SELECTION OF DECOMMISSIONING METHODS FOR GAS PLANT FACILITIES USING ANALYTICAL NETWORK PROCESS

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Abstract

The high complexity of decommissioning decisions presents a challenging problem for decision-makers due to the various parameters and stakeholders involved. Currently, a Floating Production Unit, BW Joko Tole located at the Lapangan Terang Sirasun Batur field, in East Madura Waters are expected to be decommissioned as gas reserves are running low for the upcoming 9 years. Multi-Criteria Decision Analysis has begun to be implemented by several oil and gas companies and several studies applied various MCDA methods in choosing the best alternatives. Analytical Network Process is a powerful tool to handle the interdependencies of elements involved in decommissioning, as no other MCDA methods can accommodate these relationships between elements. This study aims to simulate the implementation of the Analytical Network Process as one of MCDA methods in choosing decommissioning methods for these facilities, specifically pipelines and umbilicals operated by FPU BW Joko Tole. Regulatory review is carried out to determine the suitable alternatives, criteria, and sub-criteria needed to be considered in choosing decommissioning alternatives and evaluated using the Analytical Network Process (ANP). This study will provide an example of the ANP network model in decommissioning decisions followed by a sensitivity analysis to determine the robustness of the chosen alternatives and the values of each element involved.

Keywords: Decommissioning, Multi Criteria Decision Analysis (MCDA), Analytical Network Process (ANP), Pipelines, Umbilical.

1. Introduction

As recorded in December 2019 by SKK Migas, there are a total of 634 units of offshore platforms located throughout various locations in Indonesia and approximately 69% of them are at least 30 years old. These conditions also occur globally as many offshore oil and gas production facilities are reaching the end of their operational life and is expected to cause a rise of decommissioning activities in the next 30 years (Burdon et al., 2018). This presents an upcoming challenge in the future for oil and gas industries to carry out decommissioning activities to their production facilities.

Decommissioning of offshore facilities is generally viewed to be more complicated than installation of new-built facilities (Na et al., 2017). In consequence, decision makings regarding to decommissioning presents a challenging problem as there are various parameters and stakeholders needed to be considered.

The utilization of Multi Criteria Decision Making in oil and gas sectors are starting to be implemented in either academical studies or real decommissioning project and Analytical Hierarchy Process is the most commonly applied method in the oil & gas sector. Companies such as Xodus and Repsol had also begun implementing application of Multi Criteria Decision Making, specifically the Analytical Hierarchy Process in selecting the decommissioning methods (Martins et al., 2020).

Another MCDM method, namely Analytical Network Process (ANP), is a generalization and a more comprehensive version of AHP (Chen et al., 2019). ANP

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still offers the consistency verification, an attribute that is considered one of the strongest advantage that these two methods possess, but unlike AHP and any other MCDM methods, ANP can handle and measure the interdependencies that occur between elements involved. In decommissioning cases, interdependencies between criteria, subcriteria and alternatives are highly possible, and the implementation of ANP can be beneficial so as to provide a more accurate and robust result.

Currently, a Floating Production Unit, BW Joko Tole located in Terang Sirasun Batur Field, East Madura Waters is expected to reach the end of its operational life in 2030 as gas reserves are running low, so a development of a decommissioning plan is needed soon. ANP will be implemented in this paper to select the suitable decommissioning method for the gas plant facilities.

2. Methodology

This paper presents the selection of decommissioning methods for gas generating facilities by ANP. First, a review of international and national regulations regarding decommissioning of oil & gas facilities is carried out as a basis for developing alternative methods and ensuring that the proposed method complies with regulations. Second, the ANP process is applied to select the decommissioning process in the Terang Sirasun Batur field as a case study. Then a sensitivity analysis is performed to present the robustness and consistency of the results. Finally, the selected decommissioning method is obtained.

2.1 Regulatory Review

To further understand how decommissioning works in Indonesia, a regulatory review is carried out, covering both international and national regulations. This is carried out to identify the possible decommissioning methods to be carried out as alternatives and to provide insights in terms of criteria and sub-criteria to take into consideration in making the ANP network model. The regulation reviewed are as follows.

