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Identification of Key Factors in the Decommissioning of Offshore Oil and Gas Installations.

Joe Ford[1], Sean Loughney[1], Eduardo Blanco-Davis[1], Ava Shahrokhi[1], Ana Armada Bras[1], Jin Wang[1]

[1]School of Engineering, Liverpool John Moores University, Liverpool, United Kingdom. E-mail: j.m.ford@2019.ljmu.ac.uk
s.loughney@ljmu.ac.uk e.e.blancodavis@ljmu.ac.uk a.shahrokhi@ljmu.ac.uk a.m.armadabras@ljmu.ac.uk j.wang@ljmu.ac.uk

Decommissioning of ageing installations continues to be a crucial concern for the offshore oil and gas industry. Within the next decade, it is anticipated that several structures will be required to undergo the decommissioning process. With the removal of these installations comes the management of waste materials in line with current regulations. Prior to the reuse, recycling, or disposal of any materials, they must be decontaminated from hazardous waste. This paper builds on previous research, which identified the knowledge of current decommissioning legislation as one of the critical issues. Expert judgements have been analysed using an analytical hierarchy process.

Keywords: Offshore Decommissioning, Analytical Hierarchy Process, Legislation

1. Introduction

Over the next decade, 2021 – 2031, it is expected that 126 topside structures will undergo decommissioning within the United Kingdom Continental Shelf (UKCS) (NSTA, 2022). Decommissioning of an offshore installation occurs when it reaches the end of its design and is no longer financially viable. The decommissioning process involves the handling of hazardous waste materials. Prior to the handling of these hazardous waste materials, they must be identified in order to be transported and processed in line with current legislation. This paper builds on previous research by Ford et al. (2021), which identified the perceived lack of importance of the knowledge of legislation as an issue within the decommissioning process.

1.1. *Aim and objectives*

The aim of this paper is to identify the key factors in the decommissioning of oil and gas installations. The research objectives of this paper are:

(i) Identify & evaluate gaps in the current regulatory regime & offshore waste stream.
(ii) Conduct a risk-based verification of operator roles & responsibilities and subsequent non-compliance.
(iii) Conduct multi-attribute decision analysis to rank requirements to determine the most influential factors across the offshore waste stream.

2. Literature Review

Decommissioning within the UKCS is subject to many detailed legislations and regulations. It has been previously identified that the knowledge of current legislation throughout the waste stream is not deemed as important (Ford et al. 2021). This reinforced the claims that have previously been made by Calder (2019) that legislation is a key issue in the offshore industry and the waste stream. SEPA (2019) identified that there are issues concerning the boundaries and area of jurisdiction, which could be the reason for the perceived lack of importance of the knowledge of legislation.

Tan et al. (2021) reviewed the literature concerning decommissioning factors, estimation methodologies of decommissioning costs and environmental impact. Tan et al. (2021) concludes that there is currently a lack of data, and databases used for estimating decommissioning cost and environmental impact are error-prone. This supports the work conducted by Ahiaga-Dagbui et al. (2017), which suggests that information and knowledge need to be more freely shared among operators and contractors. Together, these issues have the potential to combine and reduce the sustainability of the decommissioning process. Wilkinson et al. (2016) discuss the importance of communication between stakeholders and those responsible for planning the decommissioning process of an offshore installation. When tasks such as risk assessments are outsourced, it is difficult for stakeholders to judge the technically complex issues and have confidence in the final proposals. Walker and Roberts (2013) also raised a similar issue stating the lack of knowledge sharing, trust issues and skills deficiency.

With the current move towards a circular economy (Milios et al., 2019), ways to decommission an installation safely and sustainably need to be developed. Part of the decommissioning process must address how to handle hazardous waste materials from the installation. These hazardous materials must be identified, handled, transported, and processed in line with current legislation.

