. The longer distance between the logistics operation location and the field location will lead to another mode of transportation, such as helicopters, that might not be needed for shorter distances. Port infrastructure conditions become important attributes that can succeed in the logistics operation, especially for marine operations. This research will compare the port infrastructure for jetty size that might differ between one port and other ports. The small jetty dimension will provide limited space for operation and increase the hazard of accidents. The bigger jetty size will provide many advantages for logistics operation, not only to minimize the risk from potential hazards during activities at the jetty location but also to provide flexibility for logistics operation for bigger material dimensions.

The availability of space for XYZ vessels to berth at the jetty location becomes one attribute to consider in the selection of logistics operation location. One port might be very busy handling vessel berthing for other needs and leave no space for XYZ berthing or have to wait for a long time to get the berthing space. This waiting time will take a longer lead time of 1 vessel trip from the field location to the shore location and return to the field location. The jetty waiting time should be minimized because the vessel is required to return to the field location for other operation activities, or sometimes, the materials are urgently required by the offshore operation team. For personnel transfer, an on-schedule vessel trip is required to reduce personnel fatigue and also to catch the flight for personnel who want to go back to their hometown. In the shutdown period in which the offshore production facilities is stopped to have periodical maintenance, there will be a lot of vessel trip from offshore location to shore location to mobilize personnel and materials for those activities. In this period, vessel trip lead time (including jetty waiting time) becomes very critical because the maintenance program should finish as soon as possible so the production facilities can start production again. The local government plays a vital role in succeeding XYZ oil and gas production operations, such as issuing required permits and also helping XYZ in educating and socializing XYZ activities to the local community. The existence of XYZ operation in such an area will create opportunities for local suppliers to participate and also will provide additional income to the local government. This will create a win-win condition between XYZ and the local government (including the local community). XYZ can provide a positive contribution in terms of economy and other aspects to the field area regency, and the local government can support XYZ in succeeding in the production operation. Engagement of local parties in XYZ production operation is good for XYZ production sustainability by maintaining smooth production operation in a safe and timely manner.

C. *Decision Alternatives*

XYZ's upcoming production fields are located in a different location from the existing field. To support the new 5 additional fields (B, C, D, E, and F), XYZ will have two additional production units, which are FPU and MOPU. FPU will be operated to support B, C, E, and F fields, while MOPU will be operated to support D field. To simplify the model, this research will use FPU and MOPU locations as the destination in offshore locations instead of using wellhead platform locations for each field. FPU and MOPU will represent each related field with the production unit location. FPU and MOPU will be the center of material and personnel movement from offshore to onshore (or vice versa) and between field locations.

TABLE IV: DECISION ALTERNATIVES

Alternative No.	Production Unit	Operation Activity	Location (Port)
1	FPU	Material Supply Personnel Transfer	Trunojoyo
	MOPU	Material Supply Personnel Transfer	Trunojoyo
2	FPU	Material Supply Personnel Transfer	Tanjungwangi
	MOPU	Material Supply Personnel Transfer	Tanjungwangi
3	FPU	Material Supply Personnel Transfer	Tanjungwangi
	MOPU	Material Supply Personnel Transfer	Trunojoyo
4	FPU	Material Supply Personnel Transfer	Trunojoyo Kalianget
	MOPU	Material Supply Personnel Transfer	Trunojoyo
5	FPU	Material Supply Personnel Transfer	Tanjungwangi Kalianget
	MOPU	Material Supply Personnel Transfer	Trunojoyo

Note. Trunojoyo Port (Sampang); Tanjungwangi Port (Banyuwangi); Kalianget Port (Sumenep).

The alternative logistics operation location for the upcoming production fields will use the port location for the location selection. This research will focus on 3 port locations that were considered to become alternatives because of the relevancy with XYZ fields' location and existing logistics operation, which are Trunojoyo port in Sampang regency, Kalianget port in Sumenep regency, and Tanjungwangi port in Banyuwangi regency. Trunojoyo port is considered an alternative location because it is an existing logistics operation to support A field, and there are around 20%-35% of empty spaces in the Sampang shore base that can be optimized to support another field. Kalianget port is considered an alternative location because B, C, D, E, and F fields are located in Sumenep regency, and the port location is very close to the FPU compared to other locations. Tanjungwangi port is considered an alternative location because XYZ has an existing warehouse there to store drilling materials (called XYZ Banyuwangi shore base), and this port is used to support drilling operations. There are possibilities to optimize the current XYZ Banyuwangi shore base to support new production field operations and also consider the jetty size and infrastructure of Tanjungwangi port that can support heavy materials with big dimensions. The map for FPU and MOPU locations and the related ports to be considered as alternatives are shown in Fig. 4.