- United Nations Convention on Law of The Sea III 1982
- IMO's Guidelines and Standards for the removal of offshore structures and installations
- Indonesia's Act No. 1 1970 about Work Safety
- Indonesia's Act No. 17 2008 about Shipping
- Indonesia' Act No. 32 2004 about Sea
- Indonesia's Act No. 32 2009 about Environmental Portection and Management
- Indonesia's Government Regulations No. 17 1974 about Supervision of Implementation of Oil and Gas Offshore Exploration and Exploitation
- Indonesia's Government Regulations No. 18 1999 about Management of Hazardous and Toxic Waste
- Indonesia's Government Regulations No. 19 1999 about Control of Marine Pollution and Damage
- Indonesia's Government Regulations No. 21 2010 about Protection of Marine Environment
- SKK Migas Work Guidelines about Abandonment and Site Restoration

These regulations address the general aspects in decommissioning activities in Indonesia. UNCLOS III 1982 article 60 regulates the structures and installations in exclusive economic zone and states the obligation for all unused structure and installation to be abandoned. However this is discussed more in IMO's guidelines for removal of offshore structure and installation (IMO Resolution A.672 (16)) that non-removal is allowed as long as it still comply to this guideline. It also covers all the aspects that should be considered in offshore structure and installation decision making. On the national regulation perspective, Indonesia's Act No. 17 2008, Act No. 32 2009 and Government Regulation No. 17 1974 requires all offshore structures and installation to be removed taking into account the technical matters, marine traffic, environmental impacts and safety. This aspects is explained in more detail in Act No 1 1970, Government Regulations No. 18 1999, Government Regulation No. 19 1999 and Government Regulations

No. 21 2010. SKK Migas guidelines regulates the legal and permit aspects as well as the financial in decomissioning planning.

2.2 Analytical Network Process

Analytical Network Process was developed by Saaty in 1996 as a developed form of AHP in a generalized form to handle feedback networks (Saaty & Vargas, 2013). Both this method utilizes the pairwise comparison between its elements, but ANP provides the ability to accommodate interdependencies between its elements (Hidayat & Artana, 2015) whereas AHP do not. Therefore, **the structure of ANP is in form of network, unlike its predecessor, AHP with its form of hierarchy.**

Fig. 1 shows a network structure of ANP and the components in it. C_1 and C_2 act as a source component, usually it resembles the goal node. C_3 and C_4 act as intermediate component, it stands between the source component and the sink component, this component resembles the criteria and sub-criteria. C_5, the sink component resembles the alternatives, as the entire network ends with this component, it can be seen that all the arrows go in it. The loop shown in C_2 and C_5 represents the inner dependencies in each component, meanwhile the arrows connecting each component represents the outer dependencies.

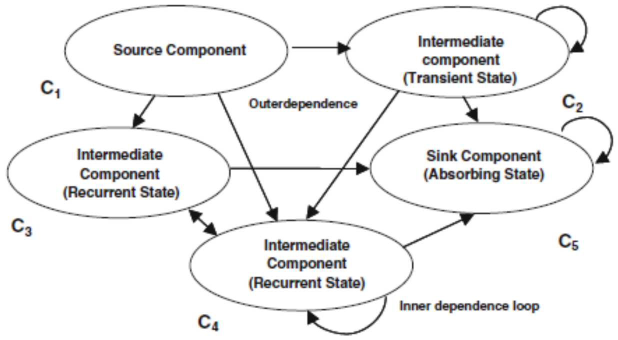

Fig. 1 Network Structure of ANP (Saaty & Vargas, 2013)

All these dependencies between components are represented by eigenvectors derived from the pairwise comparisons between each component. These vectors are then arranged into a matrix that represents all the dependencies in the network structure of ANP. This matrix is called the supermatrix.

$$W_{ij} = \begin{bmatrix} W_{i1}^{(j1)} & W_{i1}^{(j2)} & \cdots & W_{i1}^{(jn_j)} \\ W_{i2}^{(j1)} & W_{i2}^{(j2)} & \cdots & W_{i2}^{(jn_j)} \\ \vdots & \vdots & \cdots & \vdots \\ W_{in_i}^{(j1)} & W_{in_i}^{(j2)} & & W_{in_i}^{(jn_j)} \end{bmatrix}$$

Fig. 2 Arrangement of supermatrix (Saaty & Vargas, 2013)

Before the formation of supermatrix, as stated before, pairwise comparison between components must be done. In this research, pairwise comparison is conducted by distributing a set of questionnaires to a group of experts and academics. A total of 17 respondents is gathered to fill in the questionnaire of pairwise comparisons. The ratings used in these pairwise comparisons refer to Saaty's scale as shown in table 1 below.