Part of the decommissioning process is to identify the waste and categorise it according to the European Union (EU) Waste Hierarchy (EU, 2008). From this, an active waste management plan can be formulated. Waste is defined as "*any substance or object which the holder discards or intends or is required to discard*" by the EU Waste Framework Directive (EU, 2008). The waste from offshore installations ranges from asbestos to equipment contaminated with naturally occurring radioactive material (NORM). Marques et al. (2021) identified that recycling rates are often much lower than are commonly believed. It is often thought that the recycling rates stand at 95% of materials, but only 33% of the total material is brought ashore, and of that, 95% may be recycled. Meaning that a substantial volume of material is often left offshore in situ.

3. Research Methodology

In order to ensure that this research paper was a success, a research framework was developed based on a format proposed by the Health and Safety Executive Risk Assessment Framework (HSE, 2006). The proposed framework is shown in Fig. 1.

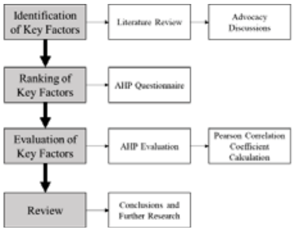

Fig. 1. Proposed Research Framework

The initial stage of the research involved a literature review to identify potential key factors in the decommissioning process. This was used as a basis for advocacy discussions with experts from the decommissioning sector. The second stage involved the distribution of a pairwise comparison questionnaire. The results of the questionnaire were evaluated using an analytical hierarchy process (AHP) and further scrutinised through the calculation of the Pearson correlation coefficients. Following the completion of these stages, a conclusion could be reached, and suggestions for further research could be made.

3.1. *Overview of advocacy discussions*

Interviews can be defined as "conservations between a researcher and those being researched" (Hammond & Wellington 2020). The goal of an interview is to find out what cannot be directly observed or measured (Greener & Greener, 2016). Interviews can be classified into three types: structured, semi-structured and unstructured. Prior to them being conducted, consideration must be made as to the relation between the aims of the overall research and the aims of the interview (Hammond & Wellington 2020). An unstructured approach was chosen to allow for the interviewee to talk freely and at length about aspects of the research, they deemed important. The key findings would be used to develop criteria and alternatives for the AHP.

Experts were approached to take part in the unstructured interviews. Franz and Larson (2002) noted that in group discussions, experts are more likely to mention relevant information than other respondents. The background of an expert enhances their knowledge, abilities and expertise that are relevant to the discussion. An expert can be defined as "a person who is very knowledgeable about or skilful in a particular area" (Stevenson, 2010). The ability to be classified as an expert depends on the experience and skills gained over the years (Finkbeiner, 2017). Through the experience that they possess from working within the decommissioning sector, the experts are more likely to recall relevant information and distinguish it from irrelevant information (Franz & Larson, 2002). The aim of each advocacy discussion was to establish what each expert identified as the key issues for decommissioning and the management of hazardous waste.

3.2. *Overview of analytical hierarchy process*

Analytical Hierarchy Process (AHP) is a technique developed by Thomas Saaty during the 1970s. It is a multicriteria decision-making method that allows for a degree of inconsistency due to the input of human judgement. The process follows a framework that breaks down a problem into hierarchal levels to allow them to be compared, ranked and aggregated for a solution (Saaty and Kearns, 1985).

The questionnaire requires the respondent to compare an overall goal, criteria and alternatives and rank their importance using the Saaty Scale. This is a scale of relative importance that Saaty recommended to enable subjective pairwise comparisons (Saaty and Kearns, 1985).

The first step in the AHP process is to define the problem and identify the goals or objective. This enables a hierarchal structure to be developed from the top goal to sub-criteria to alternatives. The hierarchal structure is shown in Fig. 2.

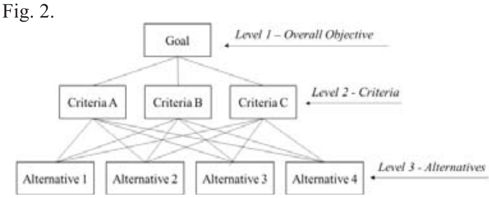

Fig. 2: Example of the hierarchal structure

Once the hierarchy has been determined, a questionnaire can be developed to allow for each alternative and criteria to be compared. A questionnaire is developed to allow the comparison of the criteria and alternatives. The results of the questionnaire enable a pair-wise comparison matrix to be produced.