Due to there being two additional production units to be supported and those production units being located in different locations, this research will consider mixed port location as the decision alternative. This mixed port location will be an additional alternative to a single port location that can increase operation optimization. Kalianget port is excluded from the option for material supply due to the maximum water depth being only 2 meters (as per Indonesian Government Ministry of Communication decree number 76 the year 2019). The alternative locations are in Table IV.

D. Decision Hierarchy

After the decision criteria, decision sub-criteria, and decision alternatives have been completely defined, a decision hierarchy can be created. The decision hierarchy for this research is shown in Fig. 5.

E. Pairwise Comparisons

After the hierarchy model is developed, the next step is to conduct a pairwise comparison between criteria, sub-criteria, and alternatives. Pairwise comparison is required to gather priority or weight between criteria, sub-criteria, or alternatives that will impact the business solution. Pairwise comparison data was collected through a questionnaire to 6 respondents as the expert for this research. The experts will provide their professional judgment during the pairwise comparison data collection. The data was collected through direct discussion and guidance to fill out the form. A sample of pairwise comparison tables between criteria is shown in Table V.

TABLE V: PAIRWISE COMPARISON BETWEEN CRITERIA

Options		Score								
		1	2	3	4	5	6	7	8	9
Financial	HSE									
Financial	Production									
HSE	Production									