Table 1. Saaty's scale

Rating	Definition
1	Equal Importance
3	Moderate Importance
5	Strong Importance
7	Very Strong Importance
9	Extreme Importance

These judgments are then inserted into a pairwise comparison matrix. Before proceeding to the next process, all the judgments are aggregated using the geometric mean method (GMM) to form a new individual judgments that represents these group of respondents (Aczel & Saaty, 1983)

$$a_w = (a_1 \times a_2 \times a_3 \times \ldots \times a_n)^{\frac{1}{n}}$$

(2.1)

Where:

a_w : aggregated judgments
a_i : judgments
n : number of respondents

These new formed judgment after aggregation is then normalized by dividing the total value of matrix in one column to get the normalize weights.

Calculation of consistency ratio can be carried out once eigen value and maximum eigen value is obtained. The maximum consistency allowed is 0,1. This calculation is conducted to check the consistency of the judgment has been given. The following is the equation for obtaining Consistency Index.

$$CI = \frac{(\lambda_{max}-n)}{(n-1)} \tag{2.2}$$

$$CR = \frac{CI}{RI} \tag{2.3}$$

Where:

CI : Consistency Index
CR : Consistency Ratio
RI : Random Consistency Index

Table 2. Random Consistency Index

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.4	1.45	1.49

2.2.1 Determination of Alternatives

Aside from regulatory issues, leave in situ is excluded from the alternatives due to technical perspective. It is needed additional research regarding its effect on environment and this would take a lot more time to accomplish.

The determination of removal option is focused on umbilical and pipelines located on Terang Sirasun Batur field, this is because the removal of other subsea equipment located in the field such as PLET, manifold, UTA, MCS, SDU and other equipment can be done simply by lifting it up to the surface with and there are no alternative methods available for it.

Through some research regarding decommissioning vessels available in Indonesia as it is required that vessels operating decommissioning work is registered in Indonesian flag state, it is then decided that the alternatives used in this model for the pipelines and umbilicals will be Cut and Lift (A1) and Reverse S-Lay (A2) method. Fig. 3 shows the location of Terang Sirasun Batur field.

2.2.2 Determination of Criteria and Sub-criteria

Criteria and sub-criteria are then defined through regulatory review that has been done previously and through some literature reviews (Artana et al., 2013; Pratiwi et al., 2019) and previous decommissioning projects(CNRI, 2014; Repsol, 2017; Shell, 2017; Xodus, 2017) . There are 4 criteria determined, technical, safety, economic, and social. Table 3 shows all the criteria and sub-criteria used in this research and Fig. 4 shows the interdependencies of alternatives, criteria and sub-criteria in the ANP network model.

Table 3. List of criteria and sub-criteria

Criteria	Sub-criteria
Technical (T)	Work Duration (T1)
	Technical Complexity (T2)
	Vessel Availability (T3)
Safety (SA)	Risk of Operational Failure (SA1)
	Risk of Marine Accidents (SA2)
Economic (E)	Operational Cost (E1)
	Charter Rate (E2)
Social (S)	Impact to Marine Traffic (S1)
	Impact to Local Fisheries (S2)