The questionnaire requires the respondent to compare criteria and alternatives and to rank their importance using the Saaty Scale. For example, in this analysis, the scale is as follows: "1 is equal importance between two criteria", "3 is moderate importance", "5 is strong importance", "7 is very strong importance", "9 is extreme importance", and "2, 4, 6, and 8 are intermediate values of importance". A ranking of 9 indicates absolute importance of one criteria over another. This fundamental scale has been shown to be a scale that captures individual preferences with respect to quantitative and qualitative attributes (Saaty and Kearns, 1985).

To identify the importance of each alternative in relation to the criteria, an AHP approach containing a pair-wise comparison matrix will be used. To conduct the pair-wise comparison matrix, at first, set up n criteria in the row and column of an n×n matrix.

The judgements on pairs of attributes Ai and Aj are represented by an n×n matrix A as shown in Eq. (1)

$$A = (a_{ij}) = \begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ {}^{a}/_{a_{12}} & 1 & \dots & a_{2n} \\ . & . & \dots & . \\ {}^{1}/_{a_{1n}} & {}^{1}/_{a_{2n}} & \dots & 1 \end{bmatrix} \quad (1)$$

where i, j = 1,2,3, …, n and each aij is the relative importance of attribute Ai to attribute Aj.

For a matrix of order n, (n×(n-1)/2) comparisons are required. According to Ahmed et al. (2005), each element in the pair-wise comparison matrix carries a weight vector which indicates their priority in terms of its overall contribution to the decision-making process. These weight values are found using Eq. (2).

$$w_k = \frac{1}{n}\sum_{j=1}^{n}\left(\frac{a_{kj}}{\sum_{i=1}^{n} a_{ij}}\right) \; (k = 1, 2, 3, \dots, n) \quad (2)$$

where aij is the entry of row i and column j in the comparison matrix of order n.

The weight values obtained in the pair-wise comparison matrix are checked for consistency purpose using a Consistency Ratio (CR). The CR value is computed using the following equations:

$$\lambda_{max} = \frac{\sum_{j=1}^{n} \frac{\sum_{k=1}^{n} w_k a_{jk}}{w_j}}{n} \quad (3)$$

$$CI = \frac{\lambda_{max} - n}{n-1} \quad (4)$$

$$CR = CI/RI \quad (5)$$

where n equals the number of items being compared, λ_{max} stands for maximum weight value of the n×n comparison matrix, RI stands for average random index (Table 1), and CI stands for consistency index.

The consistency ratio must be less than 10%. Saaty and Kearns (1985) suggests that in some cases, 20% may be tolerated. Should the inconsistency level in the pair-wise comparison be unacceptably high, a revisit to the expert judgements would be required. It is also possible to approach more domain experts in the elicitation process.

Table 1: Random consistency index (Saaty and Kearns, 1985)

n	2	3	4	5	6	7	8	9	10
RI	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

The consistency ratio must be less than 10%. Saaty and Kearns (1985) suggest that in some cases, 20% may be tolerated. If the consistency ratio is exceeded, then the experts must revise their judgements.

$$CR = \frac{CI}{RI} \leq 10\% \quad (6)$$

The final priority matrix for each expert can be produced by finding the sum of the products of the weight for each criterion and weight for each alternative.

$$Final\ priority\ for\ Each\ Altenative\ = \sum_{i=1}^{n} W_{ij}\, W_{criteria\ i} \quad (7)$$

When there are multiple expert respondents, an aggregated response is required. A procedure is only considered satisfactory if it:

(i) Reflects the collective judgements of the respondents.
(ii) Responds to changes in individual preferences.
(iii) Provides ranking for the alternatives presented (Saaty and Vargas, 2013).