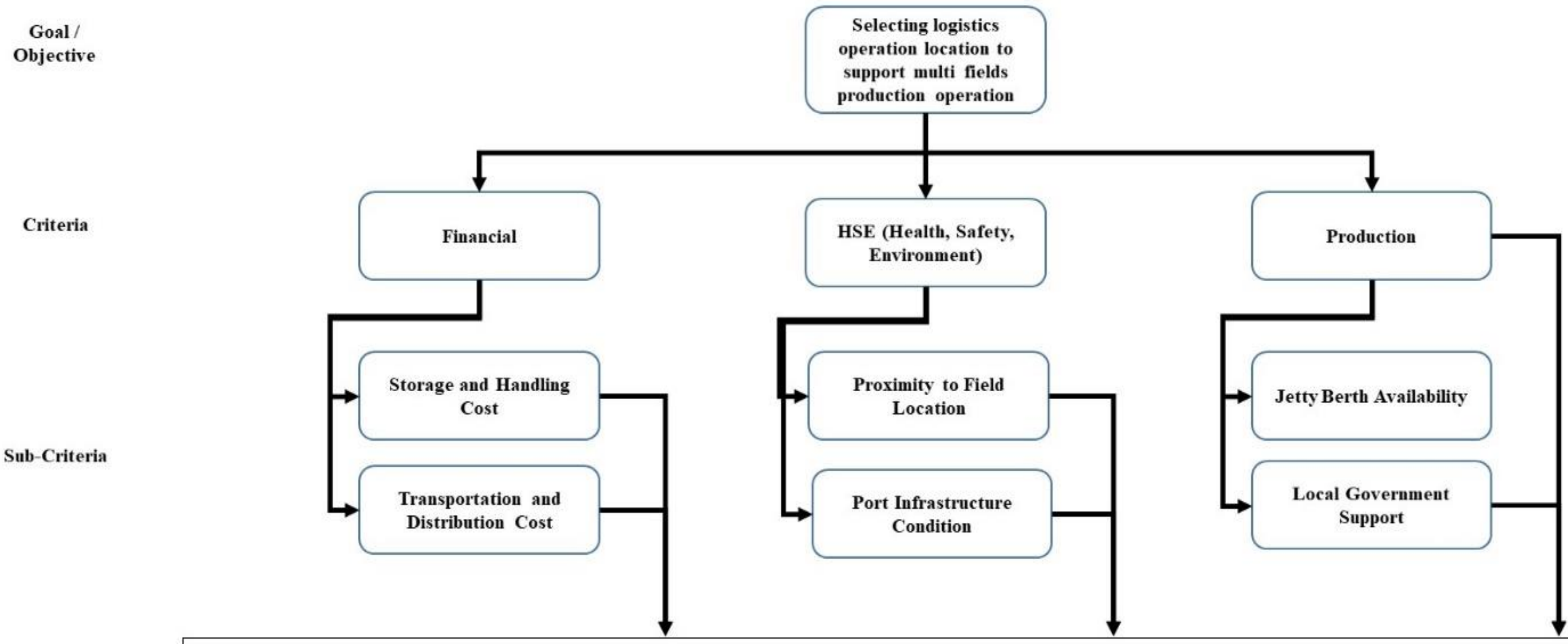
V. DATA ANALYSIS

After the pairwise comparison data was collected, the data was then submitted for further calculation to free web-based AHP data processing tools developed by Klaud D Goepel (2018) through the website https://bpmsg.com/. Table VI shows pairwise comparison results between criteria from the experts. HSE criteria were selected as the most important criteria with the percentage of priority 69.4%. From the calculation tools, the consolidated consistency ratio for the data is 2.1%, which is still below 10% and can be categorized as valid data. A total of 5 of 6 experts agreed that HSE is a very important factor in oil and gas operations. This significant HSE priority is affected by a lot of risks that might happen during the operation, which will impact humans, assets, the environment, sustainable company operation, and also the company reputation. No one will know the impact of an accident, and it can destroy everything that currently exists.

TABLE VI: INDIVIDUAL- AND GROUP-LEVEL PRIORITY JUDGEMENTS FOR CRITERIA

Participant	Financial	HSE	Production	CR_{max}
Respondent 1	9.10%	81.80%	9.10%	0.00%
Respondent 2	15.00%	72.50%	12.50%	3.70%
Respondent 3	9.10%	81.80%	9.10%	0.00%
Respondent 4	6.30%	67.20%	26.50%	3.00%
Respondent 5	41.30%	26.00%	32.70%	5.60%
Respondent 6	8.10%	73.10%	18.80%	6.80%
Group result	12.90%	69.40%	17.70%	2.10%

For pairwise comparison between sub-criteria under financial criteria, the priority of storage and handling costs is almost the same as selected transportation and distribution



Alternative

Alternative No.	Production Unit	Operation Activity	Location
1	FPU	Material Supply	Trunojoyo Port (Sampang)
		Personnel Transfer	
	MOPU	Material Supply	Trunojoyo Port (Sampang)
		Personnel Transfer	
2	FPU	Material Supply	Tanjungwangi Port (Banyuwangi)
		Personnel Transfer	
	MOPU	Material Supply	Tanjungwangi Port (Banyuwangi)
		Personnel Transfer	
3	FPU	Material Supply	Tanjungwangi Port (Banyuwangi)
		Personnel Transfer	
	MOPU	Material Supply	Trunojoyo Port (Sampang)
		Personnel Transfer	
4	FPU	Material Supply	Trunojoyo Port (Sampang)
		Personnel Transfer	Kalianget Port (Sumenep)
	MOPU	Material Supply	Trunojoyo Port (Sampang)
		Personnel Transfer	
5	FPU	Material Supply	Tanjungwangi Port (Banyuwangi)
		Personnel Transfer	Kalianget Port (Sumenep)
	MOPU	Material Supply	Trunojoyo Port (Sampang)
		Personnel Transfer	

Fig. 5. case study decision hierarchy.

costs (see Table VII). Although 3 experts selected transportation and distribution cost as a higher priority and only 2 experts selected storage and handling cost as a higher priority, as a group result, storage and handling cost has 1% higher priority than transportation and distribution cost. The consistency ratio for this pairwise comparison is 0% and labeled as valid.

TABLE VII: GROUP- AND INDIVIDUAL-LEVEL PRIORITY JUDGEMENT FOR SUB-CRITERIA UNDER FINANCIAL CRITERIA

Participant	Storage and Handling Costs	Transportation and Distribution Costs	CR_{max}
Respondent 1	50.00%	50.00%	0.00%
Respondent 2	20.00%	80.00%	0.00%
Respondent 3	90.00%	10.00%	0.00%
Respondent 4	75.00%	25.00%	0.00%
Respondent 5	33.30%	66.70%	0.00%
Respondent 6	25.00%	75.00%	0.00%
Group result	50.50%	49.50%	0.00%

For pairwise comparison between sub-criteria under HSE criteria, it is clear that from data in Table VIII, Proximity to Field Location becomes the priority with dominant preferences (73.5%) by the experts. The consistency ratio is 0%. 4 experts provided significant weight on the proximity to the Field Location, while 2 experts provided equal weight. Proximity to Field Location could provide a significant impact on operation flexibility. It is not only ensuring the materials and personnel arrive at the offshore location in the desired schedule during normal operation but also during an emergency, which will reduce the impact of an accident. A shorter distance between the logistics operation location and the field location will also make the personnel depart to the offshore location less fatigued and be able to start their duty in the offshore location as scheduled.