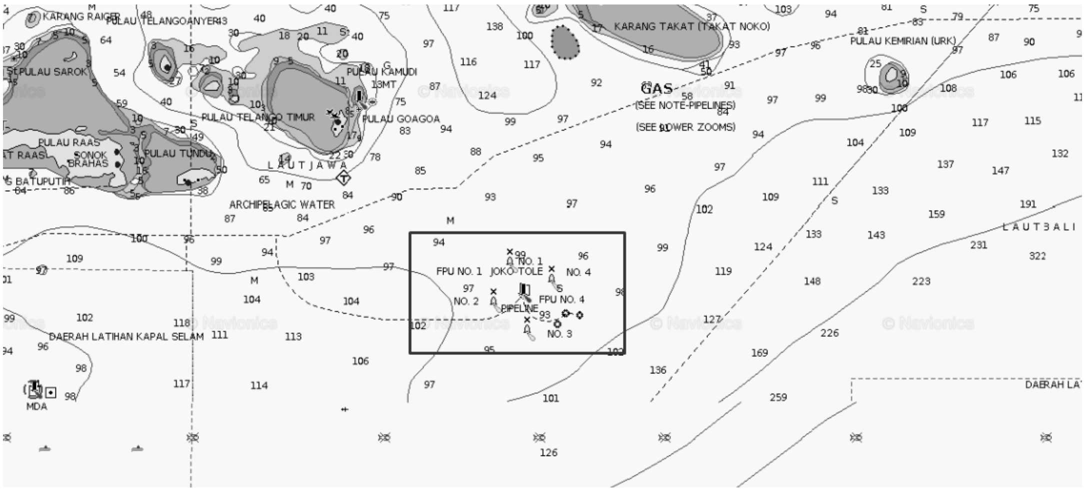

Fig. 3 Location of BW Joko Tole

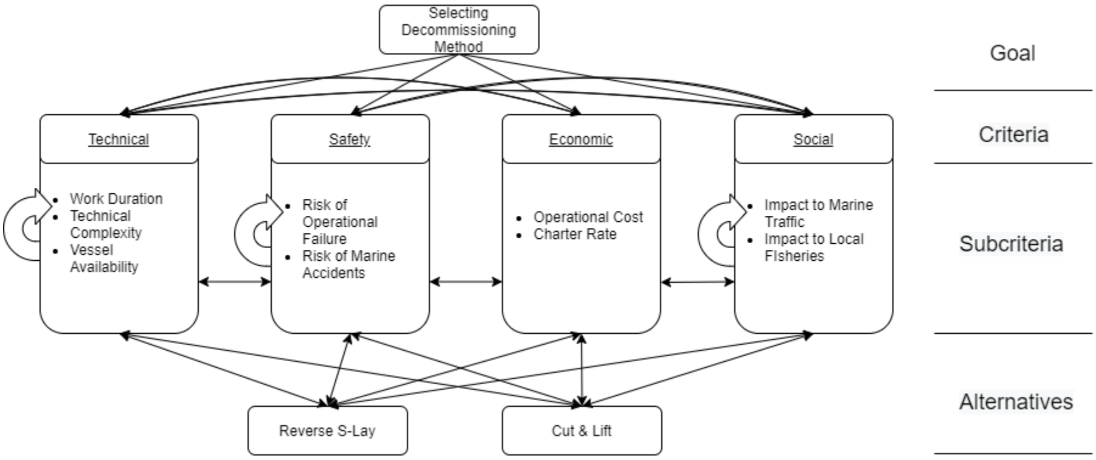

Fig. 4 ANP Network Model

3. Result and Discussion

3.1 Analytical Network Process Calculation

This research involved a total of 17 experts from companies and universities to give their opinion in the form of pairwise comparison from the questionnaire given. The data acquired from experts judgments are first aggregated using the geometric mean method to form a new individual comparison matrix for each pariwise comparison. Table 4 shows one of the pairwise comparison matrix of criteria with respect to goal.

Calculation of eigen vectors are carried out after the aggregation of judgments and is followed by calculation of consistency ratio to make sure that the newly formed aggregated judgments are still consistent. Throughout this process it is proven that all the pairwise comparisons, approximately 30-40 matrixes (including cluster comparisons) still fulfills the < 0,1 C.R., indicating that they are consistent.