If none of the respondent's opinions is considered greater than the others, then an aggregated response can be found using the geometric mean of the weights (Saaty and Vargas, 2013). The geometric mean method is used when a consensus cannot be made through discussion.

$$W^G = \left(\prod_{i=1}^{n} W_i\right)^{1/n} = \sqrt[n]{W_1 W_2 W_3 \ldots \ldots \ldots W_n} \quad (8)$$

3.3. *Overview of the Pearson correlation coefficient*

Following the AHP analysis, the Pearson Correlation Coefficient, also known as the Product Moment Correlation Coefficient (Sedgwick 2012), was calculated to determine if any relationships existed between each of the respondents. It is anticipated that respondents from similar backgrounds would elicit similar responses and that those from different backgrounds would produce contrasting responses. The Pearson Correlation Coefficient is used to measure the extent of two variables predicting each other and shows the relationship between them. It is used to establish the strength of the relationship between two numerical variables (Breman-Brown & Saunders 2008). It is limited to testing linear relationships as significant curvilinear relationships can result in non-significant values (Armstrong 2019).

The Pearson coefficient, denoted by r, is calculated using Eq. (9).

$$r = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2 \sum(y_i - \bar{y})^2}} \quad (9)$$

Where r is the Pearson correlation coefficient, x_i is the value of the x-variable in the sample, $\bar{x}$ is the mean of the values of the x-variable, y_i is the value of the y-variable in a sample and $\bar{y}$ is the mean of the values of the y-variable.

The value of the person coefficient indicates the type and strength of the correlation. A positive correlation indicates that the values being analysed move in the same direction. Consequently, a negative correlation indicates the values being analysed move in the opposite direction.

Table 2 indicates the strength of the correlation for each magnitude of the Pearson correlation coefficient. A magnitude of one indicates that the correlation is perfect, and a value of zero indicates that there is no correlation

Table 2. Pearson Correlation Coefficient Magnitude Strengths

Pearson correlation coefficient (magnitude)	Correlation strength
$0.8 \leq r \leq 1.0$	Very Strong
$0.5 \leq r \leq 0.8$	Strong
$0.3 \leq r \leq 0.5$	Medium
$0.0 \leq r \leq 0.3$	Low

4. Data Gathering and Results

4.1 *Advocacy discussions*

Experts were approached to take part in virtual interviews. An unstructured approach was chosen to allow for the interviewee to talk freely and at length about aspects of the research they deemed important. The key findings would be used to develop criteria and alternatives for the AHP. The backgrounds of each expert approached to take part are shown in Table 3. Each expert currently works within the decommissioning sector at manager level or above.

Table 3. Background details of experts chosen for semi-structured interviews and discussions.

Expert	Background
1	Project executive at an environmental protection agency with focus on decommissioning.
2	Project manager at an environmental protection agency with focus on decommissioning.
3	Business development director for regulator-backed, not-for-profit trade body for energy decommissioning.
4	Decommissioning manager, not-for-profit representative body for UK offshore oil and gas industry.

Each unstructured interview was conducted as a discussion using online video conferencing software. Each followed the format of introductions, research outline, findings from work completed and discussion on findings. This gave each expert the opportunity to voice what they felt as the most important issues affecting the decommissioning process. The results are summarised in Table 4.

Table 4. Summary of key points made during semi-structured interviews and discussions with industry experts.

Expert	Key Points
Expert 1	• High volumes of waste. • Lack of understanding of the waste management process. • Different values between environmental and safety regulations. • Length of waste stream – aim to reduce it.
Expert 2	• Lack of understanding of legislative compliance along the waste stream by operators. • Extent of conformity and discrepancies along the waste stream.
Expert 3	• Lack of understanding of waste management by operators. • Sector dismissive of waste and onshore costs. • Lack of knowledge sharing. • Duty of care and disposal of liability concerning onshore activities as part of the waste stream. • Misidentification/mislabelling of legacy chemicals.
Expert 4	• Lack of knowledge sharing. • Lack of understanding of CDM regulations with regards to decommissioning. • Lack of clarity of legal jurisdiction and duty of care across different stages of decommissioning. • Issues with mishandling, mislabelling and difficulty identifying older assets and equipment due to missing historical data.