For pairwise comparison between sub-criteria under Production criteria, vessel berthing availability at the jetty was selected with higher priorities than local government support (as shown in Table IX). Two respondents chose vessel berthing availability over local government support, while one respondent chose local government support over vessel berthing availability. Three respondents chose equal importance between the sub-criteria. The consistency ratio is 0%. Vessel berthing availability will play a direct impact on the operation activity. When the jetty is too crowded and there is no space for the company's vessel to berth, the operation activity will impact negatively. In terms of timing, the vessel is scheduled to berth at the shore area on a routine basis. Usually, each vessel will berth at the shore location 2 times a week, and it can be more than that, especially during the offshore facilities maintenance period. In an urgent situation, this jetty situation will become critical and can influence the total vessel transportation time.

TABLE VIII: GROUP- AND INDIVIDUAL-LEVEL PRIORITY JUDGEMENT FOR SUB-CRITERIA UNDER HSE CRITERIA

Participant	Proximity to Field Location	Port Infrastructure Condition	CR_{max}
Respondent 1	83.30%	16.70%	0.00%
Respondent 2	85.70%	14.30%	0.00%
Respondent 3	50.00%	50.00%	0.00%
Respondent 4	83.30%	16.70%	0.00%
Respondent 5	75.00%	25.00%	0.00%
Respondent 6	50.00%	50.00%	0.00%
Group result	73.50%	26.50%	0.00%

TABLE IX: GROUP- AND INDIVIDUAL-LEVEL PRIORITY JUDGEMENT FOR SUB-CRITERIA UNDER PRODUCTION CRITERIA

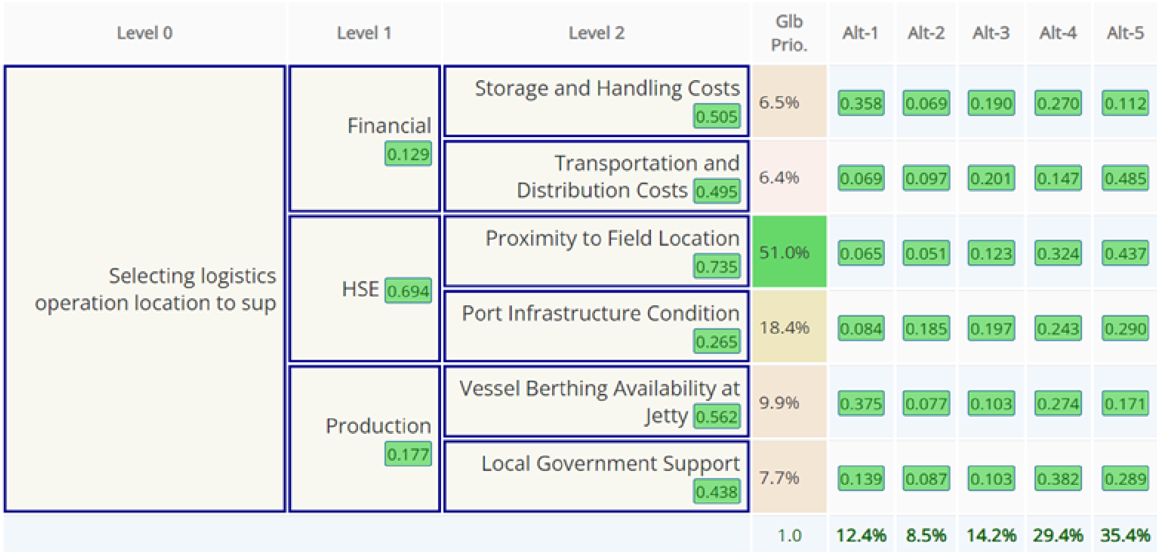
Participant	Vessel Berthing Availability at Jetty	Local Government Support	CR_{max}
Respondent 1	50.00%	50.00%	0.00%
Respondent 2	50.00%	50.00%	0.00%
Respondent 3	75.00%	25.00%	0.00%
Respondent 4	75.00%	25.00%	0.00%
Respondent 5	33.30%	66.70%	0.00%
Respondent 6	50.00%	50.00%	0.00%
Group result	56.20%	43.80%	0.00%