Table 4. Pairwise comparison of criteria wrt goal

Goal	Technical	Safety	Economical	Social
Technical	1.000	0.216	0.836	1.844
Safety	4.626	1.000	4.960	6.648
Economical	1.196	0.202	1.000	1.526
Social	0.542	0.150	0.655	1.000

Table 5. Unweighted Supermatrix

	Alternative	Goal	Criteria	Subcriteria

	A1	A2	G	T	SA	E	S	T1	T2	T3	SA1	SA2	E1	E2	S1	S2
A1	0.00	0.00	0.00	0.5	0.38	0.45	0.45	0.31	0.42	0.44	0.40	0.36	0.42	0.44	0.50	0.42
A2	0.00	0.00	0.00	0.65	0.62	0.55	0.55	0.69	0.58	0.56	0.60	0.64	0.58	0.56	0.50	0.58
G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T	0.00	0.00	0.14	0.00	0.57	0.32	0.19	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
SA	0.00	0.00	0.63	0.67	0.00	0.58	0.61	0.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00
E	0.00	0.00	0.14	0.24	0.28	0.00	0.20	0.00	0.00	0.00	0.00	0.00	1.00	1.00	0.00	0.00
S	0.00	0.00	0.09	0.09	0.15	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00
T1	0.30	0.38	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T2	0.32	0.32	0.00	0.40	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T3	0.38	0.30	0.00	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SA1	0.44	0.53	0.00	0.00	0.63	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
SA2	0.56	0.47	0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
E1	0.55	0.42	0.00	0.00	0.00	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2	0.46	0.56	0.00	0.00	0.00	0.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S1	0.55	0.46	0.00	0.00	0.00	0.00	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
S2	0.45	0.55	0.00	0.00	0.00	0.00	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00

Table 6. Weighted Supermatrix

	Alternative		Goal	Criteria				Subcriteria								
	A1	A2	G	T	SA	E	S	T1	T2	T3	SA1	SA2	E1	E2	S1	S2
A1	0.00	0.00	0.00	0.5	0.38	0.45	0.45	0.31	0.42	0.44	0.40	0.36	0.42	0.44	0.50	0.42
A2	0.00	0.00	0.00	0.65	0.62	0.55	0.55	0.69	0.58	0.56	0.60	0.64	0.58	0.56	0.50	0.58
G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T	0.00	0.00	0.14	0.00	0.57	0.32	0.19	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
SA	0.00	0.00	0.63	0.67	0.00	0.58	0.61	0.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00
E	0.00	0.00	0.14	0.24	0.28	0.00	0.20	0.00	0.00	0.00	0.00	0.00	1.00	1.00	0.00	0.00
S	0.00	0.00	0.09	0.09	0.15	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00
T1	0.30	0.38	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T2	0.32	0.32	0.00	0.40	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T3	0.38	0.30	0.00	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SA1	0.44	0.53	0.00	0.00	0.63	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
SA2	0.56	0.47	0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
E1	0.55	0.42	0.00	0.00	0.00	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2	0.46	0.56	0.00	0.00	0.00	0.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S1	0.55	0.46	0.00	0.00	0.00	0.00	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
S2	0.45	0.55	0.00	0.00	0.00	0.00	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00

Table 7. Limiting Supermatrix

	Alternative		Goal	Criteria				Subcriteria								
	A1	A2	G	T	SA	E	S	T1	T2	T3	SA1	SA2	E1	E2	S1	S2
A1	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
A2	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
SA	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
E	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
S	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02

T1	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
T2	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
T3	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
SA1	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
SA2	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
E1	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
E2	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
S1	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
S2	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02

The eigen vectors acquired in the process prior to consistency ratio calculation are arranged to form the unweighted supermatrix. Unweighted supermatrix represents all the eigen vectors of the pairwise comparison matrix with value of eigen vectors before it is normalized based on their cluster. Table 5 shows the unweighted supermatrix of this ANP model.

The unweighted supermatrix is then converted to the weighted supermatrix as shown in Table 6 by multiplying the eigevectors within it with the eigenvectors otained from the cluster comparison, each with their respective clusters this process will form a stochastic matrix .The weighted supermatrix is then transformed to a limiting supermatrix by multiplying it with itself over and over again until it eventually becomes stable and all its column has the same numbers. In this research, this process is done with the help of MATLAB. It is very important to make sure that the weighted supermatrix is already in stochastic state, otherwise the matrix multiplication will keep going to an infinite cycle and limiting supermatrix cannot be formed. Table 7 below shows the Limiting Supermatrix after 64 iterations in the software.