The emerging theme from the expert discussions was that of concern over the understanding of the legislative requirements along the waste stream. This is consistent with the findings from the previous study conducted. Several factors could explain this observation, firstly due to the length of the waste stream and the large number of stakeholders involved. Secondly, the lack of knowledge sharing among stakeholders. The lack of knowledge sharing would also account for the issues with the identification of legacy chemicals and old assets. The key points raised in the discussions with the industry experts will be used to develop an AHP hierarchy and a pairwise questionnaire that can be distributed to a larger number of industry experts.

4.2 *Analytical hierarchy process*

The key factors identified during the advocacy discussions were used to produce a hierarchy of criteria and alternatives. The process follows a framework that breaks down a problem into hierarchical levels to allow them to be compared, ranked, and aggregated for a solution (Saaty and Kearns, 1985). The number of alternatives has been limited to seven as cognitive science suggests that a person's working memory capacity is in the order of 7 ± 2 (Mu & Pereyra-Rojas, 2017).

The AHP hierarchy consisted of a top goal, four criteria and seven alternatives and is outlined as follows and shown in Fig.3:

Top goal: To select the most important factors affecting the decommissioning process

C1. *Criteria 1*: Understanding of onshore regulations - the understanding of the current, applicable onshore regulations during decommissioning activities.

C2. *Criteria 2:* Understanding of offshore regulations - the understanding of the current, applicable offshore regulations during decommissioning activities.

C3. *Criteria 3:* Reduction in length of waste stream - the reduction in the length of the waste stream during the decommissioning process.

C4. *Criteria 4:* Reduction in volume of waste - the reduction in the volume of waste along the waste stream during the decommissioning process.

A1. *Alternative 1:* Reducing costs of decommissioning process – methods to reduce the cost of the decommissioning process.

A2. *Alternative 2:* Knowledge & best practice sharing – the knowledge and best practice sharing amongst parties conducting the decommissioning process.

A3. *Alternative 3:* Understanding of liability throughout the waste stream – the understanding of the liability of individual stakeholders throughout the waste stream of the decommissioning process.

A4. *Alternative 4:* Knowledge of offshore process by onshore personnel – the knowledge of the offshore decommissioning processes by the onshore personnel that are conducting the decommissioning process.

A5. *Alternative 5:* Understanding of legislative compliance along waste stream – the understanding of current legislative requirements along the waste stream during the decommissioning process.

A6. *Alternative 6:* Identification of older equipment – the identification of older equipment that may be present onboard installations prior to the commencement of decommissioning.

A7. *Alternative 7:* Reuse of recertified/remanufactured equipment – the reuse of recertified/remanufactured equipment that has been removed from installations during the decommissioning process.

The questionnaire will require respondents to compare criteria and alternatives and rank their importance using the Saaty Scale (Saaty and Kearns, 1985). The questionnaire will also gather demographic data of the respondents in the form of years of experience, industry sector and educational background.

The demographics of the respondents to the AHP questionnaire are shown in Table 5. Respondents two and five work in the education sector, whilst respondents one, three and four work in industry.

Table 5. Demographics of Respondents to AHP Questionnaire

Respondent	Area of Expertise	Current Role
1	Safety Engineering	Supply chain
2	Maritime Engineering	Researcher
3	Project Management	Supply Chain
4	Well Plugging & Abandonment	Consultancy
5	Waste Management	Lecturer

The method outlined in section 3.2 was followed in order to complete the AHP calculations. The responses to the