After performing pairwise comparisons for criteria and sub-criteria, the next step is to conduct pairwise comparisons between alternatives. A pairwise comparison between alternatives was conducted for every sub-criteria. This will result in the global priority of alternatives on criteria and sub-criteria. There are a total of 5 alternative solutions to be compared in this research under 6 sub-criteria. As shown by Fig. 6, in the Financial criteria, alternative 1 has the highest priority on storage and handling cost sub-criteria, while for transportation and distribution criteria, alternative 5 has the highest priority. In HSE criteria, alternative 5 becomes the most prioritized on proximity to field location sub-criteria and port infrastructure sub-criteria. In Production criteria, alternative 1 has the highest priority on vessel berthing availability at jetty sub-criteria, while for local government support, sub-criteria won by alternative 4 has the highest priority. In global priority, alternative 5 has the highest weight and becomes the priority among other alternatives in the decision hierarchy. This result means that alternative 5 is the selected solution for this research.

VI. CONCLUSION

This research is focused on selecting the best logistics operation location for supporting multi-production field operations in XYZ. A multi-criteria decision-making method is used to solve the business issue, which is the Analytical Hierarchy Process that could break down the complex problem into a hierarchy. AHP, as part of the MCDM method, is used to solve the business issue with the involvement of experts to provide their professional judgment in selecting the preferred options. To construct an AHP decision hierarchy, decision criteria and sub-criteria need to be defined. The decision criteria in this research are derived from XYZ strategic pillars that are related to logistics operations to support the production activities, which are HSE (Health, Safety, and Environment), Financial, and Production. The sub-criteria for this research are taken from previous research for selecting logistical locations.

This research uses port location to select the logistics operation location for the upcoming production fields. Three port locations that are considered to become alternatives in this research are Trunojoyo Port in Sampang Regency, Kalianget Port in Sumenep Regency, and Tanjungwangi Port in Banyuwangi Regency. These ports are considered alternatives due to the relevancy of XYZ fields' location and existing logistics operation. Kalianget port is excluded from the option for material supply due to the maximum water depth being only 2 meters (as per Indonesian Government Ministry of Communication decree no. 76 the year 2019).



Level 0	Level 1	Level 2	Glb Prio.	Alt-1	Alt-2	Alt-3	Alt-4	Alt-5
Selecting logistics operation location to sup	Financial 0.129	Storage and Handling Costs 0.505	6.5%	0.358	0.069	0.190	0.270	0.112
		Transportation and Distribution Costs 0.495	6.4%	0.069	0.097	0.201	0.147	0.485
	HSE 0.694	Proximity to Field Location 0.735	51.0%	0.065	0.051	0.123	0.324	0.437
		Port Infrastructure Condition 0.265	18.4%	0.084	0.185	0.197	0.243	0.290
	Production 0.177	Vessel Berthing Availability at Jetty 0.562	9.9%	0.375	0.077	0.103	0.274	0.171
		Local Government Support 0.438	7.7%	0.139	0.087	0.103	0.382	0.289
			1.0	12.4%	8.5%	14.2%	29.4%	35.4%

Fig. 6. Global priority of criteria, sub criteria, and alternatives.

This research considers mixed port locations as the decision alternatives because there will be two additional production units to be supported, which are located in different locations. There are a total of 5 alternative locations to be selected for business solutions.

From the questionnaire filled by the experts, after being analyzed by the AHP method through pairwise comparison, HSE criteria became the most preferred by experts with priority 69.4%. For sub-criteria, the most preferred by experts is proximity to field location with priority 51%. From this result, the selected logistics operation location as the business solution is alternative 5 with a priority of 35.4%. Alternative 5 has the highest priority compared to other alternatives. These pairwise comparison results have CR values below 10%. These results are also in line with company data such as distance to field location, which alternative 5 has the closest distance and lowest transportation and distribution cost.

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