3.2 Selection of Decommissioning Results

From the limiting supermatrix, the limiting weights of each subcriteria, criteria and alternatives can be obtained as shown in table 8. These weights are still global weights, so we need to normalize these weights according to each their clusters to get the final weights of sub-criteria, criteria and alternatives.

From the analytical network process calculation done, the safety criteria came out as the most important criteria (56.8%), followed by technical (19.5%), economical (15.3%) and social (8.4%). Table 8 below summarizes all the criteria and sub-criteria weights resulted from the normalization of limiting weights obtained from the limiting supermatrix before.

From these criteria and subcriteria weights, we obtained Reverse S-Lay as the selected method with a weight of 60.5% , outperforming the Cut and Lift method with a weight of 39.5%.

3.3 Sensitivity Analysis

ANP Sensitivity Analysis is conducted to see the possible changes to the alternative priorities obtained, so as to see the robustness and consistency of the results. In this research, the sensitivity analysis of the ones from ANP with other MCDM methods are compared to verify that ANP can outperform other MCDM methods, in this case, the chosen method to be compared is AHP, due to these reasons:

- Due to their similar process, the data acquired for ANP can be reprocessed for the calculation using AHP. The structure model can also be adjusted from the network structure to the hierarchy structure.
- The AHP method is the only MCDM method know to have been applied in real projects by a number of companies in the oil & gas sectors (Martins et al., 2020). Namely Xodus and Repsol back in 2017 for their offshore structures (Repsol, 2017; Xodus, 2017). Hence with this comparison it is possible to determine whether ANP can be an alternative to MCDM methods in decommissioning projects.

The adjustments made to the network structure to transform it to the hierarchy structure resulted in a slight difference to the weights obtained at the end of the process. So before proceeding to the sensitivity analysis, the results are examined to see if there are any difference in results

From the AHP, Reverse S-Lay obtained a weight of 60% meanwhile Cut & Lift obtained a weight of 40%. As for the criteria rankings, the results stays the same with the ones from ANP. Safety remain to be the most important (63,4%), followed by technical (13,8%), economical (14,1%) and social (8,4%). Table 9 shows the comparison of the results from both methods.

Table 8. Criteria and sub-criteria normalized priorities

Criteria	Normalized Priorities	Subcriteria	Normalized Priorities
Technical	19.5%	Work Duration	28.5%
		Technical Complexity	40.7%
		Vessel Availability	30.7%
Safety	56.8%	Risk of Operational Failure	52.0%
		Risk of Marine Accidents	48.0%
Economical	15.3%	Operational Cost	45.6%
		Charter Rate	54.4%
Social	8.4%	Impact to Marine Traffic	49.8%
		Impact to Local Fisheries	50.2%

Table 9. Comparison of weights from AHP and ANP

Criteria	AHP Weight	ANP Weight	Subcriteria	AHP Weight	ANP Weight
Technical	13.8%	19.5%	Work Duration	23.3%	28.5%
			Technical Complexity	40.2%	40.7%
			Vessel Availability	36.5%	30.7%
Safety	63.4%	56.8%	Risk of Operational Failure	62.7%	52.0%
			Risk of Marine Accidents	37.3%	48.0%
Economical	14.1%	15.3%	Operational Cost	40.%	45.6%
			Charter Rate	59.2%	54.4%
Social	8.7%	8.4%	Impact to Marine Traffic	50.9%	49.8%
			Impact to Local Fisheries	49.1%	50.2%

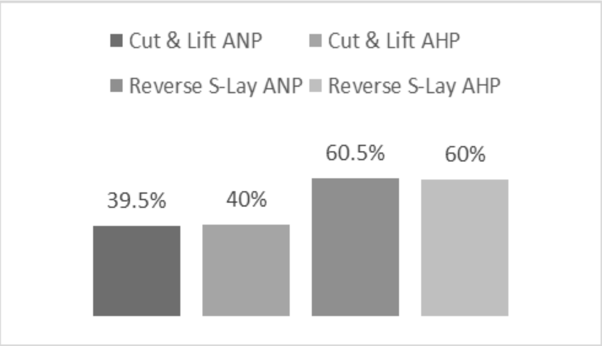

Fig. 5 Results from AHP and ANP

On to the sensitivity analysis the data acquired before is inputted to the Super Decisions software to aid in analyzing the change of alternative priorities resulted from changing the weights of criteria. Comparison is done to 4 criteria with respect to goal because the hierarchical structure of AHP won't allow the sensitivity analysis of sub-criteria with respect to goal.