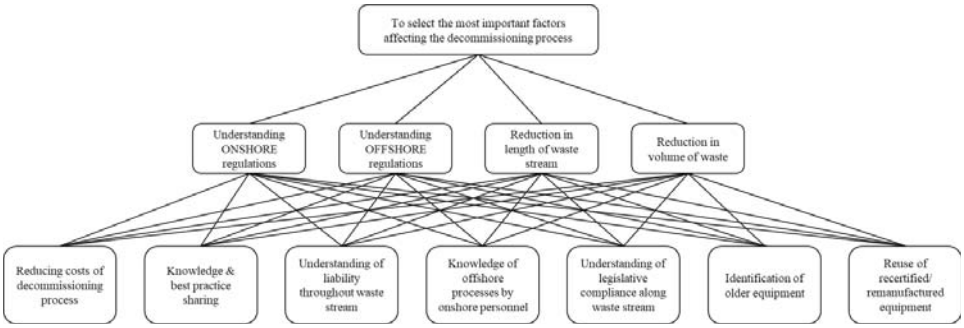

Fig. 3: Example of the hierarchal structure

distributed questionnaire allowed for the formulation of pairwise comparison matrices. Table 6 shows the pairwise comparison matrix for the level one criteria for one individual expert's judgements.

Table 6: Pair-wise comparison matrix for level 1 criteria

	C1	C2	C3	C4
C1	1	1	7	7
C2	1	1	7	7
C3	1/7	1/7	1	1
C4	1/7	1/7	1	1
SUM	**2.29**	**2.29**	**16.0**	**16.0**

Using the data from Table 6, a standardised matrix could be created. This is shown in Table 7. The matrix is created by dividing the ranking of each criteria by the sum of their column. If the standardisation is correct, the sum of each of the column will equal one.

Table 7: Normalised comparison matrix for level 1 criteria

	C1	C2	C3	C4	Criteria Weights
C1	0.44	0.44	0.44	0.44	0.44
C2	0.44	0.44	0.44	0.44	0.44
C3	0.06	0.06	0.06	0.06	0.06
C4	0.06	0.06	0.06	0.06	0.06
SUM	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**

Using Eq. (3), the maximum eigenvector can be determined.

$$\lambda_{max} = \left(\frac{1}{0.44} \times 0.44\right) + \left(\frac{1}{0.44} \times 0.44\right) + \left(\frac{1}{0.06} \times 0.06\right) + \left(\frac{1}{0.06} \times 0.06\right) = 4$$

This allows for the consistency index to be calculated using Eq. (4).

$$CI = \frac{4-4}{4-1} = 0.00$$

The consistency ratio is calculated using the random index shown in Table 1 and Eq. (5).

$$CR = \frac{0.00}{0.9} = 0.00$$

The final priority matrix can be calculated by combining the individual weights for each criteria and alternative.

Saaty states that consistency ratios should be less than 0.1 otherwise the responses are not consistent, although a ratio of 0.2 can be tolerable (Wedley, 1993). The initial results of the AHP analysis resulted in inadequate consistency ratios. These results justified including the calculation of the Pearson Correlation Coefficient to determine if there was any similarity in the responses.

The weightings for each respondent for the level one criteria compared to the overall goal are shown in Table 5. It can be seen that the majority of respondents identified that criteria two – the understanding of offshore regulations is of the highest importance. The offshore industry is subject to several legislations and regulations. It is positive that the expert respondents identified that the understanding of these is of importance. The fact that there is no consensus on what the most important factor reflects the findings of the literature review and previous research. Several key factors had been identified, but there was no clear indication of which is most important.

Table 8. Criteria Weightings for Each Respondent (R) for the overall goal.

Overall Goal-To select the most important factors affecting the decommissioning process						
	R1	R2	R3	R4	R5	R6
C1	23%	57%	32%	10%	17%	42%
C2	65%	26%	44%	60%	17%	42%
C3	4%	13%	11%	15%	33%	8%
C4	8%	4%	12%	15%	33%	85

Table 9 shows the weightings for each respondent for the criteria 'understanding offshore regulations. Again, there is no overall clear consensus on which alternative represents the key factor for each criteria. The results reflect the findings of the literature review, previous expert discussions and the individual roles of each expert. For example, respondent five, who has expertise in waste management, selected the alternative concerned with waste as being the most significant.

Table 9. Criteria weightings for each respondent (R), for criteria two.

	R1	R2	R3	R4	R5	R6
A1	21%	28%	41%	23%	21%	20%
A2	41%	17%	21%	7%	4%	13%
A3	16%	19%	6%	25%	25%	5%
A4	4%	12%	11%	18%	6%	3%
A5	6%	18%	13%	11%	25%	6%
A6	2%	2%	4%	8%	10%	26%
A7	11%	4%	4%	8%	10%	27%

Despite some of the consistency ratios of the AHP being higher than the required 0.1, the individual responses highlight the trends in what are perceived as the key factors in the decommissioning process. Overall, the understanding of offshore regulations, reduction in costs, knowledge and best practice sharing and the understanding of liabilities throughout the waste stream are highlighted. This reiterates the findings of the literature review and the advocacy discussions. The complex, everchanging area of regulations and legislations are a key factor in decommissioning. Without a clear understanding of them, the risk of liability throughout the process and along the waste stream would increase. The concept of knowledge and best practice sharing has been raised in the literature review of the decommissioning closeout reports and advocacy discussions. The large number of stakeholders and everchanging staffing of offshore installations results in a loss of knowledge and also the reluctance to share amongst individual parties. It is thought that in the process of reducing costs, the decommissioning process would be carefully scrutinised and, in turn, a greater understanding of the current statutory regime achieved.

The responses of each individual respondent reflect their own roles and areas of expertise. For example, the respondent with a background in waste management felt that the alternatives in the pairwise comparison questionnaire that dealt with waste management were the most important. Respondent 1, who deals with the supply chain, identified that knowledge and best practice sharing were key. Despite their consistency ratios of less than 0.1, there are patterns in the responses of each respondent that were expected from the results of the literature review and the advocacy discussions with experts.

Further dissection of the individual responses identified a trend in the choice of responses. The respondents had a clear preference for what they saw as the key factors that could be linked back to their area of expertise and current roles.

4.3 *Pearson Correlation Coefficients*

Pearson Coefficients were calculated in order to compare each respondent's opinions on each criteria in the AHP analysis to determine if they are in agreement or disagreement. The results of these calculations are shown in Table 10.

Table 10. Pearson Correlation Coefficients for each comparison between responses of each expert respondent

Respondents	Goal	C1	C2	C3	C4
R1-R2	0.680	0.203	0.211	-0.220	-0.112
R1-R3	0.872	0.092	-0.115	-0.190	0.026
R1-R4	0.649	0.356	-0.032	0.236	-0.195
R1-R5	-0.965	-0.282	0.029	0.292	0.388
R2-R3	0.603	-0.073	0.094	0.256	0.046
R2-R4	0.397	0.491	0.399	-0.126	-0.228
R2-R5	-0.680	0.138	0.238	0.163	-0.442
R3-R4	0.685	0.067	-0.206	-0.218	-0.185
R3-R5	-0.729	-0.248	-0.080	0.204	-0.042
R4-R5	-0.476	0.072	0.087	0.510	0.343

In order to determine if there was any correlation between respondents, the Pearson correlation coefficient was calculated in order to compare the pairwise comparisons between each respondent. The results show that for the overall goal - *To select the most important factors affecting the decommissioning process* - the majority of respondents were in agreement that criteria two – *the understanding of offshore regulations* - is the most important. This echoes what has been identified from the literature review and also within the discussions with industry experts that sustainable and successful decommissioning of offshore installations are relevant and important. The literature review highlighted the current importance and relevance of the decommissioning of offshore installations due to the number of installations requiring decommissioning. It is also important to obey the legislation and regulations as laid out by the UK government and internal law. During decommissioning, it is crucial to work towards net zero targets. The advocacy discussion backs up the importance of decommissioning; firstly, as the experts agreed to take part, they must feel that decommissioning is essential. Secondly, they held strong opinions on the current issues within the decommissioning sector.

The respondents are in agreement that understanding onshore and offshore regulations, reducing the waste stream and reducing the volume of waste is essential but have differing views on which factor is the most important. They are in agreement it is important but not in agreement as to which is more important. This is due to the background of the respondents. Due to the small sample number, the results highlight their different views strongly.