The change of weights in the software depends on the sensitivity parameter alpha, whose value is set to 0.5 as the neutral point. A value increase to 0.75 means a linear increase of 50% while a value decrease of 0.25 means a linear decrease of 50% of the weights (Dobrea et al., 2015).

The comparisons shown by Fig. 6, Fig 7, Fig. 8 and Fig. 9 showed that ANP performs better in terms of consistency after changes of weight is applied. Out of 4 graphs, ANP can maintain a better consistency than its counterpart AHP. On the technical criteria, AHP performs better in terms of consistency although the changes don't go towards the intersection point which leads to change of alternatives chosen.

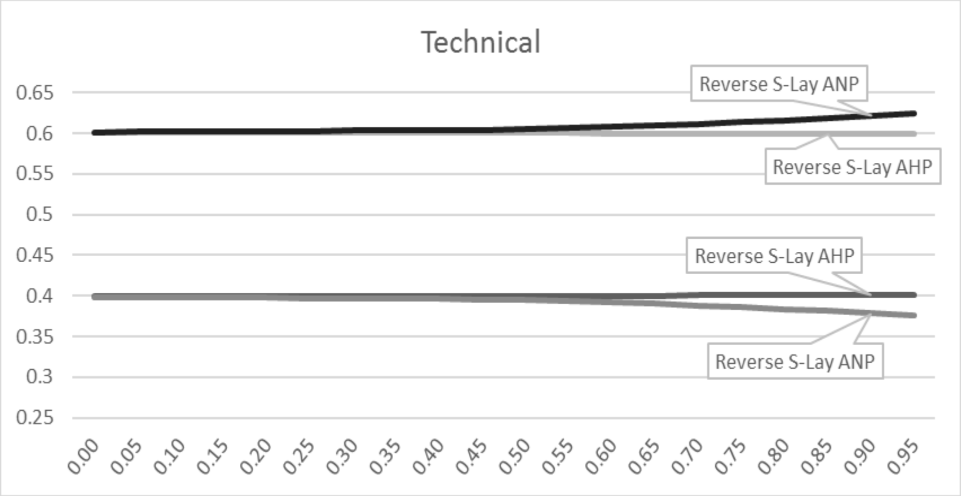

Fig. 6 Technical Criteria Sensitivity Analysis

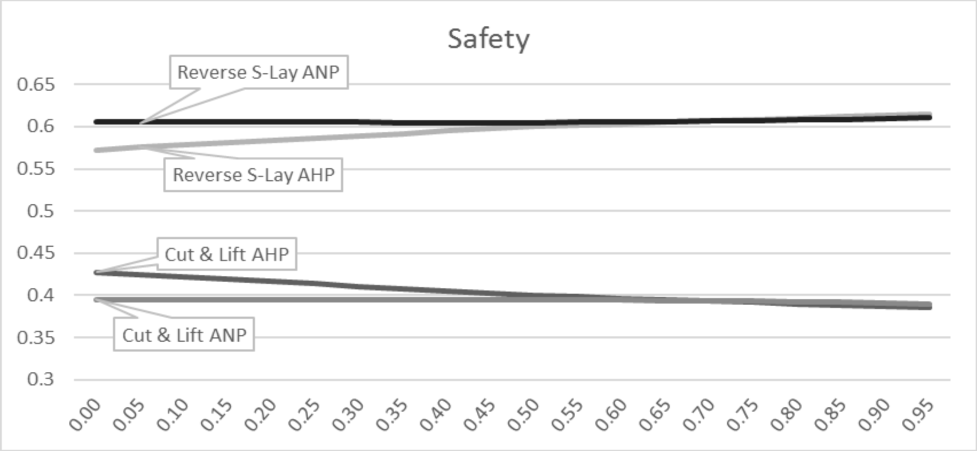

Fig 7. Safety Criteria Sensitivity Analysis

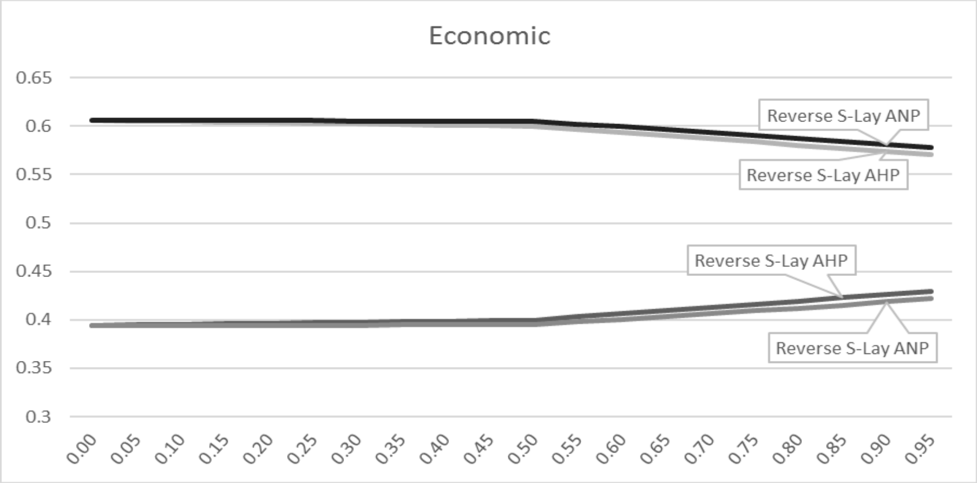

Fig 8. Economic Criteria Sensitivity Analysis

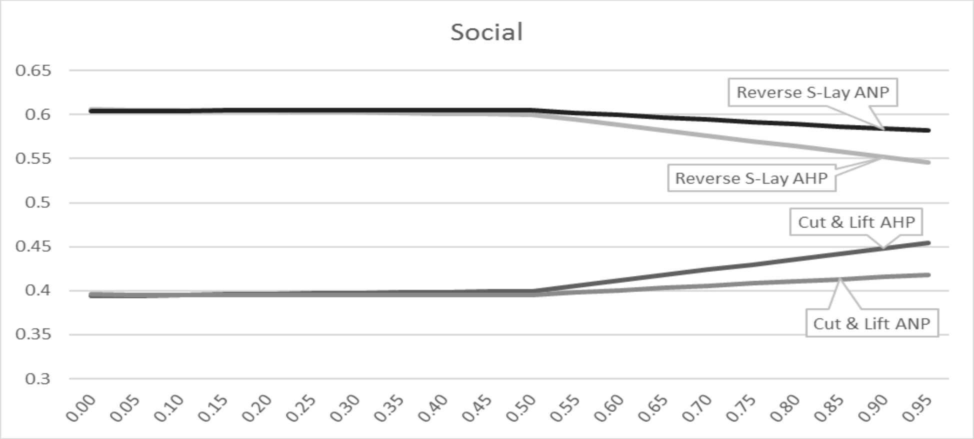

Fig 9. Social Criteria Sensitivity Analysis

4. Conclusion

This paper presents a simple ANP model for choosing decommissioning methods for oil & gas sector. Throughout this research respondents from various institutions and companies are involved to give their judgments in the questionnaire given. On real practice, it would be better if those participated in the decision making comes from the same group of stakeholders who know well all aspects considered in the decision-making process for a more accurate and satisfying results.

The performance of ANP shown from the comparisons done with AHP, a method which have known to be used on real decommissioning projects, showed a better performance in terms of consistency and robustness of the results acquired. However, ANP takes a longer time to conduct because the more feedbacks it accommodates, the more comparisons needed to be done, hence more research. While no changes occurred from sensitivity analysis, this is due to the strong preference of the experts participating in the survey. On other cases where alternatives have a slight difference in results, ANP's strength in terms of consistency can be proven helpful for a more robust result.

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