The results for criteria one show that none of the respondents are in strong agreement or strong disagreement. There is a general medium to low agreement that this is important. The Pearson correlation coefficient shows a low to medium positive correlation, whilst respondents three and respondent five have a low to medium negative correlation. This shows that they are not all in agreement with each other. The AHP results show that knowledge and best practice sharing, as well as the knowledge of liability, are important in understanding the onshore regulations. This makes sense as to fully understand onshore regulations with regards to decommissioning, knowledge and best practice sharing would be beneficial, as would an understanding of liability and legislative compliance. Again, the individual respondents' backgrounds are reflected in their responses. In order to ensure compliance and maximise sustainability, it makes sense to have a good understanding of the legislations.

Criteria two resulted in a mix of positive and negative low to medium correlations. This illustrates that each respondent recognises that offshore legislation and regulations are important but to differing degrees of importance. This highlights that this is still a relevant area for discussion in decommissioning. During advocacy discussions, the experts highlighted the lack of understanding of legislations and regulations offshore. The Pearson correlation coefficient indicates low correlation strength. This shows it is still of importance, but a detailed look at individual AHP questionnaire responses again highlight that respondents are not in total agreement as to which factor is the most important. The expert discussions highlighted the understanding of regulations as an important factor which is reflected in the Pearson correlation coefficient.

Criteria three, to reduce the length of the waste stream, shows, again, a mixture of correlations. Whilst all agreed with respondent five, they did not necessarily agree with each other. Responses are mixed; those with positive correlations are at the top end of the low-strength positive correlation, whilst the negative correlation is also top of the low-strength. The differing opinion could be due to the roles of each respondent. If they completed the AHP questionnaire purely thinking about their current role, the reduction of the length of the waste stream may or may not seem important to them individually. Again, knowledge and understanding are highlighted as being potentially important, as well as a reduction in costs and identification of older equipment. This makes sense as knowledge of good practice, commonly present waste materials and machinery would aid the reduction of the waste stream and help to reduce costs.

Criteria four, to reduce the overall volume of waste, shows that most respondents do not agree on the level of importance. Respondents four and five agree to the importance of liability throughout the waste stream.

5. Conclusion

For each criteria, the respondents were compared using the Pearson correlation coefficient. The results indicated that all the respondents identified that decommissioning is important and that there are key factors involved. When combined with the results of the AHP, it is shown that the key factors for each criteria are reduced to the following:

(i) Reduction in costs
(ii) Knowledge and best practice sharing,
(iii) Liability throughout the waste stream.

This echoes what has already been identified in the literature review and the advocacy discussions. So, the findings boil down to the knowledge of legislation and regulations. This underlines the need for a holistic, fluid framework that can be used throughout the decommissioning process. If a framework is developed using the knowledge and best practice of current/past stakeholders, this would aid in the understanding of legislations, regulations and liabilities, which would have a knock-on effect on the cost reduction and sustainability of the decommissioning process.

It was anticipated that there would be an agreement between the respondents from similar backgrounds; for example, the respondents involved in the education sector would hold similar views, but this has not been the case. Each respondent has a different level of expertise which has resulted in their different opinions of the importance of each factor associated with decommissioning. Although a consensus was not reached, this initial research highlights that each of the factors is still an important factor of decommissioning that needs to be addressed. How this would be addressed still need to be identified and would involve a higher level of discussion and involvement from industry experts, but due to the almost secretive nature of the industry and the reluctance to cooperate, this is not the case.

6. Further Work

This research is part of an ongoing project at Liverpool John Moores University. Following on from the initial AHP analysis and the detailed analysis of the questionnaire responses, it became apparent that only a fraction of the alternatives were selected during the comparisons. Another questionnaire using only those alternatives and criteria is being developed and forwarded to the initial respondents for further consideration. A Bayesian network will be created and refined to reflect this. The final stage of the research project will be to produce a holistic framework for use during the decommissioning process.

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